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Embedded Emissions and Import-Value Adjustment under  
Carbon Border Policy  
Evidence from the EU CBAM Transitional Phase

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# Abstract

The Carbon Border Adjustment Mechanism (CBAM) is the European Union's (EU) import-side response to carbon-leakage concerns as free allocation under the European Union Emissions Trading System (EU ETS) is phased out. Its first operational stage was a reporting-only transitional phase. From October 2023, importers of covered goods had to report embedded emissions, but they did not yet surrender CBAM certificates.

This thesis examines whether this transitional phase was associated with changes in EU import values and whether such changes varied with pre-policy carbon intensity. Monthly Eurostat COMEXT import data are combined with exporter-product carbon-intensity measures from EXIOBASE. The empirical analysis compares CBAM-covered imports with nearby non-covered imports and estimates carbon-intensity gradients using Poisson Pseudo Maximum Likelihood (PPML) models with high-dimensional fixed effects. Event-study specifications assess pre-event dynamics and the timing of adjustment around the CBAM proposal and the start of reporting.

CBAM-covered import values declined relative to comparable non-covered imports over the period in which CBAM moved from proposal to reporting, and the cumulative reporting-phase differential is statistically significant. However, the event studies show no distinct shift around either the 2021 CBAM proposal or the 2023 start of reporting, and there is no robust evidence of stronger adjustment among more carbon-intensive exporter-product relationships. The findings therefore point to broad import-value adjustment during the gradual introduction of CBAM, but not to a distinct policy-date effect, an emissions-proportional response, or evidence of reduced carbon leakage.

**Keywords:** Carbon Border Adjustment Mechanism; carbon leakage; EU ETS; trade policy; carbon intensity; PPML

## Zusammenfassung

Der Carbon Border Adjustment Mechanism (CBAM) ist ein importseitiges Instrument der Europäischen Union (EU), das Carbon-Leakage-Risiken adressieren soll, während die kostenlose Zuteilung im Europäischen Emissionshandel (EU ETS) schrittweise ausläuft. Die erste operative Phase war jedoch noch kein bepreister Grenzausgleich, sondern eine Übergangsphase mit Berichtspflichten. Seit Oktober 2023 mussten Importeure erfasster Waren eingebettete Emissionen melden, aber noch keine CBAM-Zertifikate abgeben.

Diese Masterarbeit untersucht, ob diese Übergangsphase mit Veränderungen der EU-Importwerte verbunden war und ob solche Veränderungen mit der vor den Politikereignissen gemessenen CO<sub>2</sub>-Intensität zusammenhingen. Monatliche Importdaten aus Eurostat COMEXT werden mit exporteur-produktbezogenen CO<sub>2</sub>-Intensitäten aus EXIOBASE kombiniert. Der empirische Ansatz vergleicht CBAM-erfasste Importe mit nahegelegenen nicht erfassten Importen und schätzt CO<sub>2</sub>-Intensitätsgradienten mit Poisson-Pseudo-Maximum-Likelihood-Modellen (PPML) mit hochdimensionalen Fixed Effects. Event-Study-Spezifikationen prüfen Vorbehandlungsdynamiken und die zeitliche Entwicklung um den CBAM-Vorschlag und den Beginn der Berichtspflichten.

In dem Zeitraum, in dem der CBAM vom Vorschlag in die Berichtsphase überging, entwickelten sich die Importwerte CBAM-erfasster Waren schwächer als jene vergleichbarer nicht erfasster Waren und die kumulative Differenz in der Berichtsphase ist statistisch signifikant. Die Event Studies zeigen jedoch weder rund um den CBAM-Vorschlag von 2021 noch rund um den Beginn der Berichtsphase 2023 einen eindeutigen Bruch. Auch für eine stärkere Anpassung besonders CO<sub>2</sub>-intensiver Exporteur-Produkt-Beziehungen gibt es keine robuste Evidenz. Die Ergebnisse sprechen daher für eine allgemeine Anpassung der Importwerte während der schrittweisen Einführung des CBAM, nicht aber für einen klaren zeitlich abgegrenzten Politikeffekt, eine emissionsproportionale Reaktion oder eine nachweisbare Verringerung von Carbon Leakage.

**Schlagwörter:** Carbon Border Adjustment Mechanism; Carbon Leakage; EU ETS; Handelspolitik; CO<sub>2</sub>-Intensität; PPML

# Table of Contents

|                                                                      |    |
|----------------------------------------------------------------------|----|
| List of Figures .....                                                | IV |
| List of Tables .....                                                 | V  |
| List of Abbreviations .....                                          | VI |
| 1 Introduction .....                                                 | 1  |
| 2 Institutional Background and Policy Timing .....                   | 3  |
| 2.1 The EU ETS, Free Allocation, and Carbon Leakage .....            | 3  |
| 2.2 CBAM Design and Policy Timeline .....                            | 4  |
| 2.3 Why a Reporting-Only Phase Can Affect Trade .....                | 6  |
| 2.4 The Definitive Regime and Recent Developments .....              | 7  |
| 3 Data .....                                                         | 8  |
| 3.1 Trade Flows .....                                                | 8  |
| 3.2 Emissions Intensity .....                                        | 10 |
| 3.3 Estimation Panels .....                                          | 12 |
| 4 Empirical Strategy .....                                           | 13 |
| 4.1 Specifications .....                                             | 13 |
| 4.1.1 Baseline covered-effect specification .....                    | 14 |
| 4.1.2 Pooled intensity specification .....                           | 14 |
| 4.1.3 Covered-split intensity specification .....                    | 14 |
| 4.2 Event Study Design .....                                         | 15 |
| 4.3 Identification .....                                             | 16 |
| 5 Results .....                                                      | 18 |
| 5.1 Baseline Covered-Import Differentials .....                      | 18 |
| 5.2 Intensity-Gradient Results .....                                 | 21 |
| 5.3 Dynamic Evidence .....                                           | 23 |
| 6 Discussion .....                                                   | 25 |
| 6.1 Interpreting Transitional-Phase Import-Value Differentials ..... | 25 |
| 6.2 Implications and Limits .....                                    | 27 |
| 7 Conclusion .....                                                   | 29 |
| References .....                                                     | 31 |
| Appendix .....                                                       | 34 |
| Alternative Functional Form .....                                    | 34 |
| Dynamic Robustness .....                                             | 35 |
| Inference Robustness .....                                           | 38 |
| Fixed-Effects Robustness .....                                       | 39 |
| Use of Artificial Intelligence Tools .....                           | 40 |

## List of Figures

|          |                                                                                              |    |
|----------|----------------------------------------------------------------------------------------------|----|
| Figure 1 | CBAM policy timeline and empirical window. ....                                              | 5  |
| Figure 2 | Data construction and mapping from customs records to final estimation panels. . .           | 8  |
| Figure 3 | Quarterly event-study estimates for CBAM-covered relative to non-covered import values. .... | 20 |
| Figure 4 | Monthly carbon-intensity event-study estimates around the CBAM announcement. ....            | 23 |
| Figure 5 | Monthly carbon-intensity event-study estimates around the start of CBAM reporting. ....      | 24 |
| Figure 6 | Monthly baseline event-study estimates for covered versus non-covered import values. ....    | 35 |
| Figure 7 | Quarterly event-study estimates for carbon-intensity gradients. ....                         | 36 |
| Figure 8 | Monthly event-study estimates using log carbon intensity. ....                               | 37 |

## List of Tables

|         |                                                                          |    |
|---------|--------------------------------------------------------------------------|----|
| Table 1 | Estimation sample overview .....                                         | 10 |
| Table 2 | Distribution of pre-policy carbon intensity .....                        | 12 |
| Table 3 | Baseline covered-import value differentials .....                        | 19 |
| Table 4 | Pooled carbon-intensity gradients on EU import values .....              | 21 |
| Table 5 | Covered-split carbon-intensity gradients on EU import values .....       | 22 |
| Table 6 | Log-intensity robustness of static carbon-intensity specifications ..... | 34 |
| Table 7 | Inference robustness under alternative variance estimators .....         | 38 |
| Table 8 | Robustness to product-by-time fixed effects .....                        | 39 |

## List of Abbreviations

| Abbreviation | Meaning                                                       |
|--------------|---------------------------------------------------------------|
| CBAM         | Carbon Border Adjustment Mechanism                            |
| CN8          | Combined Nomenclature, eight-digit product code               |
| COMEXT       | Eurostat international trade in goods database                |
| CPA          | Classification of Products by Activity                        |
| DiD          | Difference-in-differences                                     |
| EU           | European Union                                                |
| EU ETS       | European Union Emissions Trading System                       |
| EXIOBASE     | Environmentally extended multi-regional input-output database |
| HS           | Harmonized System                                             |
| IQR          | Interquartile range                                           |
| MRV          | Monitoring, reporting, and verification                       |
| PPML         | Poisson Pseudo Maximum Likelihood                             |
| PXP          | Product-by-product input-output table                         |

# 1 Introduction

The European Union (EU) has made carbon pricing one of the central instruments of its climate policy. The European Climate Law makes climate neutrality by 2050 legally binding and sets a 2030 target of reducing net greenhouse-gas emissions by at least 55 percent relative to 1990 (European Parliament and Council of the European Union, 2021, Art. 2(1), Art. 4(1)). Carbon pricing within the EU, especially through the European Union Emissions Trading System (EU ETS), creates incentives to reduce emissions in regulated sectors. At the same time, the EU's regulatory authority is territorially limited. Producers outside the EU do not necessarily face comparable carbon costs (Jakob, 2021, pp. 609–610; European Parliament and Council of the European Union, 2023, Recitals 9–11).

This difference creates a trade-policy problem. If EU producers face carbon costs that foreign competitors do not face to the same extent, demand, production, or emissions may shift toward jurisdictions with weaker climate constraints. The literature describes this problem as carbon leakage. It can operate through fossil-fuel price effects, trade and production responses, or strategic reactions by other jurisdictions (Jakob, 2021, pp. 609–610). Empirical evidence of large leakage under existing climate policies remains limited, partly because exposed sectors have often been protected through free allocation or related compensation mechanisms (Grubb et al., 2022, p. 753; Jakob, 2021, p. 610).

The Carbon Border Adjustment Mechanism (CBAM) is the EU's attempt to address part of this problem at the border. While free allocation reduces the carbon-cost exposure of EU producers, CBAM applies a carbon-pricing logic to selected imports as free allocation is phased out (European Parliament and Council of the European Union, 2023, Recitals 9–11, Art. 1). Model-based work suggests that border adjustments can reduce import-side leakage under some designs, but their effects depend on product coverage, export treatment, information requirements, and downstream cost pass-through (Bellora & Fontagné, 2023, pp. 1–3, 10–12; Böhringer et al., 2017, pp. 35–37; Branger & Quirion, 2014, pp. 29–31, 35–36). CBAM is therefore not a purely technical complement to the EU ETS. It links climate policy to market access and raises the question of how far unilateral carbon pricing can be extended through trade policy.

The first operational stage of CBAM is the transitional reporting phase. It began on 1 October 2023, before importers had to surrender CBAM certificates. Importers of covered goods were required to report embedded emissions, while the financial obligation to surrender certificates was reserved for the later definitive regime (European Parliament and Council of the European Union, 2023, Art. 32, Art. 35; European Commission, 2023, Art. 3). This timing creates the empirical question of the thesis: whether a reporting regime without a paid border carbon price was already associated with changes in EU import values.

The thesis asks whether the CBAM transitional phase was associated with changes in EU import patterns, measured through monthly import values, and whether any adjustment was stronger for more carbon-intensive covered imports. A closely related empirical study is Freij (2025, pp. 1–2, 23–26), which studies the same transitional phase in a matched difference-in-differences design based on Coarsened Exact Matching. The study compares CBAM-covered bilateral imports into EU countries with matched imports into non-EU countries and treats transitional reporting as a non-tariff trade-cost shock. It reports lower covered EU imports after reporting begins, although the PPML robustness specification gives weaker evidence. The contribution of this thesis is to separate the legal coverage margin from the carbon-intensity margin. The analysis asks both whether covered imports changed relative to nearby non-covered imports and whether import-value adjustment was stronger for more carbon-intensive exporter-product cells.

The empirical analysis is organized around three *ex ante* expectations:

1. **Covered-margin expectation.** If CBAM increased expected trade costs for regulated goods, CBAM-covered imports should decline relative to non-covered imports after the announcement or the start of reporting.
2. **Reporting-phase expectation.** If the reporting phase mattered as a concrete administrative obligation rather than only as a political signal, import-value adjustment should be stronger around the start of reporting than around the announcement alone.
3. **Carbon-intensity expectation.** If the adjustment is related to carbon-leakage exposure, the decline should be stronger for more carbon-intensive covered imports.

These expectations are directional, not mechanical predictions. During the sample period, CBAM did not yet impose a direct carbon charge. Carbon intensity could nevertheless matter through reporting burdens, information frictions, regulatory uncertainty, and anticipation of future costs.

To take these expectations to the data, the thesis uses monthly EU import values from Eurostat COMEXT (Eurostat, 2026b). The underlying trade data are observed at the eight-digit level of the EU Combined Nomenclature (CN8), which gives enough product detail to distinguish CBAM-covered goods from nearby non-covered goods. The sample is restricted to the product space around CBAM sectors, so the comparison is not drawn against unrelated parts of EU trade. For the carbon-intensity analysis, these detailed trade flows are linked to broader EXIOBASE product groups through Classification of Products by Activity (CPA) correspondences (Eurostat, 2026a) and combined with a pre-policy exporter-product measure of carbon intensity from EXIOBASE product-by-product accounts (Stadler et al., 2018). Carbon intensity is fixed as the 2017–2019 average, before both the CBAM announcement and the start of transitional reporting. This avoids measuring carbon exposure with post-policy adjustment. The main spec-

ifications use Poisson Pseudo Maximum Likelihood (PPML) models with high-dimensional fixed effects and event-study designs around the announcement and reporting dates.

The thesis contributes to the emerging empirical literature on CBAM by separating two questions that are often linked but empirically distinct. The first is whether CBAM-covered imports changed differently from nearby non-covered imports around the policy milestones. The second is whether import-value adjustment varies with pre-policy carbon intensity, especially among covered flows. This distinction is important because the transitional phase did not yet price embedded emissions directly. Evidence from this period can speak to early import-value adjustment under reporting obligations, but not directly to foreign production choices, firm-level abatement, or global carbon-leakage mitigation.

The remainder of the thesis is structured as follows. Section 2 describes the institutional background of the EU ETS, carbon leakage, and CBAM, with particular attention to the timing of the transitional reporting phase. Section 3 explains the construction of the trade panel and the carbon-intensity measure. Section 4 presents the empirical strategy, including the baseline covered-import comparison, the carbon-intensity specifications, and the event-study designs. Section 5 reports the empirical results. Section 6 discusses their interpretation, limitations, and policy relevance. Section 7 concludes.

## **2 Institutional Background and Policy Timing**

### **2.1 The EU ETS, Free Allocation, and Carbon Leakage**

CBAM is part of the European Union’s carbon-pricing architecture and is directly linked to the EU ETS. The EU ETS requires covered installations to surrender allowances for their verified greenhouse-gas emissions. This obligation exposes regulated production to a carbon cost. Producers outside the EU are not subject to the EU ETS and may face different carbon-pricing regimes in their home jurisdictions. The resulting difference in carbon-cost treatment is part of the economic rationale for CBAM (Bellora & Fontagné, 2023, p. 1; European Parliament and Council of the European Union, 2023, Recitals 9–11).

Carbon leakage occurs when emissions reductions in one regulated region are partly offset by higher emissions elsewhere. One channel operates through international energy markets. Lower fossil-fuel demand in the regulated region can reduce world prices and raise consumption abroad. A second channel operates through product markets when carbon costs shift demand, trade, or production toward less regulated jurisdictions. Climate policy can also alter the incentives of other jurisdictions to strengthen or weaken their own mitigation efforts (Jakob, 2021, pp. 609–610).

Empirical research has found limited evidence of large ex-post leakage under existing climate policies. These findings reflect the policies that firms actually faced. Emissions-intensive and trade-exposed sectors were often protected through free allocation or related compensation measures, which reduced their exposure to carbon costs (Grubb et al., 2022, pp. 753, 762; Jakob, 2021, p. 610). Limited observed leakage under these conditions does not establish how firms would respond without such protection.

Free allocation has been a central instrument for addressing competitiveness and leakage concerns under the EU ETS (European Parliament and Council of the European Union, 2023, Recitals 9–11). It lowers the allowance costs borne by covered producers. It can also weaken carbon-cost pass-through and reduce incentives for efficient material use (Grubb et al., 2022, pp. 766–767). Firm-level evidence indicates that broad allocation rules can compensate firms beyond their estimated relocation risk (Martin et al., 2014, pp. 2482–2485). CBAM changes this policy approach. As free allocation is phased out in the covered sectors, part of the leakage protection shifts from compensation of EU producers toward an adjustment applied to selected imports (European Parliament and Council of the European Union, 2023, Recitals 9–11, Art. 1).

## **2.2 CBAM Design and Policy Timeline**

Regulation (EU) 2023/956 defines CBAM as an instrument for addressing carbon-leakage risk while free allocation is gradually phased out in the covered sectors (European Parliament and Council of the European Union, 2023, Recitals 9–11, Art. 1). CBAM does not extend the EU ETS as a legal system beyond the European Union. It creates a separate set of obligations for selected imports. Under the definitive regime, the number of certificates to be surrendered depends on the embedded emissions declared for those goods and on the applicable deductions (European Parliament and Council of the European Union, 2023, Arts. 4–6, 9, 21–22).

The initial product scope covers cement, iron and steel, aluminium, fertilisers, electricity, and hydrogen (European Parliament and Council of the European Union, 2023, Annex I). These sectors combine high emissions exposure with international trade and feature prominently in the literature on carbon leakage and border adjustment (Bellora & Fontagné, 2023, pp. 1–3; Branger & Quirion, 2014, pp. 29–31). The empirical analysis focuses on the tangible goods within this scope and excludes electricity.

Figure 1 summarises the policy milestones that define the announcement and reporting windows used in the empirical analysis.

*The sample covers the proposal and reporting phase; financial obligations fall outside the observation window.*

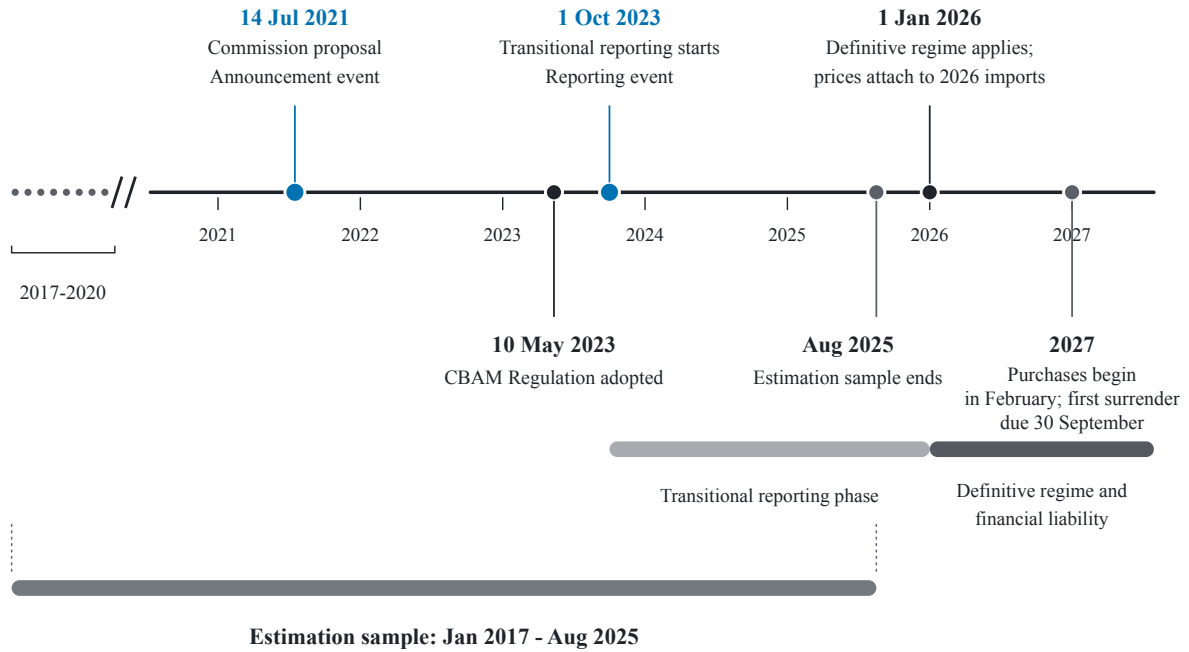


Figure 1: CBAM policy timeline and empirical window.

The Commission presented its formal CBAM proposal on 14 July 2021 (European Commission, 2021). This date marks a change in the institutional status of the policy. Earlier political commitments had signalled the intention to introduce a carbon border measure. The formal proposal specified the planned legal design, product scope, transitional period, and later certificate obligation. Firms could update their expectations once these elements became more concrete. July 2021 is used as the first event date for this reason.

The policy remained subject to negotiation after the proposal. Regulation (EU) 2023/956 was adopted in May 2023. The subsequent implementing regulation specified the information that importers had to report and the methods used to calculate embedded emissions during the transitional phase (European Parliament and Council of the European Union, 2023; European Commission, 2023, Arts. 3–6). These legal steps increased the credibility of the mechanism and clarified its operational requirements before reporting began.

Transitional reporting started on 1 October 2023. From that date, importers of covered goods had to submit information on imported quantities, direct and indirect embedded emissions where applicable, and carbon prices paid in the country of origin. They did not yet have to surrender CBAM certificates (European Parliament and Council of the European Union, 2023, Arts. 32, 35; European Commission, 2023, Arts. 3–6). October 2023 is used as the second event date because CBAM moved from a proposed and legislated mechanism to an operational reporting obligation.

The two event dates mark distinct changes in the policy framework. They do not imply that firms could adjust only in July 2021 or October 2023. Adoption of the regulation and publication of the reporting rules provided additional information between the two milestones. Importers and foreign suppliers could respond as the policy became more credible and the compliance requirements became clearer. The empirical analysis tests whether import values nevertheless show a discrete change around either event.

### **2.3 Why a Reporting-Only Phase Can Affect Trade**

The empirical relevance of the reporting date comes from the change in obligations, not from the introduction of a paid border carbon price. From 1 October 2023, importers of covered goods had to report embedded emissions. Certificate surrender remained reserved for the later definitive regime (European Parliament and Council of the European Union, 2023, Art. 32, Art. 35; European Commission, 2023, Art. 3).

This legal distinction matters for the expected adjustment channel. The transitional phase did not impose a payment linked to declared embedded emissions, but it created administrative obligations for importers. They had to collect emissions information from foreign producers, calculate embedded emissions according to the reporting methodology, and submit quarterly CBAM reports (European Commission, 2023, Art. 3–6). In economic terms, the transitional phase is closer to a non-tariff trade cost than to a carbon tax. Freij (2025, pp. 23–26) studies the trade effects of this reporting phase in a matched difference-in-differences design. The main estimates point to lower covered EU imports after reporting begins, although the PPML robustness specification is smaller and statistically weaker.

The absence of certificate surrender does not make carbon intensity irrelevant. First, reporting embedded emissions may be more costly where production processes are carbon-intensive, poorly documented, or located in countries with weaker monitoring and verification systems. Second, non-compliance penalties are defined per tonne of unreported emissions, so compliance risk can scale with emissions content even before a certificate price is charged (European Commission, 2023, Art. 16). Third, importers may also adjust sourcing before financial obligations formally bind if the definitive regime is credible and future compliance costs are expected to matter. These mechanisms are weaker than a direct carbon price, but they make an intensity gradient during the transitional phase economically plausible.

This last channel links CBAM to the trade-policy uncertainty literature. In models with sunk entry costs or supplier-relationship costs, firms need not wait until policy costs are fully realised before adjusting. Handley (2014, pp. 50–53) shows how uncertainty over future trade policy can delay exporter entry and dampen responses to current tariff changes. Handley & Limão (2015, pp. 189–190, 210–211) show that credible changes in policy commitments can affect entry and

export sales even when current applied barriers are low. For CBAM, the implication is narrower. The reporting phase may affect trade not because importers already pay a border carbon price, but because documentation costs, compliance risk, and expected future obligations can enter sourcing decisions before the definitive regime starts.

## **2.4 The Definitive Regime and Recent Developments**

The definitive CBAM regime follows the transitional reporting phase. Under this regime, importers must obtain authorised CBAM declarant status, declare embedded emissions, and surrender CBAM certificates for covered imports (European Parliament and Council of the European Union, 2023, Art. 4–6, Art. 22). Certificate prices are linked to EU ETS allowance prices, and importers may deduct a carbon price already paid in the country of production (European Parliament and Council of the European Union, 2023, Art. 9, Art. 21). These financial obligations begin after the sample period of this thesis. The empirical analysis is limited to the transitional phase, in which reporting obligations existed but certificate surrender did not yet apply.

The definitive regime is connected to the gradual phase-out of free allowances under the EU ETS. As free allocation declines, CBAM is intended to expose covered imports more closely to the carbon-cost logic faced by EU producers (European Parliament and Council of the European Union, 2023, Recitals 9–11, Art. 1). In model-based studies, border adjustments can reduce leakage, but their effectiveness depends on design choices, product coverage, treatment of exports, and information requirements (Bellora & Fontagné, 2023, p. 1; Böhringer et al., 2017, pp. 35–36; Branger & Quirion, 2014, p. 29). This literature provides an important benchmark, but it mainly concerns a priced border instrument. The transitional phase studied here is an earlier and weaker stage of the policy.

Recent work stresses the limits of the definitive design. Ambec et al. (2024, pp. 1–2) show that CBAM mainly levels the playing field in the EU market and does not by itself address export competitiveness. Campolmi et al. (2025, pp. 1–3) emphasise that pricing import-embedded emissions is constrained by information requirements and propose a leakage border adjustment mechanism that does not require foreign carbon-intensity data. These arguments matter for the interpretation of the transitional phase as well. If the definitive regime is already constrained by information requirements, a reporting-only phase can plausibly affect trade through documentation costs, supplier coordination, and expectations rather than through an actual carbon price. After the sample period, the CBAM framework was simplified and adjusted further. Regulation (EU) 2025/2083 introduced a 50-tonne annual threshold that exempts small importers from CBAM obligations (European Parliament and Council of the European Union, 2025). The Commission stated that this threshold would reduce the number of importers subject to CBAM

obligations while keeping almost all embedded emissions in scope (European Commission, 2025). These later changes do not affect the estimates in this thesis. They are still relevant for the policy trajectory because they show how the reporting framework is being narrowed before the financially binding stage becomes fully operational.

### 3 Data

The data construction combines customs-level import values with pre-policy carbon-intensity exposure. Figure 2 summarises the main steps from raw COMEXT records to the final estimation panels.

*Trade outcomes and carbon intensity are aligned at the exporter  $\times$  EXIO-product level.*

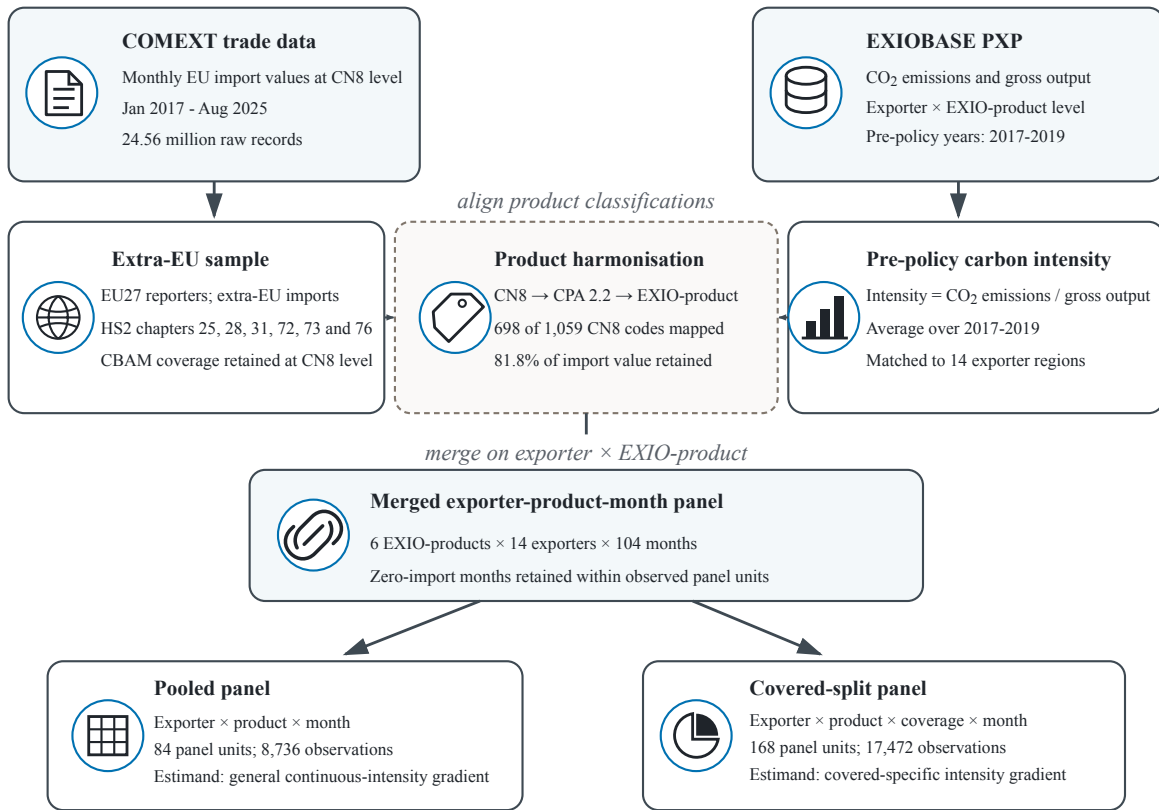


Figure 2: Data construction and mapping from customs records to final estimation panels.

#### 3.1 Trade Flows

The empirical analysis combines monthly EU import data with a pre-policy measure of exporter-product carbon intensity. The trade data come from Eurostat COMEXT and are observed at the eight-digit level of the Combined Nomenclature (CN8) (Eurostat, 2026b). This level of detail is needed because CBAM coverage is defined for specific product codes, while the later carbon-intensity measure is available only at a broader product-group level. Working from CN8 data makes it possible to identify CBAM-covered goods before aggregation.

The initial product universe is restricted to the HS2 chapters surrounding the tangible CBAM sectors: chapters 25, 28, 31, 72, 73, and 76. These chapters cover the relevant neighbourhood around cement, chemicals and fertilisers, iron and steel, and aluminium. The restriction keeps the comparison group close to the CBAM product scope. Covered imports are compared with nearby non-covered imports rather than with unrelated parts of EU trade. This choice is important for the baseline comparison because products far outside the CBAM sectoral space would provide a less informative control group.

The dependent variable is monthly import value in euros. Physical quantities are not used as the main outcome because CN8 products can be reported in different units. After aggregation to exporter  $\times$  EXIO-product cells, a quantity measure would combine heterogeneous physical measures and would be difficult to interpret. Import values are not a perfect measure of trade adjustment, but they are consistently observed and additively aggregable across CN8 products, exporters, months, and mapped EXIO-product groups. The estimates should consequently be read as changes in import values, not as separate evidence on physical quantities, unit values, product quality, or embodied emissions.

The main data-construction problem is that trade flows and emissions intensities are not observed in the same product classification. Trade flows are reported at CN8 level, whereas the carbon-intensity measure used in the next subsection is attached to EXIOBASE product groups. A conservative CN8-to-EXIO bridge is constructed. The bridge uses Eurostat's correspondence between CN 2025 and CPA 2.2 as the main intermediate step and then links the CPA anchors to EXIOBASE product-by-product sectors (Eurostat, 2026a). The mapping is fixed before estimation and is used only to define product cells and merge pre-policy carbon-intensity information. Unresolved cases are excluded rather than forced into ambiguous product assignments.

This conservative mapping reduces the risk that the carbon-intensity ranking is driven by noisy product matches. The cost is that some CN8-level product detail is lost and the final exposure measure cannot be interpreted as a shipment-level or installation-level measure of CBAM embedded emissions. It is better understood as a product-group exposure bridge between detailed trade data and broader EXIOBASE carbon-intensity information.

CBAM coverage is carried through the mapping at the CN8 level before aggregation. This step matters because CBAM coverage is more detailed than the EXIO-product groups used for carbon intensity. Keeping the covered indicator before aggregation allows the final split panel to distinguish covered and non-covered flows within the same exporter  $\times$  EXIO-product environment. The resulting panel is used later to compare covered and non-covered import values and to test whether carbon-intensity gradients are concentrated in covered trade.

Table 1 describes the covered-split panel used for the baseline and covered-split intensity specifications. It contains 17,472 observations, formed by 168 exporter  $\times$  EXIO-product  $\times$  coverage-status units observed over 104 months. Covered and non-covered flows each contribute 8,736 observations. Months without recorded imports remain in the balanced panel as zero-valued cells, accounting for 1,193 observations. The table also reports how total import value is distributed across the two coverage categories. These shares describe the composition of the estimation sample and are not estimates of a CBAM effect.

Table 1: Estimation sample overview

| Statistic                                                | Covered        | Non-covered     | Full sample     |
|----------------------------------------------------------|----------------|-----------------|-----------------|
| Observations                                             | 8,736          | 8,736           | 17,472          |
| Zero-import cells                                        | 297            | 896             | 1,193           |
| Share of zero-import cells (%)                           | 3.40           | 10.26           | 6.83            |
| Total import value (EUR)                                 | 37,712,966,733 | 330,157,533,100 | 367,870,499,834 |
| Share of import value (%)                                | 10.25          | 89.75           | 100.00          |
| Unique exporter $\times$ product $\times$ coverage cells | 84             | 84              | 168             |
| Unique exporters                                         | 14             | 14              | 14              |
| Unique EXIO-product groups                               | 6              | 6               | 6               |
| Months                                                   | 104            | 104             | 104             |

*Covered and non-covered columns refer to the split estimation panel used in the baseline and covered-split intensity specifications.*

*Within observed exporter  $\times$  product  $\times$  coverage units, months without recorded imports are retained as zero-valued observations rather than treated as missing.*

*Import values are measured in EUR.*

### 3.2 Emissions Intensity

The second part of the dataset measures carbon exposure before the CBAM policy events. This measure is constructed from EXIOBASE product-by-product accounts, which link sectoral output to environmental stressor accounts across countries and product groups (Stadler et al., 2018, pp. 502–503). The resulting variable is not a reported CBAM emissions value. It is a pre-policy exporter-product measure of carbon intensity that can be merged with the mapped trade panel.

The intensity series uses three CO<sub>2</sub> stressor categories from EXIOBASE: combustion emissions, non-combustion emissions from cement production, and non-combustion emissions from lime production. These emissions are divided by sectoral gross output and averaged over the years 2017 to 2019. The averaging window ends before both the formal CBAM proposal and the start of transitional reporting. This timing is important because the exposure variable should capture pre-policy carbon intensity, not emissions or trade patterns that may already reflect CBAM-

related adjustment. Since EXIOBASE output is measured in million euros, the intensity variable is measured in kilograms of CO<sub>2</sub> per million euros of gross output.

The variable is best understood as a pre-policy exporter-product carbon-exposure proxy. It is not a certified measure of embedded emissions at the shipment, installation, or firm level. CBAM reporting ultimately requires more specific information on covered goods and their embedded emissions (European Commission, 2023, Art. 3–6). The EXIOBASE-based measure is broader. Its advantage is that it provides a consistent carbon-intensity ranking across exporter-product cells in the full estimation panel. Its limitation is that it cannot capture within-product producer heterogeneity, firm-level abatement, shipment-specific emissions, or changes in emissions intensity after the policy milestones.

Using a pre-policy intensity measure also fits the economic question of the thesis. CBAM is concerned with differences in embedded carbon across producers when climate-policy ambition differs internationally (Bellora & Fontagné, 2023, pp. 1–2; Jakob, 2021, pp. 609–610). An exposure measure that already includes post-policy adaptation would blur the margin of interest. The intensity variable is fixed before the relevant policy shocks and is used to explain variation in later import-value adjustment.

The distribution of the pre-policy intensity measure is strongly right-skewed. To limit the influence of extreme observations, the variable is winsorised at the 1<sup>st</sup> and 99<sup>th</sup> percentiles before estimation. Table 2 reports its distribution across the 84 exporter-product units in the pooled panel. The median is 422,607 kilograms of CO<sub>2</sub> per million euros of output, compared with 4.74 million at the 90<sup>th</sup> percentile and 17.78 million at the maximum. These upper-tail values make a standard-deviation scaling difficult to interpret. The main specifications instead divide the winsorised level measure by its interquartile range of 1.75 million. A one-unit increase in the scaled variable represents an interquartile-range increase in pre-policy carbon intensity. It describes the import-value difference associated with moving from the 25<sup>th</sup> to the 75<sup>th</sup> percentile of pre-policy carbon intensity.

Table 2: Distribution of pre-policy carbon intensity

| Statistic                              | Value      |
|----------------------------------------|------------|
| Unique exporter $\times$ product units | 84         |
| Mean                                   | 1,564,131  |
| 25th percentile                        | 113,977    |
| Median                                 | 422,607    |
| 75th percentile                        | 1,865,678  |
| 90th percentile                        | 4,741,517  |
| Maximum                                | 17,780,524 |
| Interquartile range (IQR)              | 1,751,701  |

*The table is computed on unique exporter  $\times$  product units from the pooled panel, so the time-invariant intensity measure is not mechanically repeated across months.*

*Carbon intensity is measured in kilograms of CO<sub>2</sub> per million euros of gross output.*

### 3.3 Estimation Panels

Two monthly estimation panels result from the mapping procedure. The first is a pooled panel at the exporter  $\times$  EXIO-product  $\times$  month level. Covered and non-covered CN8 goods that map into the same exporter-product cell are aggregated together. This structure aligns the trade outcome with the level at which carbon intensity is measured. It is used to test whether imports from more carbon-intensive exporter-product cells change differently after the CBAM policy milestones.

A second panel keeps the CBAM coverage distinction after aggregation. It is defined at the exporter  $\times$  EXIO-product  $\times$  covered-status  $\times$  month level. This split panel separates covered and non-covered flows within the same exporter-product environment. It supports the baseline covered-import comparison and the covered-split intensity specification. The first use asks whether CBAM-covered imports changed differently from nearby non-covered imports. The second asks whether the carbon-intensity gradient is concentrated in the covered part of trade.

The panels are constructed from the same mapped trade flows, but they answer different empirical questions because they retain different dimensions of those flows. The pooled panel removes the coverage split to match the level of the EXIOBASE intensity measure and estimates the broad exporter-product intensity gradient. The split panel retains the legal coverage margin and tests whether that gradient is concentrated in covered trade. The distinction lies in the estimand and the level of aggregation, not in the underlying trade universe.

The final sample spans 14 exporters, 6 EXIOBASE product groups, and 104 months from January 2017 to August 2025. The pooled panel contains 84 exporter-product units and 8,736

monthly observations. The split panel contains 168 exporter-product-coverage units and 17,472 monthly observations. The larger number of observations in the split panel reflects the retained coverage dimension rather than additional trade flows. Both panels aggregate to the same total import value of approximately EUR 367.9 billion.

## 4 Empirical Strategy

### 4.1 Specifications

All main specifications are estimated with Poisson Pseudo Maximum Likelihood (PPML). PPML is widely used for trade-flow regressions because it avoids log-linearisation bias under heteroskedasticity and retains observations with zero trade flows (Kwon et al., 2022, pp. 1–2; Santos Silva & Tenreyro, 2006, pp. 641–645). The models include high-dimensional fixed effects to absorb persistent differences across exporter-product cells and common time shocks. This type of PPML specification is standard in applied trade settings with non-negative outcomes and many fixed effects (Correia et al., 2019, pp. 1–4).

The dependent variable is monthly import value in euros. PPML models the conditional mean as

$$E[ImportValue | X] = \exp(\eta), \quad (1)$$

where  $\eta$  is the linear index. The equations below describe the log conditional mean of import values, not a linear regression for import values. Standard errors are clustered at the exporter level in the main specifications. Because the estimation sample contains 14 exporters, exporter-clustered inference is evaluated using a Student-t distribution with 13 degrees of freedom. The appendix reports additional inference checks using heteroskedastic and panel-unit-clustered standard errors.

Let  $i$  denote the exporting country,  $s$  the EXIO-product group,  $c$  the covered-status cell, and  $t$  the month. In the split panel,  $c$  separates CBAM-covered from non-covered flows within the same exporter  $\times$  EXIO-product  $\times$  month cell. In the pooled panel, covered and non-covered flows are aggregated, so the covered-status dimension is absent.

Carbon intensity is denoted by  $Intensity_{is}^{IQR}$ . It is the winsorised pre-policy exporter-product carbon-intensity measure, scaled by the interquartile range of the unique exporter-product intensity distribution. A one-unit increase corresponds to moving from the 25th to the 75th percentile of pre-policy carbon intensity. The variables  $PostAnn_t$  and  $PostRep_t$  indicate periods after the formal CBAM proposal and after the start of transitional reporting. In the joint specifications,  $PostRep_t$  is nested within  $PostAnn_t$ . The reporting coefficient captures the additional change after reporting begins, conditional on the post-announcement period. The

cumulative post-reporting differential relative to the pre-announcement period is the sum of the announcement and reporting coefficients.

#### 4.1.1 Baseline covered-effect specification

The baseline specification is estimated on the split panel and compares CBAM-covered with non-covered imports within the same exporter  $\times$  product structure. The joint specification is

$$\eta_{isct} = \beta_A(Covered_c \times PostAnn_t) + \beta_R(Covered_c \times PostRep_t) + \alpha_{isc} + \tau_t. \quad (2)$$

Here,  $\eta_{isct}$  is the log conditional mean of monthly import value for exporter  $i$ , EXIO-product  $s$ , covered-status cell  $c$ , and month  $t$ . The fixed effect  $\alpha_{isc}$  absorbs time-invariant differences across exporter  $\times$  product  $\times$  covered-status cells. The month fixed effect  $\tau_t$  absorbs shocks common to all imports in a given month.

The coefficient  $\beta_A$  measures the differential change in covered import values after the formal CBAM proposal. The coefficient  $\beta_R$  measures the additional differential change after the start of transitional reporting in the joint specification. Announcement-only and reporting-only variants are estimated by including only the corresponding post-period interaction.

#### 4.1.2 Pooled intensity specification

The pooled intensity specification is the primary continuous-intensity specification. It is estimated on the exporter  $\times$  EXIO-product  $\times$  month panel. Covered and non-covered flows are aggregated within each exporter-product cell, so the trade outcome is aligned with the level at which carbon intensity is measured. The joint specification is given by

$$\eta_{ist} = \theta_A(Intensity_{is}^{IQR} \times PostAnn_t) + \theta_R(Intensity_{is}^{IQR} \times PostRep_t) + \alpha_{is} + \tau_t \quad (3)$$

Here,  $\eta_{ist}$  is the log conditional mean of monthly import value for exporter  $i$ , EXIO-product  $s$ , and month  $t$ . The fixed effect  $\alpha_{is}$  absorbs time-invariant differences across exporter  $\times$  product cells. The month fixed effect  $\tau_t$  absorbs shocks common to all imports in a given month.

The coefficients  $\theta_A$  and  $\theta_R$  measure whether import values from more carbon-intensive exporter-product cells change differently after the formal CBAM proposal and after the start of transitional reporting. Because  $Intensity_{is}^{IQR}$  is scaled by the interquartile range, each coefficient describes the differential import-value change associated with moving from the 25th to the 75th percentile of pre-policy carbon intensity. Announcement-only and reporting-only variants are estimated in the same way as in the baseline specification.

#### 4.1.3 Covered-split intensity specification

The covered-split intensity specification is a narrower complementary specification. It combines the continuous carbon-intensity measure with the legal CBAM coverage margin. It is estimated on the split panel, where covered and non-covered flows remain separate within exporter  $\times$  EXIO-product  $\times$  month cells. The joint specification is given by

$$\begin{aligned}\eta_{isct} = & \phi_A \left( Covered_c \times Intensity_{is}^{IQR} \times PostAnn_t \right) \\ & + \phi_R \left( Covered_c \times Intensity_{is}^{IQR} \times PostRep_t \right) + \alpha_{isc} + \tau_t.\end{aligned}\tag{4}$$

Here, the interaction term combines CBAM coverage, pre-policy carbon intensity, and the post-policy period. The coefficients  $\phi_A$  and  $\phi_R$  measure whether import-value changes within the covered margin vary with pre-policy carbon intensity. This specification treats CBAM-relevant carbon intensity as the exposure margin of interest. It does not separately decompose the average covered differential from the intensity gradient. Announcement-only and reporting-only variants are again estimated by including only the corresponding post-period interaction.

The two intensity specifications answer related but distinct questions. The pooled specification is closest to the level at which carbon intensity is observed, because both the outcome and the exposure variable are defined at the exporter  $\times$  EXIO-product level. It asks whether import values from more carbon-intensive exporter-product cells change differently in the aggregate mapped panel. The covered-split specification adds the legal coverage margin. It asks whether any carbon-intensity gradient is concentrated in the part of trade that is actually covered by CBAM. This second specification is useful because CBAM coverage is defined at a more detailed product level than the EXIO-product aggregation, but it is not the primary continuous-intensity design.

## 4.2 Event Study Design

The static specifications are complemented by event-study models to examine the timing of adjustment and the presence of pre-treatment dynamics. In these models, the single post-period interaction is replaced by a set of relative-time interactions. The period immediately before the event,  $k = -1$ , is omitted as the reference category. The variable  $EventTime_t$  measures time relative to the respective policy milestone, so that  $EventTime_t = 0$  denotes the event period itself.

For the baseline covered-effect design, the event-study specification is

$$\eta_{isct} = \sum_{k \neq -1} \beta_k (Covered_c \times \mathbb{1}\{EventTime_t = k\}) + \alpha_{isc} + \tau_t.\tag{5}$$

Each coefficient  $\beta_k$  measures the covered-versus-non-covered import-value differential at event time  $k$ , relative to the omitted pre-event period. The main text reports the baseline event studies at quarterly frequency. The announcement falls in the first month of a quarter, while the reporting phase begins exactly at the start of a quarter. Quarterly aggregation also reduces some of the short-run noise present in the monthly baseline estimates. The corresponding monthly baseline event study is reported in the appendix.

For the pooled intensity design, the event-study specification is

$$\eta_{ist} = \sum_{k \neq -1} \delta_k \left( Intensity_{is}^{IQR} \times \mathbb{1}\{EventTime_t = k\} \right) + \alpha_{is} + \tau_t. \quad (6)$$

Here, each coefficient  $\delta_k$  measures whether imports from more carbon-intensive exporter-product cells evolve differently at event time  $k$ , relative to the omitted pre-event period.

For the covered-split intensity design, the event-study specification is

$$\begin{aligned} \eta_{isct} = & \sum_{k \neq -1} \lambda_k \left( Covered_c \times Intensity_{is}^{IQR} \times \mathbb{1}\{EventTime_t = k\} \right) \\ & + \alpha_{isc} + \tau_t. \end{aligned} \quad (7)$$

Each coefficient  $\lambda_k$  measures whether the differential adjustment of CBAM-covered imports is stronger for exporter-product cells with higher pre-policy carbon intensity at event time  $k$ . The main text reports the intensity event studies at monthly frequency because the carbon-intensity specifications are estimated on monthly data and the timing of the intensity gradient is central for interpretation. Quarterly intensity event studies are reported in the appendix.

The event-study estimates are used as diagnostic evidence. Pre-event coefficients show whether the relevant comparison groups were already moving differently before the policy milestone. Post-event coefficients show whether any divergence appears around the institutional timing of CBAM or develops more gradually. The event studies hence assess the plausibility of the comparison over time. They do not remove the identifying concern if pre-event dynamics are already present.

### 4.3 Identification

The identification problem differs across the baseline and intensity specifications. The baseline specification has a DiD-style comparative structure. It compares CBAM-covered and non-covered import values within the same exporter  $\times$  EXIO-product environment before and after the relevant policy milestones. A causal interpretation would require that, without the policy milestone, covered and non-covered flows in this structured comparison group would have followed similar relative trends over time. In this thesis, that condition is used as a benchmark for interpretation, not as an assumption that is taken for granted.

The benchmark is demanding in the present setting. CBAM was introduced for sectors in which embedded emissions, carbon-cost asymmetries, and leakage concerns are central to the regulatory logic (European Parliament and Council of the European Union, 2023, Recitals 9–11, Annex I). The leakage literature also stresses that trade and production responses are especially relevant in emissions-intensive and trade-exposed sectors (Grubb et al., 2022, p. 753; Jakob,

2021, pp. 609–610). These features make the comparison economically meaningful, but also fragile in the 2021–2024 sample period.

The reason is that the CBAM-relevant product space was exposed to other shocks at the same time. The EU introduced Russia-related trade restrictions for iron and steel in March 2022 and further import restrictions including cement in April 2022 (Council of the European Union, 2026). The same period was also shaped by Russia’s war and the European energy-price shock, which affected energy-intensive industries and increased the importance of gas, electricity, and commodity-price movements (European Commission, 2026). Covered and non-covered flows within the same broad exporter-product environment may diverge for reasons other than CBAM, including sanctions, energy prices, input shortages, inventory behaviour, or sector-specific demand. The baseline comparison is treated as a structured descriptive benchmark rather than as a design that fully isolates CBAM from these contemporaneous shocks.

Event-study estimates are used to examine this concern directly. Pre-event coefficients show whether covered and non-covered import values were already moving differently before the policy milestone. Post-event coefficients show whether any divergence appears around the institutional timing of CBAM or only develops gradually. The event studies thus discipline the interpretation of the static coefficients. They do not remove the identifying concern, but they make its empirical relevance visible.

Identification in the intensity specifications relies on a different source of variation. These models use pre-policy carbon intensity as a continuous exposure measure across exporter-product cells. The relevant question is whether import-value changes after the policy milestones are systematically steeper for exporter-product cells with higher pre-policy carbon intensity. Because the intensity measure is fixed as a 2017–2019 average, it cannot mechanically reflect post-policy trade adjustment. The timing of the exposure measure is useful, but it does not make carbon intensity randomly assigned. More carbon-intensive exporter-product cells may also differ in technology, supplier structure, input dependence, product quality, market power, energy-price exposure, or country-specific industrial policy.

The pooled and covered-split intensity specifications address this problem from different angles. The pooled specification is the primary continuous-intensity design because carbon intensity is measured at the exporter  $\times$  EXIO-product level. It asks whether import values from more carbon-intensive exporter-product cells change differently in the aggregate mapped panel. The covered-split specification adds the legal coverage margin. It asks whether any carbon-intensity gradient is concentrated in the covered part of the same exporter-product environment, while non-covered flows remain available within that structure. This makes the split specification useful for assessing whether the intensity pattern is connected to CBAM coverage, but it is not the primary continuous-intensity design.

The intensity design is best read as a heterogeneity design with continuous pre-policy exposure. It is not a causal dose-response estimate of carbon intensity and not evidence of an embodied-carbon price effect. This point is especially important for the reporting phase. During the transitional period, importers faced reporting obligations but did not yet surrender CBAM certificates. A post-reporting intensity gradient could be consistent with reporting burdens, information frictions, compliance costs, anticipatory adjustment, or broader sourcing responses to the mechanism. The design cannot distinguish these channels directly.

The empirical strategy proceeds in three steps. First, the baseline specification estimates the average covered-versus-non-covered differential in the split panel. Second, the pooled and covered-split intensity specifications test whether adjustment is systematically related to pre-policy carbon intensity. Third, event studies examine pre-treatment dynamics and the timing of adjustment around the announcement and reporting dates. The appendix reports robustness checks for functional form, dynamic aggregation, inference, and time-varying product-level shocks. These checks do not change the identifying assumptions, but they show whether the main findings are sensitive to alternative modelling choices.

A final limitation concerns the dependent variable. The models use nominal import value in euros. The estimated coefficients capture changes in the value of EU imports, not physical import quantities. In CBAM-related sectors, import values can change because of quantities, prices, product quality, product composition, inventory behaviour, or sourcing decisions. The results are evidence of import-value adjustment, not direct evidence of volume reductions, abatement, or emissions-leakage mitigation.

## 5 Results

### 5.1 Baseline Covered-Import Differentials

The baseline specification compares CBAM-covered with non-covered import values within exporter-product cells. It provides a descriptive benchmark for whether the covered margin developed differently after the announcement and reporting milestones. The specification does not distinguish whether this differential reflects CBAM-related adjustment or other shocks affecting covered products during the same period.

Table 3 reports the announcement-only, reporting-only, and joint PPML estimates. The announcement-only coefficient is  $-0.134$ , corresponding to a covered-import differential of approximately  $-12.5$  percent relative to non-covered imports. The reporting-only coefficient is  $-0.144$ , or approximately  $-13.4$  percent. Both estimates are statistically significant using exporter-clustered inference with 13 degrees of freedom.

Table 3: Baseline covered-import value differentials

|                                                    | Announcement                         | Reporting                            | Joint                                |
|----------------------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| CBAM-covered $\times$ post announcement            | -0.134***<br>[-0.213, -0.055]        |                                      | -0.098**<br>[-0.174, -0.023]         |
| CBAM-covered $\times$ post reporting               |                                      | -0.144***<br>[-0.244, -0.043]        | -0.083<br>[-0.186, 0.019]            |
| Implied reporting-phase differential (joint model) |                                      |                                      | -0.181***<br>[-0.294, -0.069]        |
| Fixed effects                                      | exp $\times$ prod $\times$ cov, time | exp $\times$ prod $\times$ cov, time | exp $\times$ prod $\times$ cov, time |
| Clustering                                         | Exporter                             | Exporter                             | Exporter                             |
| Observations                                       | 17472                                | 17472                                | 17472                                |

*Dependent variable: monthly import value in EUR.*

*Brackets report exporter-clustered 95% confidence intervals using Student-t critical values with 13 degrees of freedom.*

*Significance level: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ , based on the same  $t(13)$  inference.*

*Because the reporting indicator is nested within the post-announcement indicator, the implied differential during the reporting phase equals the sum of both coefficients and is measured relative to the pre-announcement period. Its confidence interval accounts for their estimated covariance.*

*Unit of observation: exporter  $\times$  EXIOBASE-product  $\times$  covered status  $\times$  month.*

The joint specification separates the announcement phase from the subsequent change after reporting begins. The post-announcement coefficient is  $-0.098$ , which corresponds to a differential of approximately  $-9.4$  percent during the period between the announcement and the start of reporting. The additional post-reporting coefficient is  $-0.083$  and is not statistically significant at conventional levels. The implied reporting-phase differential relative to the pre-announcement period is the sum of both coefficients. It equals  $-0.181$  log points, or approximately  $-16.6$  percent, and is statistically significant. This cumulative estimate describes the relative position of covered and non-covered import values during the reporting phase. It does not show that the start of reporting itself produced a separate decline.

Figure 3 reports quarterly event-study estimates for the covered-versus-non-covered differential around the formal CBAM proposal and the start of transitional reporting. The baseline event studies are shown at quarterly frequency because the announcement falls in the first month of a quarter and the reporting phase starts exactly at the beginning of a quarter. Quarterly aggregation also reduces some of the short-run noise present at monthly frequency.

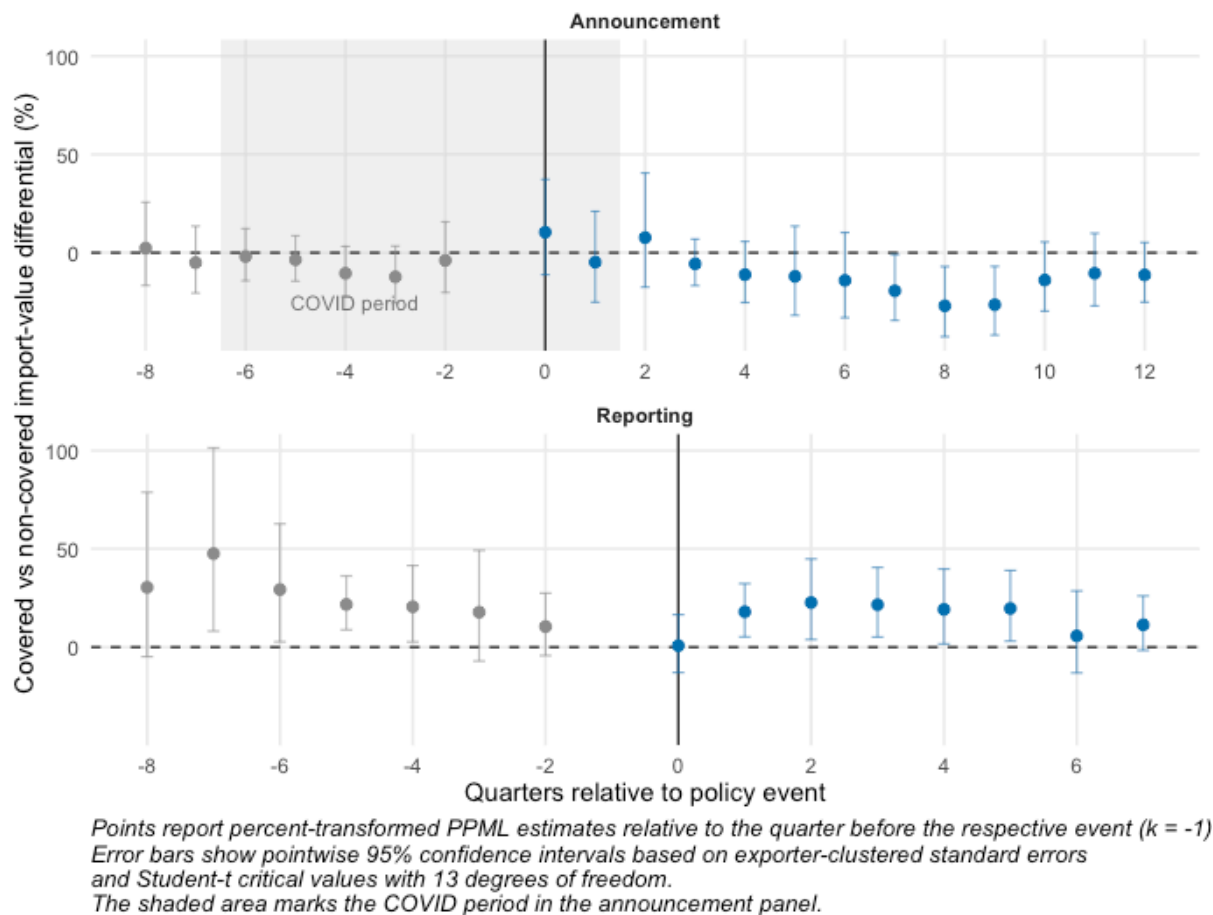


Figure 3: Quarterly event-study estimates for CBAM-covered relative to non-covered import values.

The announcement event study does not show an immediate break at the proposal date. The pre-announcement estimates are individually statistically insignificant under the final small-cluster inference. The covered-import differential becomes negative only later in the post-announcement window. In quarters seven to nine, the estimates range from approximately  $-19$  to  $-27$  percent and their pointwise confidence intervals exclude zero. The timing suggests a delayed divergence rather than a discrete adjustment at the announcement.

The reporting event study does not reveal an additional negative shift when transitional reporting begins. Several estimates in the more distant pre-reporting period are positive and statistically significant, which indicates that covered and non-covered import values were already following different paths. The post-reporting estimates do not form a sustained negative sequence. The dynamic evidence does not locate the negative average reporting-phase differential at the formal start of reporting.

The baseline results establish a negative covered-versus-non-covered import-value differential during the later part of the sample. The static estimates indicate that the differential is economically sizeable, while the event studies show that it emerged gradually and is not cleanly linked

to either policy date. The next section examines whether this relative import-value pattern varies with pre-policy carbon intensity.

## 5.2 Intensity-Gradient Results

The intensity specifications examine whether import-value differentials vary with pre-policy carbon intensity. The pooled specification first tests for a general carbon-intensity gradient across the exporter  $\times$  EXIO-product panel. Carbon intensity is scaled by the interquartile range (IQR) of the unique exporter-product intensity distribution. The coefficients can be read as the import-value differential associated with moving from the 25th to the 75th percentile of pre-policy carbon intensity.

Table 4 reports the pooled static PPML estimates for the announcement phase, the reporting phase, and the joint specification.

Table 4: Pooled carbon-intensity gradients on EU import values

|                                                          | Announcement              | Reporting                 | Joint                     |
|----------------------------------------------------------|---------------------------|---------------------------|---------------------------|
| IQR-scaled intensity $\times$ post announcement          | -0.040<br>[-0.223, 0.143] |                           | -0.014<br>[-0.161, 0.133] |
| IQR-scaled intensity $\times$ post reporting             |                           | -0.073<br>[-0.266, 0.119] | -0.065<br>[-0.171, 0.041] |
| Implied reporting-phase intensity gradient (joint model) |                           |                           | -0.079<br>[-0.326, 0.168] |
| Fixed effects                                            | exp $\times$ prod, time   | exp $\times$ prod, time   | exp $\times$ prod, time   |
| Clustering                                               | Exporter                  | Exporter                  | Exporter                  |
| Observations                                             | 8736                      | 8736                      | 8736                      |

*Dependent variable: monthly import value in EUR.*

*Carbon intensity is scaled so that a one-unit increase corresponds to one interquartile-range (IQR) increase in pre-policy exporter-product intensity.*

*Brackets report exporter-clustered 95% confidence intervals using Student-t critical values with 13 degrees of freedom.*

*Significance level: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ , based on the same  $t(13)$  inference.*

*The reporting indicator is nested within the post-announcement indicator; the implied intensity gradient during the reporting phase equals the sum of both joint-model coefficients and is measured relative to the pre-announcement period. Its confidence interval accounts for their estimated covariance.*

*The pooled specification combines covered and non-covered flows within the same exporter  $\times$  EXIOBASE-product  $\times$  month cell.*

The pooled estimates are negative but imprecisely estimated. In the announcement-only specification, a one-IQR increase in pre-policy carbon intensity is associated with a coefficient of  $-0.040$ , equivalent to an import-value differential of approximately  $-3.9$  percent. The reporting-only coefficient is  $-0.073$ , or approximately  $-7.0$  percent. Neither estimate is statistically significant.

In the joint specification, the announcement-phase gradient is  $-0.014$  and the additional post-reporting change is  $-0.065$ . Their sum gives an implied reporting-phase gradient of  $-0.079$  relative to the pre-announcement period, corresponding to approximately  $-7.6$  percent for a one-IQR increase in carbon intensity. The confidence interval includes zero. The pooled spec-

ification does not provide statistically precise evidence of a broad negative carbon-intensity gradient in import values.

The covered-split specification retains the CBAM coverage distinction within each exporter  $\times$  EXIO-product environment. It tests whether the carbon-intensity gradient is concentrated in covered trade rather than applying across the pooled product cell. Table 5 reports the corresponding estimates.

Table 5: Covered-split carbon-intensity gradients on EU import values

|                                                                  | Announcement                         | Reporting                            | Joint                                |
|------------------------------------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| Covered $\times$ IQR-scaled intensity $\times$ post announcement | -0.033<br>[-0.133, 0.067]            |                                      | -0.010<br>[-0.098, 0.079]            |
| Covered $\times$ IQR-scaled intensity $\times$ post reporting    |                                      | -0.069<br>[-0.167, 0.030]            | -0.063**<br>[-0.121, -0.004]         |
| Implied reporting-phase intensity gradient (joint model)         |                                      |                                      | -0.072<br>[-0.201, 0.056]            |
| Fixed effects                                                    | exp $\times$ prod $\times$ cov, time | exp $\times$ prod $\times$ cov, time | exp $\times$ prod $\times$ cov, time |
| Clustering                                                       | Exporter                             | Exporter                             | Exporter                             |
| Observations                                                     | 17472                                | 17472                                | 17472                                |

*Dependent variable: monthly import value in EUR.*

*Carbon intensity is scaled so that a one-unit increase corresponds to one interquartile-range (IQR) increase in pre-policy exporter-product intensity.*

*Brackets report exporter-clustered 95% confidence intervals using Student-t critical values with 13 degrees of freedom.*

*Significance level: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ , based on the same  $t(13)$  inference.*

*The reporting indicator is nested within the post-announcement indicator; the implied intensity gradient during the reporting phase equals the sum of both joint-model coefficients and is measured relative to the pre-announcement period. Its confidence interval accounts for their estimated covariance.*

*The covered-split specification keeps covered and non-covered flows separate within the same exporter  $\times$  EXIOBASE-product environment.*

The announcement-only coefficient in the covered-split specification is  $-0.033$ , corresponding to an import-value differential of approximately  $-3.2$  percent for a one-IQR increase in carbon intensity. The reporting-only coefficient is  $-0.069$ , or approximately  $-6.7$  percent. Both confidence intervals include zero.

In the joint specification, the announcement-phase coefficient is  $-0.010$ . The additional change after reporting begins is  $-0.063$  and is statistically significant at the 5 percent level. This coefficient compares the reporting phase with the preceding announcement phase. It does not measure the full reporting-phase gradient relative to the pre-announcement period.

The implied reporting-phase gradient relative to the pre-announcement period is the sum of the two joint-model coefficients. It equals  $-0.072$ , corresponding to approximately  $-7.0$  percent for a one-IQR increase in carbon intensity. Its confidence interval includes zero. The statistical significance of the additional reporting term is thus not matched by a statistically significant cumulative reporting-phase gradient.

The difference between the two intensity specifications is limited to the additional reporting coefficient in the covered-split joint model. The pooled coefficients remain imprecise, and the cumulative reporting-phase gradients in both specifications are statistically indistinguishable

from zero. The monthly event studies examine whether the dynamic paths support a discrete change at either policy milestone.

### 5.3 Dynamic Evidence

The monthly event studies examine whether the static intensity coefficients correspond to a visible change around either policy milestone. Figure 4 and Figure 5 report the pooled and covered-split estimates relative to the month before the respective event.

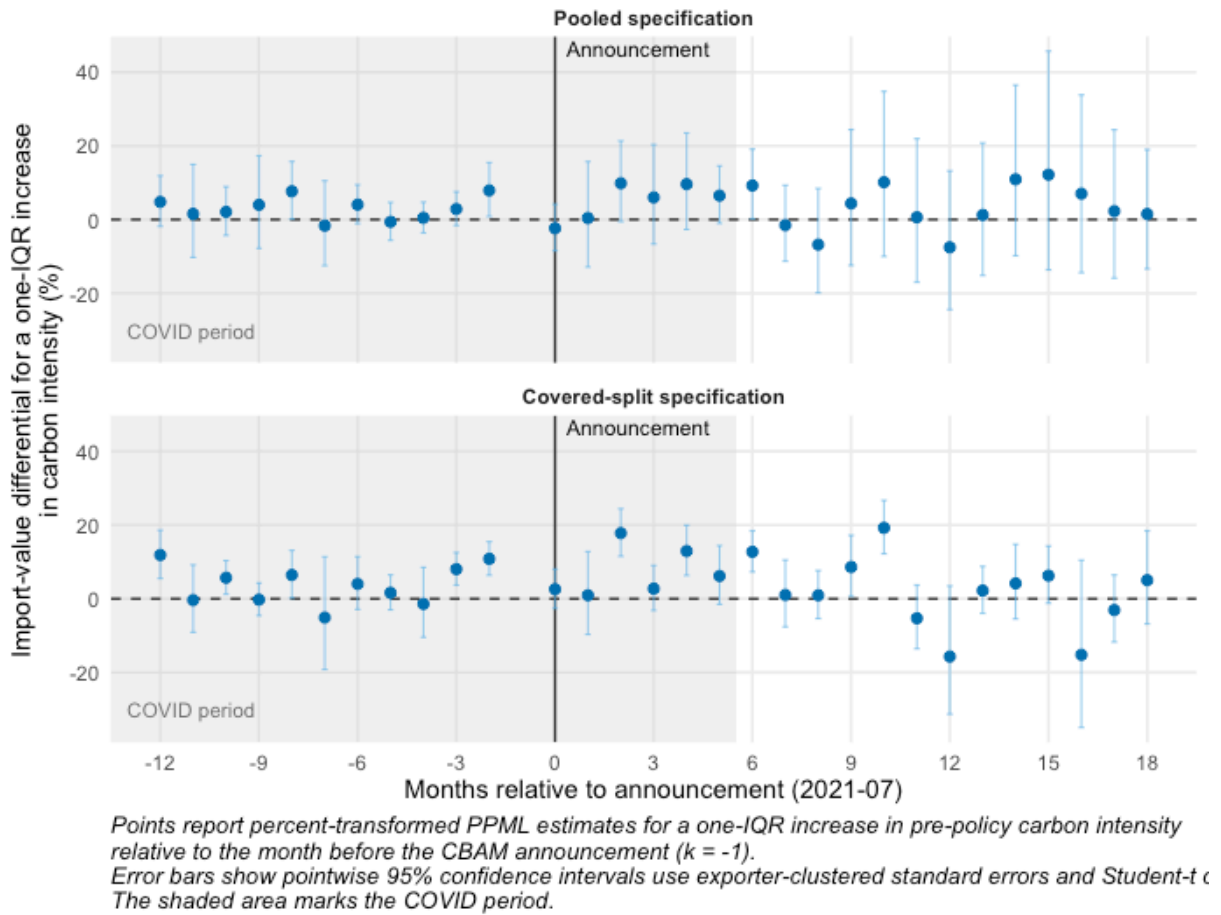


Figure 4: Monthly carbon-intensity event-study estimates around the CBAM announcement. The pooled announcement path does not show a sustained negative carbon-intensity gradient. The estimates vary around zero, with several isolated positive coefficients after the announcement. The covered-split path is also irregular. Positive estimates appear both before and after the policy date, and no persistent decline begins at the announcement. The monthly evidence does not support an announcement-specific negative gradient for more carbon-intensive exporter-product relationships.

Figure 5 reports the corresponding monthly paths around the start of transitional reporting.

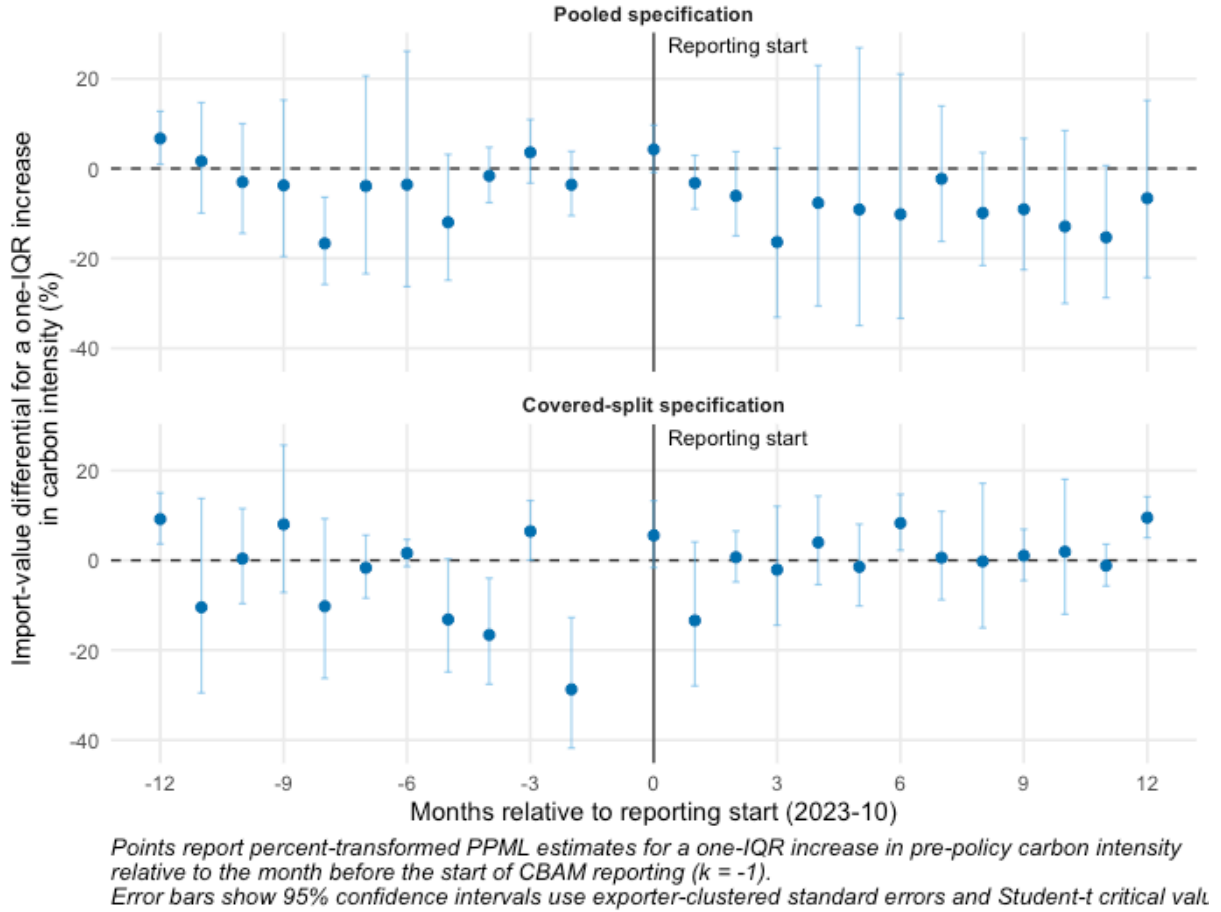


Figure 5: Monthly carbon-intensity event-study estimates around the start of CBAM reporting.

The pooled reporting path is more consistently negative than the announcement path. Most post-reporting point estimates lie below zero, but their pointwise confidence intervals include zero. The pre-reporting estimates also vary over time, which makes it difficult to interpret the negative post-event sequence as a discrete break at the start of reporting.

The covered-split reporting path provides even less support for such a break. Its pre-treatment estimates are irregular, while the post-reporting coefficients are mixed and include positive values. The path does not show a sustained negative gradient beginning in October 2023. The event study does not locate the statistically significant additional reporting coefficient from the static joint model at the formal reporting date.

The dynamic results qualify the static intensity estimates. The pooled reporting path contains suggestive negative movement, but the estimates remain imprecise and the pre-event path is not flat. The covered-split dynamics do not provide corresponding evidence of a reporting-date break. Across the pooled and covered-split designs, the event studies do not establish a clear or persistent negative carbon-intensity gradient during the sample period.

The appendix reports alternative functional forms, dynamic frequencies, variance estimators, and product-by-time fixed effects. These checks change the precision and magnitude of individual coefficients, but they do not produce a stable carbon-intensity gradient across specifications.

## **6 Discussion**

During the sample period, CBAM was still in its reporting-only transitional phase. Importers of covered goods had to report embedded emissions, but they did not yet surrender CBAM certificates (European Parliament and Council of the European Union, 2023, Art. 32, Art. 35; European Commission, 2023, Art. 3). This institutional distinction is central for interpretation. Much of the theoretical and simulation literature studies border adjustment as a price-based leakage instrument. Under the definitive regime, a charge linked to embedded emissions can change relative costs between domestic and foreign producers. By contrast, the transitional phase created reporting obligations, information requirements, and future regulatory exposure before the financial mechanism became binding. The question is narrower than whether CBAM already reduced carbon leakage. It is whether the movement from proposal to operational reporting coincided with changes in EU import values.

### **6.1 Interpreting Transitional-Phase Import-Value Differentials**

Across the baseline specifications, the clearest empirical pattern is the broad covered-versus-non-covered differential. Covered import values decline relative to nearby non-covered import values during the later part of the sample. In the joint model, the cumulative reporting-phase differential is negative and statistically significant, while the additional reporting coefficient itself is not. That combination matters. It points to a gradual divergence during the period in which CBAM became legally and operationally concrete, not to a separate discrete decline exactly when reporting began.

Event-study evidence reinforces this reading. Around the July 2021 proposal, the estimates do not show an immediate negative break. Around the October 2023 reporting date, they also do not show a clean additional negative shift. Negative covered differentials appear only later in the window. Such timing is consistent with gradual adjustment as regulatory uncertainty declines and operational details become clearer. It is not consistent with a simple story in which one policy date alone triggered the full import-value pattern.

Several institutional steps may have contributed to this gradual timing. The formal proposal, the adoption of Regulation (EU) 2023/956, the implementing regulation on transitional reporting, and the start of reporting changed different aspects of the policy environment. Some steps increased legal credibility. Others specified reporting rules or made compliance obligations operational. Trade-policy uncertainty provides a useful lens for this sequence. When market

access depends on sunk costs, supplier relationships, or entry decisions, firms may adjust before future policy costs are fully realised (Handley, 2014, pp. 50–53; Handley & Limão, 2015, pp. 189–190, 210–211). For CBAM, however, this interpretation must remain narrow. The design cannot separate anticipatory sourcing from other sectoral shocks affecting the same product space.

A leakage interpretation would go beyond what the estimates identify. Carbon leakage is an emissions outcome, not an import-value outcome. It can operate through fossil-fuel markets, through competition between regulated and unregulated producers, and through strategic responses by other jurisdictions (Jakob, 2021, pp. 609–610). The data used here measure EU import values. They do not measure production relocation, embodied emissions, or global emissions. Lower import values may reflect lower quantities, lower unit values, changes in quality, product-composition shifts, inventory behaviour, rerouting, or sourcing decisions. The evidence speaks to import-value adjustment within the mapped CBAM-relevant product space. It does not directly measure emissions leakage.

Freij provides the closest empirical reference point for the transitional phase. That study treats reporting obligations as a trade-cost shock and reports lower covered EU imports after reporting begins, while the PPML robustness specification is smaller and statistically weaker (Freij, 2025, pp. 1–2, 23–26). The present results are consistent with the broader idea that reporting obligations can matter before certificate surrender begins. They are more cautious on timing. Here, the dynamic evidence points to gradual divergence rather than to a clean reporting-date break.

Carbon intensity further narrows the interpretation. The pooled specification does not provide statistically precise evidence of a broad negative carbon-intensity gradient. Import values from more carbon-intensive exporter-product cells do not systematically decline more strongly across the aggregate mapped panel. If the transitional phase had already worked like an emissions-proportional border price, a clearer negative gradient would be expected. The pooled estimates do not support that mechanism.

Adding the legal coverage margin does not overturn this conclusion. The covered-split specification contains a negative and statistically significant additional reporting coefficient in the joint model. Yet the cumulative reporting-phase gradient is not statistically distinguishable from zero, and the monthly event studies do not show a corresponding reporting-date break. The evidence therefore does not establish robust reallocation away from more carbon-intensive exporter-product relationships. It supports a broad covered-import differential, but not a stable carbon-intensity response.

Model-based studies of CBAM provide an important benchmark for this distinction. Branger and Quirion show that border carbon adjustments can reduce leakage and competitiveness losses in simulations, although effects depend on design choices (Branger & Quirion, 2014,

pp. 29–31, 35–36). Böhringer et al. compare border adjustments and output-based rebates as anti-leakage instruments and show that policy performance depends on the instrument design (Böhringer et al., 2017, pp. 35–37). Bellora and Fontagné emphasise product coverage, free allocation, export competitiveness, and downstream cost pass-through as central determinants of CBAM effects (Bellora & Fontagné, 2023, pp. 1–3, 10–12). Ambec et al. add that CBAM mainly levels the playing field in the domestic market and does not by itself address export competitiveness (Ambec et al., 2024, pp. 1–2). These studies speak primarily to the definitive regime. Their mechanisms should not be projected mechanically onto a reporting-only phase without certificate surrender.

A bounded interpretation follows from this comparison. The transitional phase appears to have been relevant for covered import values. Reporting obligations, information frictions, regulatory uncertainty, and anticipation of future obligations are plausible channels. A direct carbon-price channel is not. The empirical evidence also does not show that carbon intensity was the main force behind the broad covered-versus-non-covered divergence.

## **6.2 Implications and Limits**

One implication is that reporting architecture matters. Embedded-emissions reporting requires information to move across supply chains. Importers depend on foreign producers for emissions data, production-process information, and documentation that can be reported under CBAM rules. These requirements can create trade frictions before certificate surrender begins. The broad covered-import differential is consistent with such frictions. The absence of a robust carbon-intensity gradient prevents a stronger interpretation as an already active carbon-price mechanism.

Information constraints are especially relevant for CBAM design. Campolmi et al. emphasise that import-embedded emissions pricing requires information on foreign carbon intensities and that such requirements limit the feasible coverage of CBAM-style instruments (Campolmi et al., 2025, pp. 1–4, 40). Eicke et al. make a related point from the perspective of third countries. Exposure to CBAM depends not only on trade structure and emissions intensity, but also on institutional capacity to monitor, report, and verify product-level emissions (Eicke et al., 2021, pp. 1–2, 7–9). These arguments fit the transitional phase closely. Reporting can matter because the required information is costly, incomplete, or unevenly available across exporters.

The findings also connect to the political economy of leakage protection. Free allocation under the EU ETS has reduced competitiveness concerns, but it can weaken carbon-cost pass-through and reduce incentives for efficient material use (Grubb et al., 2022, pp. 753, 762, 766–767). Firm-level evidence further suggests that allocation rules can overcompensate firms relative to estimated relocation risk (Martin et al., 2014, pp. 2482–2485). CBAM changes the anti-leakage

instrument from producer compensation toward import-side obligations. Evidence from the transitional phase suggests that this shift can coincide with import-value changes before the definitive price regime starts. It does not show that emissions leakage has already been reduced. Policy relevance extends beyond EU importers. Several studies stress that CBAM exposure is unevenly distributed across trading partners. Eicke et al. show that relative CBAM risks are often higher in the Global South and non-EU Eastern Europe (Eicke et al., 2021, pp. 1–2). Magacho et al. show that exposure can extend beyond direct exporters through input-output linkages, employment, wages, and external dependence (Magacho et al., 2024, pp. 245, 249–250). Perdana and Vielle argue that CBAM design can be made more acceptable for least-developed countries through complementary support or revenue use (Perdana & Vielle, 2022, pp. 1–2, 8–9). The present estimates do not identify country-level welfare effects. They do, however, support the broader concern that product coverage, reporting capacity, and carbon exposure can interact before financial obligations apply.

Several limitations follow directly from the empirical design. Nominal import value in euros is the dependent variable. The estimates cannot separate quantities from unit values, quality changes, inventory behaviour, or within-product composition. Carbon intensity is measured at the exporter  $\times$  EXIO-product level and cannot capture installation-level emissions, firm-level abatement, or shipment-specific reporting values. Contemporaneous shocks in energy-intensive and trade-exposed sectors may also contribute to the covered-versus-non-covered differential. Fixed effects and robustness checks reduce some concerns, but they do not decompose the observed import-value changes into their underlying price, quantity, quality, sourcing, or emissions components. A further limitation concerns statistical inference. The main specifications cluster standard errors at the exporter level, but the sample contains only 14 exporter clusters. Finite-sample distortions may therefore remain despite the use of a Student-t reference distribution with 13 degrees of freedom. Statistical significance should consequently be interpreted with appropriate caution.

Future effects may differ once the definitive regime becomes binding. Certificate surrender links CBAM more directly to declared embedded emissions, EU ETS allowance prices, deductions for carbon prices paid abroad, and the phase-out of free allocation. These features create stronger carbon-cost incentives than the reporting-only phase observed here. Transitional-phase estimates should not be extrapolated mechanically. They may understate future carbon-intensity responses if certificate costs become salient. They may also overstate persistent adjustment if the observed divergence reflects temporary learning costs, inventory behaviour, or uncertainty during implementation.

The overall interpretation is deliberately bounded. The thesis finds a robust broad covered-import differential in the mapped import-value panel. It does not find robust evidence that this

differential is systematically stronger in more carbon-intensive exporter-product relationships. The transitional phase was relevant for the import-value patterns studied here, but the evidence is narrower than leakage mitigation and weaker than a confirmed emissions-proportional border-price effect. Its most plausible interpretation is early adjustment under reporting obligations, information frictions, and anticipation of a future price-based regime.

## 7 Conclusion

This thesis examines whether the EU Carbon Border Adjustment Mechanism was associated with changes in EU import patterns during its transitional reporting phase. Monthly COMEXT import values are combined with pre-policy EXIOBASE carbon intensities and estimated with PPML specifications that compare covered and non-covered trade flows around the CBAM proposal and the start of transitional reporting. The analysis asks whether covered import values changed differently from nearby non-covered import values, and whether any such difference was stronger in more carbon-intensive exporter-product relationships.

The answer is qualified. Covered import values diverged from non-covered import values during the period in which CBAM moved from a legislative proposal to an operational reporting regime. The static baseline estimates are negative and economically meaningful, and the cumulative reporting-phase differential in the joint specification is statistically significant. The event studies, however, do not show a clean break at either the July 2021 proposal or the October 2023 reporting start. The covered differential appears gradually. The baseline evidence is best interpreted as a covered-versus-non-covered import-value differential during CBAM's legal and operational development, not as a clean causal estimate tied to a single policy date.

The carbon-intensity evidence is more limited. The pooled intensity specification does not provide statistically precise evidence of a broad negative carbon-intensity gradient. Import values from more carbon-intensive exporter-product cells do not systematically decline more strongly across the aggregate mapped panel. The covered-split specification adds the legal coverage margin and contains a negative additional reporting coefficient in the joint model, but the cumulative reporting-phase gradient is not statistically distinguishable from zero. The dynamic estimates also do not show a corresponding reporting-date break. The results do not establish robust reallocation away from more carbon-intensive exporter-product relationships.

The main conclusion is that the CBAM transitional phase was relevant for the import-value patterns studied here, but the evidence remains narrower than leakage mitigation. During the sample period, importers reported embedded emissions but did not yet surrender CBAM certificates. The observed covered-import differential is consistent with early adjustment under reporting obligations, information frictions, compliance preparation, regulatory uncertainty, or

anticipation of the definitive regime. It is not evidence of an already active emissions-proportional border price. It is also not direct evidence that global emissions leakage was reduced.

Several limitations define this interpretation. The dependent variable is nominal import value in euros, so the estimates cannot separate quantities from prices, product quality, inventory behaviour, or within-product composition. The carbon-intensity measure is constructed at the exporter  $\times$  EXIO-product level and cannot capture installation-level emissions, shipment-specific reporting values, or firm-level abatement. The event studies also show that pre-treatment dynamics are not fully flat, which limits a strong causal interpretation. Contemporaneous shocks in energy-intensive and trade-exposed sectors may contribute to the covered-versus-non-covered differential.

The definitive CBAM regime may generate different patterns. Certificate surrender, EU ETS-linked certificate prices, deductions for carbon prices paid abroad, and the phase-out of free allocation will create stronger carbon-cost incentives than the reporting-only phase observed in this thesis. Future research should examine whether the broad covered-import differential persists once the financial regime becomes binding, and whether a clearer carbon-intensity gradient emerges when certificate costs apply. Later data with firm-level compliance information, shipment-level emissions reports, harmonised quantity measures, or more detailed price information would help separate sourcing, price, quantity, and emissions channels.

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# Appendix

## Alternative Functional Form

Table 6: Log-intensity robustness of static carbon-intensity specifications

|                                                              | Pooled specification      |                           |                              | Covered-split specification          |                                      |                                      |
|--------------------------------------------------------------|---------------------------|---------------------------|------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
|                                                              | Announcement              | Reporting                 | Joint                        | Announcement                         | Reporting                            | Joint                                |
| Log intensity $\times$<br>post announcement                  | -0.039<br>[-0.122, 0.045] |                           | -0.021<br>[-0.098, 0.057]    |                                      |                                      |                                      |
| Log intensity $\times$<br>post reporting                     |                           | -0.054<br>[-0.123, 0.016] | -0.041**<br>[-0.080, -0.002] |                                      |                                      |                                      |
| Covered $\times$ log intensity $\times$<br>post announcement |                           |                           |                              | -0.011***<br>[-0.017, -0.004]        |                                      | -0.008**<br>[-0.014, -0.002]         |
| Covered $\times$ log intensity $\times$<br>post reporting    |                           |                           |                              |                                      | -0.011**<br>[-0.019, -0.003]         | -0.006<br>[-0.015, 0.002]            |
| Fixed effects                                                | exp $\times$ prod, time   | exp $\times$ prod, time   | exp $\times$ prod, time      | exp $\times$ prod $\times$ cov, time | exp $\times$ prod $\times$ cov, time | exp $\times$ prod $\times$ cov, time |
| Clustering                                                   | Exporter                  | Exporter                  | Exporter                     | Exporter                             | Exporter                             | Exporter                             |
| Observations                                                 | 8736                      | 8736                      | 8736                         | 17472                                | 17472                                | 17472                                |

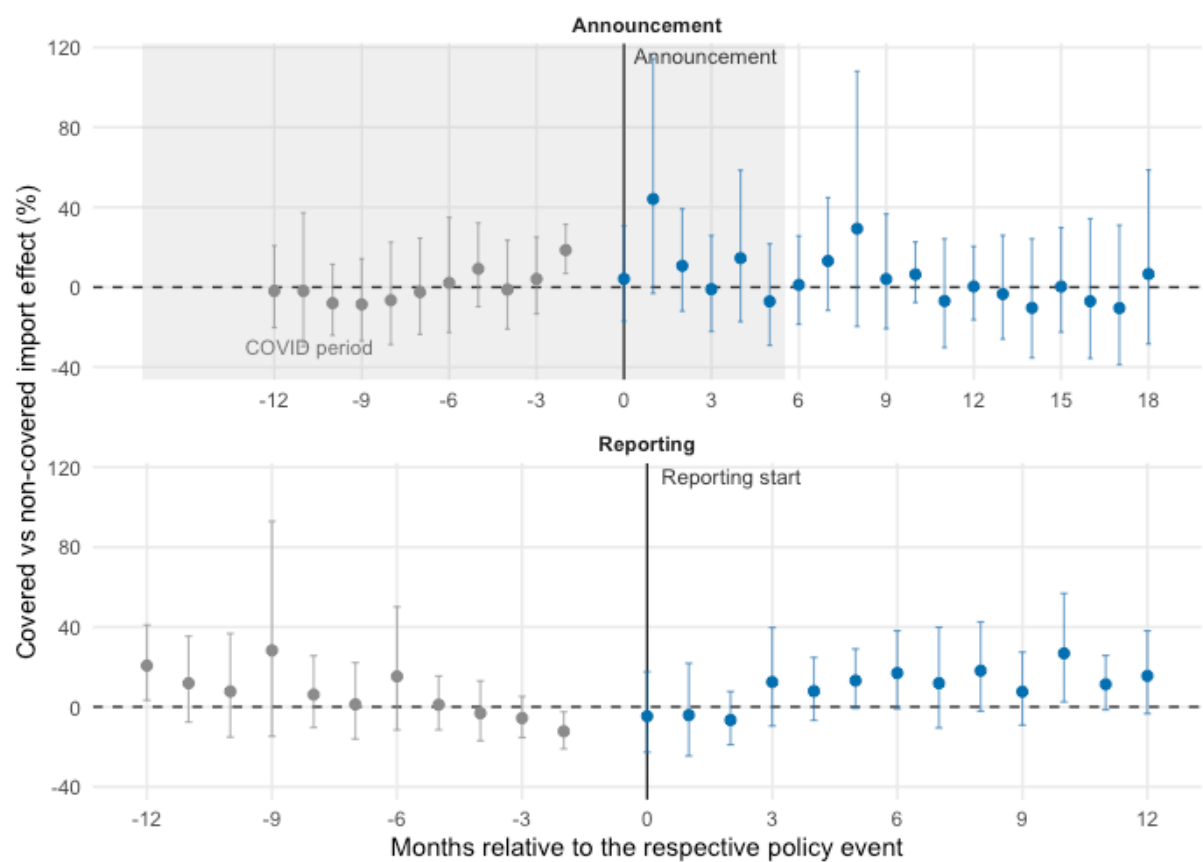
Dependent variable: monthly import value in EUR.

Log carbon intensity is the logarithm of the winsorised pre-policy exporter-product intensity measure; coefficients are not expressed per interquartile-range increase.

Brackets report exporter-clustered 95% confidence intervals using Student-*t* critical values with 13 degrees of freedom.

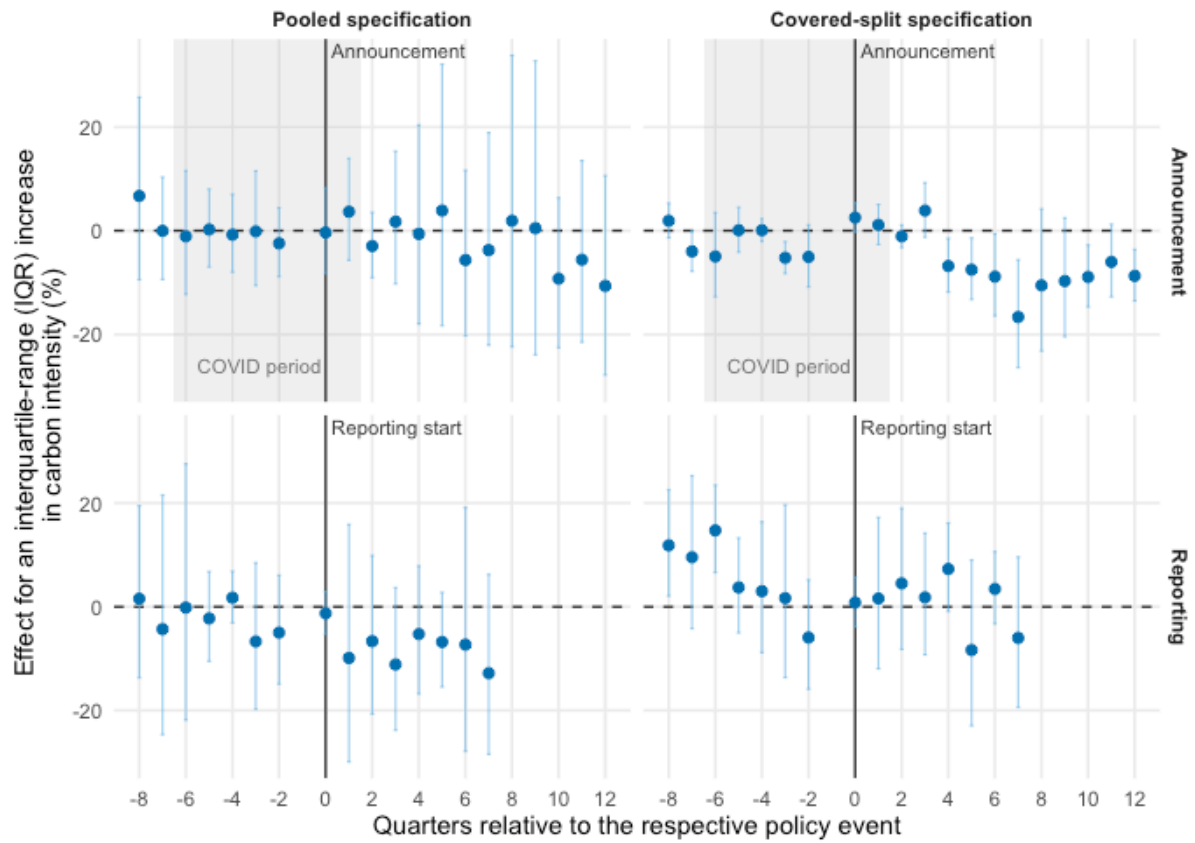
Significance level: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ , based on the same  $t(13)$  inference.

## Dynamic Robustness



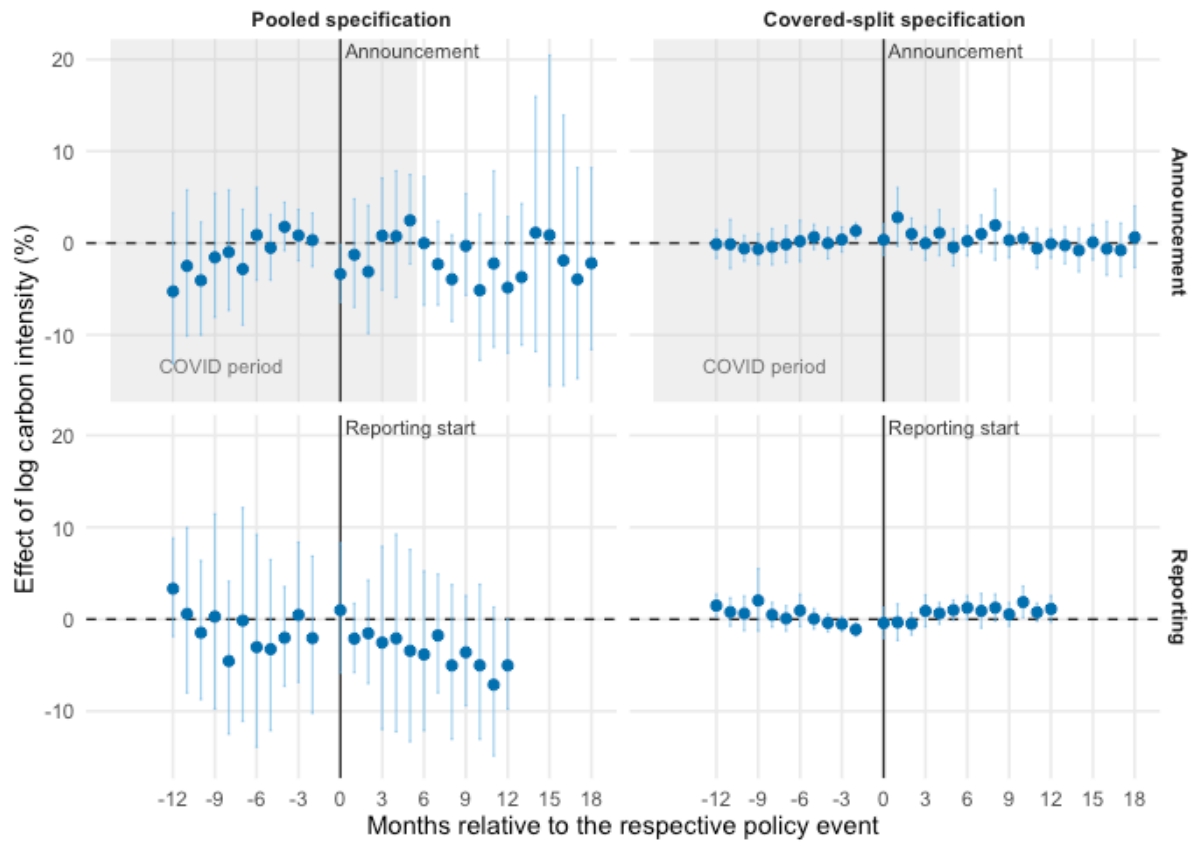
Points show percent-transformed PPML estimates and 95% confidence intervals relative to the month before the respective event ( $k = -1$ ). The shaded area marks the COVID period in the announcement panel.

Figure 6: Monthly baseline event-study estimates for covered versus non-covered import values.



Points show percent-transformed PPML estimates and 95% confidence intervals for an interquartile-range (IQR) increase in pre-policy carbon intensity relative to the quarter before the respective event ( $k = -1$ ). The shaded area marks the COVID period in the announcement panel.

Figure 7: Quarterly event-study estimates for carbon-intensity gradients.



Points show percent-transformed PPML estimates and 95% confidence intervals for the interaction between log pre-policy carbon intensity and event time, relative to the month before the respective event ( $k = -1$ ). The shaded area marks the COVID period in the announcement panel.

Figure 8: Monthly event-study estimates using log carbon intensity.

## Inference Robustness

The main specifications cluster standard errors at the exporter level. Because the final estimation sample contains 14 exporters, the main results use a Student-t reference distribution with 13 degrees of freedom. Table 7 compares this inference with heteroskedastic and panel-unit-clustered alternatives. The exercise assesses sensitivity to the variance estimator rather than changing the identification strategy.

A wild-cluster bootstrap is not reported because the standard R implementation considered for this purpose does not support the nonlinear fepois specifications used in the analysis. A manually implemented pairs-cluster bootstrap would not be equivalent to a wild-cluster procedure and may itself be sensitive to resampling variation with only 14 clusters. The robustness exercise therefore focuses on transparent alternative variance estimators while retaining the exporter-clustered specification with a Student-t reference distribution as the main approach.

Table 7: Inference robustness under alternative variance estimators

| Specification                                 | Variance estimator      | Inference robustness |                  |         |
|-----------------------------------------------|-------------------------|----------------------|------------------|---------|
|                                               |                         | Estimate             | 95% CI           | p-value |
| Baseline: Announcement                        | Heteroskedastic         | -0.134***            | [-0.173, -0.095] | 0.000   |
|                                               | Clustered by exporter   | -0.134***            | [-0.213, -0.055] | 0.003   |
|                                               | Clustered by panel unit | -0.134*              | [-0.284, 0.016]  | 0.080   |
| Baseline: Reporting                           | Heteroskedastic         | -0.144***            | [-0.189, -0.098] | 0.000   |
|                                               | Clustered by exporter   | -0.144***            | [-0.244, -0.043] | 0.009   |
|                                               | Clustered by panel unit | -0.144*              | [-0.293, 0.006]  | 0.059   |
| Baseline: Joint (announcement)                | Heteroskedastic         | -0.098***            | [-0.149, -0.048] | 0.000   |
|                                               | Clustered by exporter   | -0.098**             | [-0.174, -0.023] | 0.015   |
|                                               | Clustered by panel unit | -0.098               | [-0.229, 0.032]  | 0.139   |
| Baseline: Joint (reporting)                   | Heteroskedastic         | -0.083***            | [-0.142, -0.025] | 0.005   |
|                                               | Clustered by exporter   | -0.083               | [-0.186, 0.019]  | 0.103   |
|                                               | Clustered by panel unit | -0.083               | [-0.188, 0.022]  | 0.120   |
| Pooled intensity: Announcement                | Heteroskedastic         | -0.040**             | [-0.071, -0.008] | 0.013   |
|                                               | Clustered by exporter   | -0.040               | [-0.223, 0.143]  | 0.646   |
|                                               | Clustered by panel unit | -0.040               | [-0.228, 0.148]  | 0.674   |
| Pooled intensity: Reporting                   | Heteroskedastic         | -0.073***            | [-0.121, -0.026] | 0.002   |
|                                               | Clustered by exporter   | -0.073               | [-0.266, 0.119]  | 0.424   |
|                                               | Clustered by panel unit | -0.073               | [-0.271, 0.124]  | 0.461   |
| Pooled intensity: Joint (announcement)        | Heteroskedastic         | -0.014               | [-0.050, 0.022]  | 0.441   |
|                                               | Clustered by exporter   | -0.014               | [-0.161, 0.133]  | 0.838   |
|                                               | Clustered by panel unit | -0.014               | [-0.166, 0.138]  | 0.853   |
| Pooled intensity: Joint (reporting)           | Heteroskedastic         | -0.065**             | [-0.119, -0.010] | 0.020   |
|                                               | Clustered by exporter   | -0.065               | [-0.171, 0.041]  | 0.209   |
|                                               | Clustered by panel unit | -0.065               | [-0.174, 0.044]  | 0.241   |
| Covered-split intensity: Announcement         | Heteroskedastic         | -0.033*              | [-0.069, 0.003]  | 0.075   |
|                                               | Clustered by exporter   | -0.033               | [-0.133, 0.067]  | 0.490   |
|                                               | Clustered by panel unit | -0.033               | [-0.136, 0.070]  | 0.527   |
| Covered-split intensity: Reporting            | Heteroskedastic         | -0.069***            | [-0.113, -0.024] | 0.002   |
|                                               | Clustered by exporter   | -0.069               | [-0.167, 0.030]  | 0.157   |
|                                               | Clustered by panel unit | -0.069               | [-0.175, 0.037]  | 0.203   |
| Covered-split intensity: Joint (announcement) | Heteroskedastic         | -0.010               | [-0.054, 0.035]  | 0.677   |
|                                               | Clustered by exporter   | -0.010               | [-0.098, 0.079]  | 0.819   |
|                                               | Clustered by panel unit | -0.010               | [-0.097, 0.078]  | 0.830   |
| Covered-split intensity: Joint (reporting)    | Heteroskedastic         | -0.063**             | [-0.121, -0.005] | 0.033   |
|                                               | Clustered by exporter   | -0.063**             | [-0.121, -0.004] | 0.037   |
|                                               | Clustered by panel unit | -0.063**             | [-0.124, -0.002] | 0.044   |

The table reports identical point estimates under alternative variance estimators.

Heteroskedastic inference uses an asymptotic normal reference distribution; exporter-clustered inference uses  $t(13)$ .

Panel-unit-clustered inference uses  $t(G - 1)$ , where  $G = 84$  in pooled specifications and  $G = 168$  in baseline and covered-split specifications.

Panel units are exporter-product cells in pooled specifications and exporter-product-coverage cells in baseline and covered-split specifications.

## Fixed-Effects Robustness

Table 8: Robustness to product-by-time fixed effects

|                                                       | Pooled specification      |                           |                           | Covered-split specification   |                               |                               |
|-------------------------------------------------------|---------------------------|---------------------------|---------------------------|-------------------------------|-------------------------------|-------------------------------|
|                                                       | Announcement              | Reporting                 | Joint                     | Announcement                  | Reporting                     | Joint                         |
| IQR carbon intensity ×<br>Post-announcement           | -0.057                    |                           | -0.050                    |                               |                               |                               |
|                                                       | [-0.286, 0.173]           |                           | [-0.237, 0.137]           |                               |                               |                               |
| IQR carbon intensity ×<br>Post-reporting              |                           | -0.047                    | -0.017                    |                               |                               |                               |
|                                                       |                           | [-0.284, 0.189]           | [-0.148, 0.113]           |                               |                               |                               |
| Covered × IQR carbon intensity ×<br>Post-announcement |                           |                           |                           | -0.046                        |                               | -0.037                        |
|                                                       |                           |                           |                           | [-0.146, 0.053]               |                               | [-0.127, 0.053]               |
| Covered × IQR carbon intensity ×<br>Post-reporting    |                           |                           |                           |                               | -0.048                        | -0.027                        |
|                                                       |                           |                           |                           |                               | [-0.150, 0.053]               | [-0.096, 0.042]               |
| Fixed effects                                         | exp×prod,<br>product×time | exp×prod,<br>product×time | exp×prod,<br>product×time | exp×prod×cov,<br>product×time | exp×prod×cov,<br>product×time | exp×prod×cov,<br>product×time |
| Clustering                                            | Exporter                  | Exporter                  | Exporter                  | Exporter                      | Exporter                      | Exporter                      |
| Observations                                          | 8736                      | 8736                      | 8736                      | 17472                         | 17472                         | 17472                         |

*Dependent variable: monthly import value in EUR.*

*Significance level: \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.10$ , based on  $t(13)$  inference.*

*PPML estimates include exporter-product or exporter-product-coverage fixed effects and EXIO-product-by-month fixed effects.*

*Brackets report exporter-clustered 95% confidence intervals using Student- $t$  critical values with 13 degrees of freedom.*

## **Use of Artificial Intelligence Tools**

I used ChatGPT and Claude as support tools during the preparation of this thesis. In the empirical workflow, they helped with drafting and debugging R code, restructuring data-processing scripts, constructing regression and event-study objects, and formatting tables and figures. I reviewed, adapted, executed, and checked the code myself.

I also used AI tools for language editing, consistency checks, and as a discussion partner when revising the link between empirical results and the literature. Literature selection, interpretation of the results, final wording decisions, and responsibility for the scientific content remain my own. I am able to explain the data construction, empirical strategy, code, results, and interpretation presented in the thesis.