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The Impact of the EU CBAM on Thai Exporting Firms: Analysis of Firm-level Data*

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Abstract

To mitigate the risk of carbon leakage, the European Union (EU) introduced the Carbon Border Adjustment Mechanism (CBAM) to impose a fair price on the carbon emissions associated with the production of carbon-intensive goods imported into the EU, thereby encouraging cleaner industrial production. This paper combines firm-level exporting activity data and financial data in a difference-in-differences regression framework to examine the impact that the CBAM policy announcement and implementation have on Thai exporting firms. We find that the announcement of the CBAM negatively affected Thai firms' ability to export impacted goods to the EU, and these adverse effects intensified following the CBAM implementation. Treated firms' total export revenue decreased relative to the control group and were only able to partially mitigate the impact of this shock by increasing exports of non-CBAM goods to countries outside of the EU.

Key words: Carbon Border Adjustment Mechanism (CBAM), Thailand, exporting firm, international trade

JEL classifications: F14, F18, Q54

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1. Introduction

Climate change constitutes a global externality in that greenhouse gas emissions impose costs on the global community that are not reflected in market prices or borne solely by the emitting country (Nordhaus, 1994). Instead, these greenhouse gases are accumulated in the atmosphere and contribute to long-term climatic changes that affect all nations, regardless of their individual contribution to the problem. In such a context, unilateral efforts to reduce greenhouse gas emissions are likely to be undermined by free-riding behavior, as individual countries face little incentive to bear the costs of mitigating greenhouse gas emissions since the benefits of climate change mitigation are globally distributed. Without coordinated international action, there is a high risk of free-riding, where countries benefit from others' mitigation efforts without contributing themselves, leading to suboptimal global outcomes and the potential for carbon leakage, where production—and associated emissions—shift to jurisdictions with weaker climate policies (Nordhaus, 1994, 2018).

In recognition of these concerns, the European Union (EU) has adopted the Carbon Border Adjustment Mechanism (CBAM), a policy designed to reconcile the difference between the EU's internal carbon pricing through the Emissions Trading System (ETS) and the less stringent or absent carbon regulations in its trading partners. By imposing a carbon price on imports equivalent to that faced by domestic producers, CBAM aims to prevent carbon leakage, protect the competitiveness of EU industries, and create economic incentives for other countries to strengthen their climate policies, particularly encouraging EU's trading partners to adopt similar carbon pricing measures or reduce the carbon intensity of their exports. Thus, CBAM reflects the principles outlined by Nordhaus (1994), who argued that effective climate change mitigation requires global coordination and mechanisms that internalize the external costs of emissions across borders.

However, CBAM has sparked debate, particularly regarding its implications for developing countries. There is a concern that CBAM might impose an unfair burden on low- and middle-income countries that have historically contributed little to global emissions but are now being penalized for carbon-intensive production methods that remain essential to their economic development. While developed countries have already undergone industrialization—often with high emissions—and now possess the financial and institutional capacity to implement ambitious climate policies, many developing economies are still in earlier stages of growth and lack the resources to make rapid transitions to low-carbon alternatives. This concern is supported by empirical studies showing that non-OECD countries are disproportionately affected by CBAM,

experiencing greater output losses and production cost increases than their developed counterparts (Lin and Zhao, 2024). In particular, the results by Lin and Zhao (2024) indicate that African countries are facing the large drop in outputs, while Asian countries are experiencing the highest cost hikes. Thus, in the absence of compensatory mechanisms such as climate finance, technology transfers, or transitional exemptions, CBAM could deepen existing global inequalities and hinder the development prospects of vulnerable economies (Lin and Zhao, 2024; Advani et al., 2021).

To inform this debate, in this paper, we study the impacts of EU CBAM from the perspective of exporting firms in Thailand – a developing, export-oriented economy with exposure to carbon-intensive trade with the EU. By analyzing both the direct effects on export performance and the behavioral responses of firms, this paper offers empirical insights into how climate border policies are experienced by firms beyond the developed world.

Using a difference-in-differences strategy, we exploit variation in exposure to CBAM across firms and over time to estimate the causal effects of the announcement and implementation of CBAM on key firm outcomes, including export performance, and firms' response strategies. Our identification strategy compares firms in CBAM-covered sectors to a control group of similar firms in non-covered sectors, before and after the announcement and implementation of CBAM. This approach allows us to isolate the effect of anticipated CBAM from other contemporaneous economic shocks. The use of customs data enables granular tracking of firm-level export flows and adjustments in trade composition, while financial records provide insights on the heterogenous impacts of CBAM on exporting firms, such as in terms of firm size, age, financial health, and other economic and financial aspects. The results have direct implications for policy design, particularly with respect to sectoral targeting and support for affected firms.

In this study, we develop a panel dataset combining firm-level export data and data on firms' financial statements. The export data are sourced from Thailand Customs, a dataset that covers the universe of Thai exporting firms. This customs data provides high granularity and national coverage, allowing us to accurately trace firms' exposure to CBAM-regulated exports and changes in trade behavior over time. The data used in our analysis focuses on all exporting firms in Thailand that exported to the European Union (EU) during 2016–2024. The dataset includes firm-level information on export value (US dollars) and volume (kilograms or tons), product classification at the 6-digit Combined Nomenclature (CN) code level, export destination, and firm identification, which enables linkage with firms' financial data. Exported products are

further classified into two groups, i.e., CBAM and non-CBAM goods. From this data, we construct several key outcome variables, namely firms' export revenue to the EU (in logs), total export revenue, export revenue to non-EU countries, share of export revenue to the EU to total revenue, product diversification (number of unique 6-digit HS products exported) and export destination diversification (number of countries exported to). For firms' financial data and other characteristics, such as firm age, total revenue, and financial constraint, data was obtained from the Corporate Profile and Financial Statement (CPFS) database, which provides annual firm-level financial information. The CPFS data used in the analysis of this paper covers the period of 2015 to 2024.[1]

Our findings reveal that the announcement of the EU CBAM has exerted a significant negative impact on the treated firms' values of export to the EU and the share of export revenue as a proportion of total firm revenue. Following the announcement, treated firms experienced a deterioration in export outcomes, suggesting that market expectations and anticipatory responses had begun to materialize. This negative trajectory intensified markedly after the CBAM's formal implementation in 2023, indicating that the policy's operationalization further constrained firms' ability to maintain export volumes and revenue shares. These results underscore not only the immediate trade disruptions associated with the CBAM announcement but also the deepening impacts faced by Thai exporting firms as the policy took effect. In response, the treated firms diversify only to a limited extent by increasing exports of non-CBAM goods to countries outside the EU. We find evidence that small firms are significantly more negatively affected by the CBAM announcement. These results highlight the disproportionate vulnerability of small exporters to CBAM policy, which underscore the importance of targeted support for small and medium-sized enterprises (SMEs) in adapting to evolving climate policies.

The remainder of the paper is structured as follows. Section 2 presents the review of related literature and institutional details. Section 3 contains discussion on the methodology and data used in the analysis. Section 4 presents the main results of the paper, while Section 5 concludes and discusses the policy implications.

[1] The primary reason for requiring an additional year of financial statement data is that some of the firm's financial characteristics, such as financial constraint, must be calculated using a one-period lag.

2. Review of literature and institutional details

2.1 Related literature

A growing body of literature has explored the impacts of CBAM from both macro and micro levels. While macro-level studies primarily focus on trade flows, competitiveness, global emissions and carbon leakage, micro-level research examines firm-specific responses, such as adjustments in production, export behavior, and investment decisions.

Macro-level studies on CBAM impacts

The literature that investigate the CBAM impacts at the macro level use different modelling framework, namely multi-sector multi-region CGE model (Bellora and Fontagné, 2023; Olijslagers et al., 2024), the I-O models (Magacho et al., 2023; Schottenet al., 2021; Dechezleprêtre et al., 2025) and the structural gravity equation framework (Korpar et al., 2022).

Impacts on trade flows and competitiveness

Using the dynamic CGE model, Bellora and Fontagné (2023) find that CBAM is effective in reducing carbon leakage, but its design increases the price of carbon in the European Emissions Trading Scheme (EU-ETS). Their results also show that competitiveness losses in export markets for downstream sectors that are not covered by the CBAM and for European exporters of high-emitting industries are expected. By using the I-O model, the study by Dechezleprêtre et al., 2025 find that CBAM affects trade flows and emissions. Specifically, Dechezleprêtre et al. (2025) simulate input substitution, efficiency gains and price and quantity changes. Their results show that the CBAM effectively mitigates carbon leakage, leading emissions to fall in the non-EU countries due to a rerouting of EU imports towards less emission-intensive sources. Such shift in trade patterns reduces production in high emission economies leading to increase in global emission reductions compared to a scenario without CBAM.

Clausing et al. (2025) combine a quantitative equilibrium model with detailed plant-level data to evaluate the global impacts of CBAM policies. Their results show that CBAMs increase the global competitiveness of producers in EU markets. CBAM levels the playing field by imposing the same carbon regulation on goods imported from unregulated producers, i.e. producers outside the EU. Clausing et al. (2025) find that CBAM reduces the profit losses from carbon regulation for the producers in the EU and reduces the profit gains for producers outside the EU, who otherwise benefit from carbon regulation (e.g. EU-ETS) that targets their competition.

Employing the dynamic recursive GTAP-E general equilibrium model, Lan and Tao (2024) investigate the impacts of CBAM implementation on China's exports to the EU. Their findings show that the implementation of CBAM is projected to reduce China's total exports to the EU, though this loss will be partly offset by trade diversion effects. Carbon-intensive industries are more adversely affected in the short term, while all industries except fossil fuels face inevitable long-term negative impacts.

Impacts on emissions and carbon leakages

Using the multi-region, multi-sector structural gravity model, Korpar et al. (2022) find that, with CBAM, CO_2 emissions in EU countries increase, while global emissions are expected to decline. Using the gravity model, Aichele and Felbermayr (2015) find that border carbon adjustments can reduce global emissions, especially when major emitting countries are not part of climate agreements. The effect, however, depends on trade elasticities and emission intensities.

With the quantitative equilibrium model, Clausing et al. (2025) find that CBAM reduces emissions leakage in countries outside the EU and encourages carbon regulation in such markets. Along a similar line, Mehling et al. (2024) found that the impacts of CBAM on carbon leakage is quite modest; nevertheless, CBAM plays quite a crucial role in accelerating carbon pricing globally. In particular, the CBAM has demonstrated a spillover effect by incentivizing the acceleration of carbon pricing roadmaps across EU trading partners.

Lan and Tao (2024) employed the dynamic recursive GTAP-E general equilibrium model to numerically simulate CBAM's inhibitory effect on carbon leakage under different carbon tariff scenarios. Their results show that CBAM effectively inhibits carbon leakage, with greater inhibition observed at higher tax rates and with the expansion of covered industries. Dy and Yang (2025) use an extension to the general equilibrium quantitative trade model of Eaton and Kortum (2002) and Caliendo and Parro (2015) and find that CBAM reduces global emissions.

Impacts on regional inequality

Aichele and Felbermayr (2015) find that the impacts of CBAM are highly uneven across regions. Carbon-intensive exporters in Africa, Asia, and Eastern Europe are disproportionately affected. UNCTAD (2021) emphasizes that developing countries risk being marginalized unless given support to green their production chains.

Impacts on investment in green technology

Dechezleprêtre and Sato (2017) emphasize the potential for CBAM to drive green innovation spillovers if combined with domestic innovation policies.

Micro-level studies on CBAM impacts

The studies that look at the micro-level impacts of CBAM are emerging but still very limited. Chen et al. (2023) use firm-level emissions and trade data from Chinese exporters to estimate how CBAM could affect export volumes and emissions composition. They find that Chinese exporters may reduce the carbon intensity of exports in CBAM-covered sectors, but the response is uneven across firms depending on size and product mix. These studies suggest that CBAM can trigger heterogeneous firm-level responses, but there is a lack of causal identification of policy effects.

Vriz et al. (2025) use the shipment-level trade data and facility-level emission estimates for Indian steel producers to examine impacts of CBAM on export prices and quantities during the CBAM reporting phases. The difference-in-difference method is used to compare the impacts between the high- and low-emission intensity firms to assess whether early market responses are consistent with CBAM's objective of favoring cleaner producers while reducing reliance on more emission-intensive producers. Their results show that firms with relatively high emission intensities have experienced a decline both in terms of average unit prices and item shipment size following the introduction of CBAM reporting requirements. These results point to the possibility that CBAM-related cost expectations or shifting EU importer preferences are already influencing trade dynamics, prompting firms with higher direct emissions to lower prices and reduce their shipment sizes.

This paper fills gaps and contributes to existing literature in several ways. First, this paper leverages Thailand's rich firm-level export and financial data to identify the effects of CBAM – both CBAM announcement and implementation – on exporting firms' performance. While the existing literature has largely relied on CGE models, sectoral simulations, input–output models, or gravity models, this paper is among the very few that directly estimate behavioral responses of exporters using micro-level export transactions matched with firm financial statements. By employing a difference-in-differences framework, this paper identifies how exporting firms in Thailand with pre-CBAM exposure to regulated products adjust their export revenue, market orientation, and product-destination diversification. The findings show that exposure to CBAM leads to a significant decline in EU-bound exports, suggesting that policy-induced carbon pricing at the border via CBAM can shape export strategies even before

full implementation. This micro-evidence fills a critical gap in CBAM literature and provides empirical insight into the firm-level trade and revenue implications of CBAM.

2.2 Institutional details

The CBAM is the EU's tool to put a fair price on carbon emitted during the production of goods that enter the EU, and is established by Regulation (EU) 2023/956, which is part of the "Fit for 55" package. The CBAM is an essential element of the EU's toolbox for meeting the climate objective in line with the Paris Agreement by addressing the risk of carbon leakage that results from the EU's increased climate ambition. The CBAM is expected to also contribute to promoting decarbonization and encourage cleaner industrial production in non-EU countries. The CBAM will initially apply to imports of certain goods and selected precursors whose production is carbon-intensive and at most significant risk of carbon leakage, namely cement, iron and steel, aluminium, fertilizers, electricity and hydrogen.

The CBAM is implemented in two main phases, i.e., transitional phase and definitive regime. The transitional phase refers to the period between 1st October 2023 to 31st December 2025, while the CBAM definitive regime will start on 1st January 2026. During the transitional phase, importers in the EU must report emissions embedded in imported CBAM goods; thus, the purpose of this phase is to collect data and refine the calculation methodology. The importers in the EU do not need to buy and surrender CBAM certificates. During the definitive regime, EU importers will have to declare the emissions embedded in their imports and surrender the corresponding number of CBAM certificates each year. The price of CBAM certificates will be calculated depending on the weekly average auction price of EU ETS allowances expressed in €/ton of CO_2 emitted. If the EU importers can prove that a carbon price has already been paid during the production of the imported goods in the third countries, the corresponding amount can be deducted.

The CBAM will apply to direct (Scope 1) GHG emissions released during the production process for all goods in CBAM scope and to indirect emissions arising from the generation of electricity (Scope 2) for cement and fertilizers. Embedded emissions from input materials (Scope 3) will be included, as long as these input materials are themselves covered by CBAM.

3. Methods and data

3.1 Empirical strategy

Impacts of CBAM on exporting firm performance

The first part of the analysis investigates the impact of the CBAM on exporting firms in Thailand. Specifically, we examine whether firms in Thailand that export CBAM-covered goods to the EU experience differential outcomes following the announcement and implementation of CBAM. Our analysis explores a range of firm-level responses, including changes in export behavior, diversification strategies, and market orientation.

The analysis utilizes firm-level panel data combining detailed customs export records with financial statement data. The treatment group comprises firms in Thailand that exported CBAM-covered products to the EU prior to the CBAM announcement. A firm is classified as treated if it recorded any positive export revenue from CBAM-covered goods to the EU during 2016–2018, otherwise firms are classified as the control group. This setting enables us to exploit temporal and cross-sectional variation in exposure to CBAM to identify its effects on Thai exporting firms.

We use the difference-in-differences framework, comparing the outcomes for treated and control firms before and after CBAM's announcement and implementation. The baseline specification is given by:

$$Y_{it} = \alpha + \beta(Treat_i \times Post_t^a) + \vartheta\left(Treat_i \times Post_t^{im}\right) + \gamma_i + \lambda_t + X_{it}'\delta + \varepsilon_{it}$$

where Y_{it} represents the outcome of interest for firm i in year t, $Treat_i$ is a dummy variable equal to 1 for firms classified as CBAM-exposed exporters, $Post_t^a$ equals 1 for years following the CBAM announcement, i.e. during 2020-2024, and $Post_t^{im}$ equals 1 for years following the CBAM implementation, i.e. during 2023-2024. The coefficients of interest, β and ϑ, capture the average treatment effects of CBAM on treated firms for announcement and implementation, respectively. Firm fixed effects γ_i control for time-invariant firm characteristics, year fixed effects λ_t absorb macroeconomic and global trade shocks, and industry fixed effects. X_{it}' includes time-varying firm-level controls such as firm size, financial leverage, and industry indicators. Standard errors are clustered at the firm level.

To assess the multifaceted impacts of CBAM, we estimate the model across a set of firm-level outcome variables, including the natural logarithm of export revenue to the EU, the share of EU export revenue to total revenue, the natural logarithm of total export revenue, the share of total export revenue to total revenue, the number of distinct products exported (product diversification), the number of destination countries served (geographic diversification), the share of export revenue from CBAM-covered goods to the EU relative to total export revenue, the share of export revenue from CBAM-covered goods to the non-EU relative to total export revenue, the share

of export revenue from non-CBAM-covered goods to the EU relative to total export revenue, and the share of export revenue from non-CBAM-covered goods to the non-EU relative to total export revenue. The last 4 outcome variables are dedicated to test firms' ability to diversify. These outcomes allow us to examine not only the intensive margin of exports to the EU but also the firms' broader export strategies and resilience in response to the CBAM.

Our identification strategy hinges on the standard parallel trends assumption – that, in the absence of CBAM, the outcomes of treated and control firms would have evolved similarly. We evaluate this assumption using an event-study specification that allows for the visualization of pre-treatment trends and the dynamic evolution of treatment effects over time and conduct some robustness checks. We conduct heterogeneity analyses to examine whether treatment effects vary by firm size, firm age, financial constraint, degree of leverage, and financial health.

3.2 Data

To analyze the impacts of CBAM on treated firms' performance, we construct a panel dataset combining export data and data on firms' financial statements. The export data is from Thailand's Customs database, which is a dataset that covers the universe of Thai exporting firms. This customs data provides high granularity and national coverage, allowing us to accurately trace firms' exposure to CBAM-regulated exports and changes in trade behavior over time. The data used in our analysis focuses on all exporting firms in Thailand that exported to the EU during 2016–2023. The dataset includes firm-level information on export value (US dollars) and volume (kilograms or tons), product classification at the 6-digit Harmonized System Code (HS) code level, export destination, and firm identification, which enables linkage with firms' financial data. Exported products are further classified into two groups, i.e., CBAM and non-CBAM goods. The classification of CBAM-covered goods is aligned with the Common Nomenclature product (CN) codes published by the European Commission. The CN codes were then transformed into HS product codes (at the 6-digit level) as identified in the Thailand's Customs database.

For the Customs database, we construct several key outcome variables, namely firms' export revenue to the EU (in logs), total export revenue, export revenue to non-EU countries, share of export revenue to the EU to total revenue, product diversification (number of unique 6-digit HS products exported) and export destination diversification (number of countries exported to). We aggregate these transaction-level data into annual data at the HS-6 product level.

For firms' financial statement data and other characteristics, such as firm age, data was obtained from the Corporate Profile and Financial Statement (CPFS) database, which provides annual firm-level financial information. The CPFS data used in the analysis of this paper covers the period of 2015 to 2023[2]. The variables included in our analysis are firm size captured by log of total assets, total revenue, earnings before interest and taxes (EBIT), Altman Z-score to proxy firm's financial health, RBI index to capture financial constraints, cash conversion cycle and leverage. Firms are merged across both Thailand Customs and CPFS datasets using unique firm identifiers.

A set of criteria is applied to determine firm inclusion in the analysis. First, exporting firms must have been registered before 2020 - the year CBAM was announced. The analysis excludes certain types of exporters, specifically: firms that did not engage in export activities with the EU during 2016-2019; firms with annual export revenue to the EU below 30,000 THB; firms with annual total revenue under 100,000 THB; and firms with total assets less than 100,000 THB. These thresholds help mitigate reporting errors and exclude firms with minimal or negligible operations.

3.3 Treatment definition

Firms are classified as treated firms if they exported CBAM-covered goods to the EU during the 2016-2018 period. Specifically, a firm is classified as treated if its three-year average export revenue from CBAM goods to the EU is greater than zero; otherwise, it is placed in the control group. This treatment assignment allows us to capture the anticipated exposure of firms to the CBAM policy based on their historical trade patterns.

4. Results

4.1 Impacts of CBAM on exporting firms' export performance

This sub-section on the analysis of causal impacts of CBAM on Thailand's exporting firms during 2016-2024. Before presenting the main results, the summary statistics of key variables or characteristics of exporting firms are presented in Table 1.

The summary statistics shown in Table 1 reveal substantial heterogeneity across exporting firms in terms of export revenue, export market diversification, firm size, age, product scope, and financial conditions. Average export revenue to the EU is around THB 66 million, with substantial dispersion ranging from negligible values to THB 2.26

[2] The financial data covers the period 2015–2023, while the firm-level trade data spans 2016–2023, primarily because the calculation of certain financial variables, such as CAPEX, requires a one-period lag for property, plant and equipment (PPE).

billion, indicating that only a limited subset of exporting firms in our samples maintains significant reliance on the EU market. The export revenue to non-EU destinations is much larger on average around THB 1.02 billion and displays high dispersion among exporting firms. The distribution of export-revenue shares provides important insight into firms' exposure to CBAM-related trade flows. The share of export revenue derived from CBAM goods destined for the EU is quite small on average, indicating that only a small subset of exporting firms in Thailand is engaged in EU-bound trade in CBAM-covered products. Similarly, the share of CBAM exports to non-EU markets is also quite small. In contrast, the shares associated with non-CBAM exports dominate the overall export structure. The share of non-CBAM goods exported to the EU remains modest, consistent with the EU's relatively small role as an export destination for the majority of firms. However, the share of non-CBAM exports to non-EU markets constitutes the bulk of total export revenue, underscoring the primary importance of non-EU destinations in firms' export portfolios. Taken together, these patterns demonstrate that the export composition of most firms is both non-CBAM-intensive and non-EU-oriented, implying that CBAM exposure is highly concentrated and may generate heterogeneous effects primarily among firms with substantial reliance on EU markets and CBAM-covered product lines.

In terms of firm size, which is proxied by the logarithm of total assets, there is a relatively wide dispersion, indicating the presence of both very small and very large exporters within the sample. Similarly, there is quite a considerable variation in term of firm age across exporting firms, spanning from very young entrants to long-established incumbent firms with several decades of experience. In this study, product diversification is proxied by the number of products exported by firms. Table 1 shows high heterogeneity among exporters in terms of product diversification, ranging from a single-product firm to firms that export around 206 products. Such large dispersion reflects the coexistence of narrowly specialized exporters and highly diversified multiproduct firms typically associated with higher economies of scope. The export-market diversification also shows high dispersion among firms in the samples. Although the mean indicates limited diversification, the widespread in export destination counts implies that exposure to external regulatory shocks, including EU-specific measures such as CBAM, will vary considerably across firms depending on their geographic concentration of exports.

Financial health, approximated by the Altman Z-score, shows a positive average value that generally indicates stable financial positions; however, the large standard deviation indicates pronounced dispersion among firms. The samples contain firms with very low Altman Z-scores—suggesting distress risk—and firms with quite good

financial health. The mean of RBI index, which is a proxy for financial constraints, shows a moderate financial constraint on average. The range from strongly negative to strongly positive values for RBI implies that some exporting firms operate under severe financial constraint, while others are less financially constrained. Leverage ratios are quite low on average but the standard deviation indicates meaningful variation among firms in our sample, with some firms exhibiting relatively high leverage ratios. This heterogeneity matters for understanding differential vulnerability: firms with elevated leverage may be more sensitive to additional compliance costs or declines in export revenues arising from CBAM.

For the profitability measures, i.e., EBIT over total revenue and EBIT over total assets, the means are quite small, but the sample contains firms with significant losses as well as those with positive operating margins. Firms with lower profitability may face tighter margins to absorb potential increases in costs associated with compliance with CBAM, whereas firms with stronger profitability are likely to be more resilient.

Taken together, the summary statistics highlight a landscape of exporting firms characterized by substantial heterogeneity across size, age, diversification, financial health, and profitability. Such dispersion implies that the impact of CBAM on exporters is unlikely to be uniform.

Table 1: Summary statistics

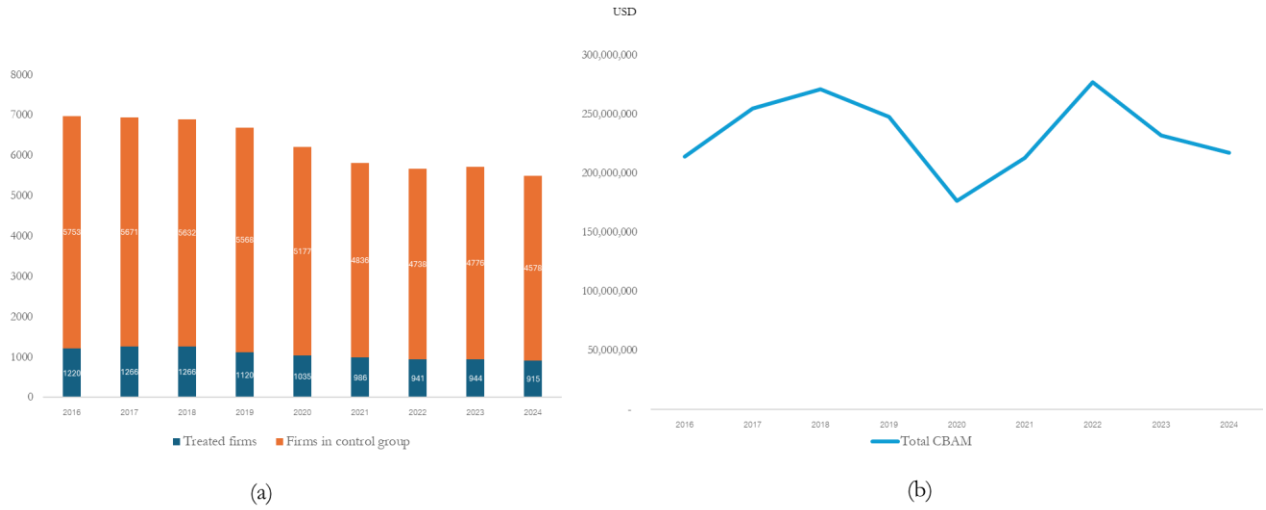
Variables	Obs	Mean	Std. Dev.	Min	Max
Export revenue to EU (THB)	50,485	66,300,000	241,000,000	474	2,260,000,000
Export revenue to non-EU (THB)	44,099	1,020,000,000	6,180,000,000	34	232,000,000,000
Total export revenue (THB)	50,533	992,000,000	6,230,000,000	0	234,000,000,000
Total revenue (THB)	50,533	2,410,000,000	23,500,000,000	0	2,170,000,000,000
Share of export revenue from CBAM goods to EU to total export revenue	50,526	0.012	0.09	0.00	1.00
Share of export revenue from CBAM goods to non-EU to total export revenue	50,526	0.025	0.13	0.00	1.00
Share of export revenue from non-CBAM goods to EU to total export revenue	50,526	0.308	0.36	0.00	1.00

Variables	Obs	Mean	Std. Dev.	Min	Max
Share of export revenue from non-CBAM goods to non-EU to total export revenue	50,526	0.655	0.37	0.00	1.00
firm age	50,429	20	12	1	93
total asset	49,703	1,980,000,000	17,400,000,000	493	1,120,000,000,000
ln (assets)	49,703	19	2	6	28
Total number of firms' export destination	36,600	1	4	0	91
Total number of firms' export destination excluding EU	36,600	1	4	0	74
Total varieties of exported products	36,600	8	11	1	206
Altman z-score measure for financial health	47,350	6	9	0	37
RBI measure for financial constraint	47,769	-3	1	-4	3
Leverage	26,727	0	1	0	3
EBIT over total revenue	47,770	0	0	-2	0
EBIT over total asset	47,824	0	0	-1	1

Shown below are some stylized facts about the treated firms, including the number of treated firms and the value of export of CBAM goods to the EU (Figure 1). Figure 1a shows the number of treated firms and firms in the control group used in the analysis, while Figure 1b shows the export values of CBAM goods to the EU for treated firms.

We begin by presenting the regression estimates that focuses on evaluating the causal effects of CBAM on Thai exporting firms using a difference-in-differences framework. The treatment variable, $Treat_i$, equals one for treated firms and zero otherwise, the variable $Post_t^a$ equals 1 for years following the CBAM announcement, i.e. during 2020-2024, and $Post_t^{im}$ equals 1 for years following the CBAM implementation, i.e. during 2023-2024. Two dependent variables are considered, namely the logarithm of export values to the EU and the share of EU export revenue to total export revenue. Models (1) and (3) in Table 2 capture only the causal effect of CBAM announcement, while models (2) and (4) in Table 2 want to capture the causal effects

of both CBAM announcement and implementation. In models (1) and (3), the key variable of interest is the interaction term, $Post^a \times Treat$, as its coefficient estimates reflect the causal effect of the treatment.



(a) (b)

Figure 1: (a) Number of firms in the analysis (b) Values of export of CBAM goods to the EU of treated firms

Table 2: Regression estimates for impacts of CBAM on firms' performance

	ln(values of export to EU)		Share of export revenue to EU to total export revenue	
	(1)	(2)	(3)	(4)
Post[a] x Treat	-0.181***	-0.144**	-0.027***	-0.027***
	(0.045)	(0.044)	(0.005)	(0.005)
Post[im] x Treat		-0.242***		-0.026***
		(0.058)		(0.006)
Constant	Yes	Yes	Yes	Yes
Adjusted R^2	0.803	0.803	0.799	0.799
n	52,394	52,394	52,394	52394
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

***, **, * denote statistically significant at 1%, 5% and 10% respectively and robust standard errors are shown in the parentheses.

The key variables of interest are $Post^a \times Treat$, an interaction term between a post CBAM announcement dummy and a treatment indicator that equals one for firms exporting CBAM-covered products to the EU, and $Post^{im} \times Treat$, an interaction term between a post CBAM implementation dummy and a treatment indicator. These

interaction terms capture the causal effects of the CBAM announcement and implementation on treated firms relative to non-treated firms, respectively. Table 2 shows the regression results.

According to Table 2, in models (1) and (3), the coefficients on $Post^a \times Treat$ are negative and statistically significant for both log of values of export to the EU and share of export values to the EU to firm total export revenue. For log of export values to the EU in model (1), the coefficient is -0.181 and statistically significant at 1%, indicating that, after CBAM announcement in 2020, treated firms experienced a 18.1% decline in the value of their EU exports relative to firms in the control group. Similarly, in model (3), the coefficient on $Post^a \times Treat$ for share of EU export revenue to total firm export revenue is -0.027 and statistically significant at 1%, suggesting that the share of revenue from EU exports fell by 2.7% for treated firms post CBAM announcement.

Models (2) and (4) in Table 2 show both the causal effects of CBAM announcement and implementation on treated firms' export performance. From model (2), after CBAM announcement in 2020, treated firms experienced a 14.4% decline in the value of their EU exports relative to firms in the control group, and experienced 24.2% decline in values of export to the EU post CBAM implementation in 2023. For the share of values of EU export to total export revenue, the causal effects on treated firms after CBAM announcement and implementation are about the same, declining around 2.7%.

The regression includes the firm fixed effects (firm FE), which controls for time-invariant unobservable characteristics at the firm level, and the year fixed effects (year FE), which controls for macroeconomic shocks and time trends common to all firms. The negative and statistically significant coefficients on the difference-in-difference terms, i.e., $Post^a \times Treat$ and $Post^{im} \times Treat$, across both outcome variables provide robust evidence that CBAM exposure led to a deterioration in the EU export performance of treated firms, consistent with the view that border carbon pricing imposes compliance costs and trade frictions, especially for firms engaged in carbon-intensive sectors.

To complement the baseline difference-in-differences estimates above, we present event study plots that visualize the dynamic treatment effects of CBAM announcement and implementation over time. The event study estimates year-specific treatment effects relative to a pre-policy baseline year. Importantly, it allows for a visual assessment of the parallel trend assumption, which is a key identifying condition of the difference-in-difference framework. If the pre-treatment coefficients are statistically

indistinguishable from zero, this supports the validity of the identification strategy. Moreover, the event study plots reveal whether the policy impact is immediate or gradual, and whether it persists, intensifies, or diminishes over time. These dynamic patterns are critical for understanding firm adjustment behavior in response to the CBAM announcement. Figures 2 and 3 show the event study plots for two outcome variables – log of export values to the EU and share of EU export revenue to total firm revenue.

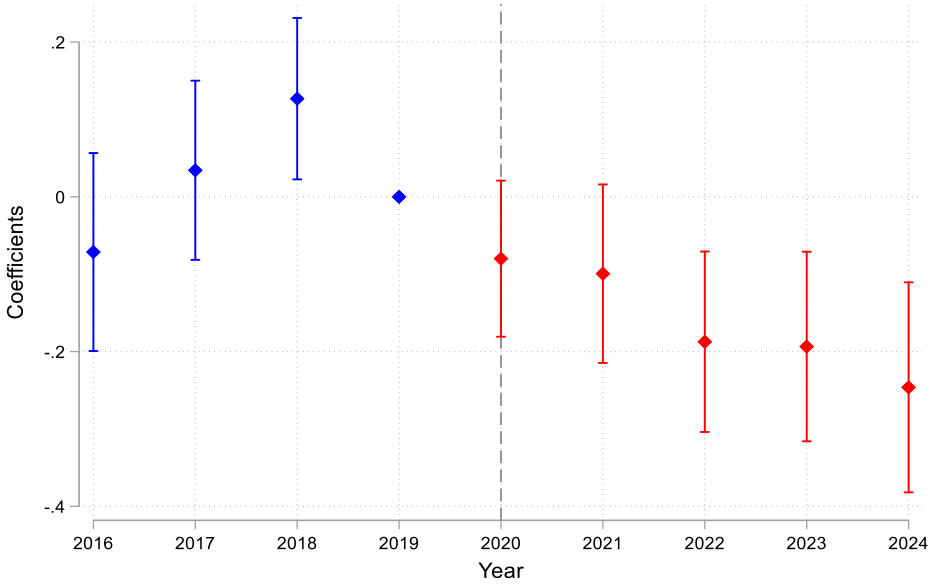


Figure 2: Event study plot - log of export values to the EU

Note: 2019 is the base year

In Figure 2, which shows the dynamic treatment effects of the CBAM announcement on the logarithm of export values to the EU, each point represents the estimated effect for a given year relative to a pre-treatment base year and vertical lines represent 95% confidence intervals. The pre-treatment coefficients (2016–2018) are close to zero and statistically insignificant, supporting the parallel trends assumption of the difference-in-differences framework. Starting from 2020, the estimates become significantly negative, indicating that treated firms experienced a substantial decline in their EU export values.

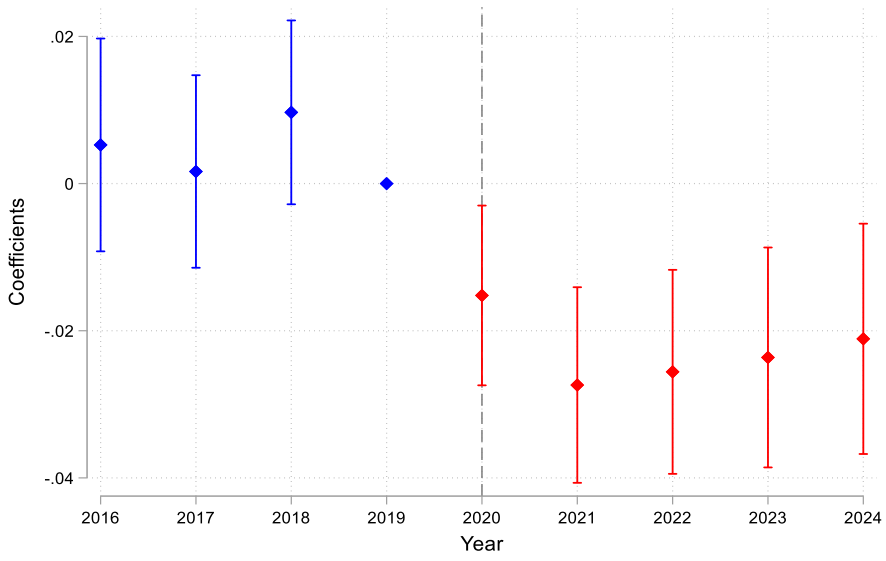


Figure 3: Event study plot - share of export values to the EU to total export revenue

Note: 2019 is the base year

Figure 3 presents the event-study estimates of the dynamic effects of the CBAM announcement on firms' share of export revenue to the EU to total export revenue. The pre-treatment coefficients are small in magnitude and statistically insignificant, indicating no evidence of differential pre-trends between treated and control firms and supporting the validity of the parallel-trends assumption. Following the CBAM announcement in 2020, the estimated coefficients turn negative and remain persistently below zero throughout the post CBAM announcement period. This pattern indicates a sustained decline in the EU export revenue share among the treated firms.

The above findings indicate that the CBAM policy announcement had a statistically and economically significant adverse effect on the export performance of treated firms, supporting the hypothesis that CBAM policy imposes meaningful trade frictions or cost burdens, particularly for carbon-intensive exporters.

4.2 Firm Responses to CBAM through Export Diversification

In addition to evaluating the overall impact of CBAM on export performance, we investigate whether firms engage in export diversification—either by expanding the range of products exported or by shifting exports toward non-EU market. Two regression analyses are conducted. The first set of regression analyses examines export diversification by constructing two outcome variables: the number of distinct products exported (measured at the 6-digit Harmonized System Code (HS) code level) and the

number of export destination countries served by each firm. The second set of analyses focuses on revenue-based export diversification, using four outcome variables that capture the composition of export earnings: (i) the share of export revenue from CBAM goods to the EU relative to firm's total export revenue; (ii) the share of export revenue from CBAM goods to non-EU countries to total export revenue; (iii) the share of export revenue from non-CBAM goods to the EU to total export revenue; and (iv) the share of export revenue from non-CBAM goods to non-EU countries to total export revenue.

4.2.1 Analyses based on counting number of export products and export destination countries

Impacts on number of products exported by firms

For the first set of analyses, two diversification outcomes are considered, namely (i) the number of distinct products (the 6-digit Harmonized System Code) exported by the firm, and (ii) the number of export destination countries served by the firm in a given year. These variables serve as proxies for product and geographical diversification, respectively. We estimate difference-in-differences regressions using these diversification outcomes as dependent variables, with the same treatment and control structure as in our main specification. Table 3 shows the estimation results for the impact of CBAM on treated firms' product diversification. As shown in Table 3, the results show that treated firms exhibit a lack of diversification in their product exported. In model (1), the coefficient of the interaction term, $Post^{a} \times Treat$, is -1.487 and statistically significant at 1%, indicating that, after CBAM announcement in 2020, treated firms exported around 1.5 product less to the EU. In model (2), which accounts for both CBAM announcement and implementation, the coefficients for $Post^{a} \times Treat$ and $Post^{im} \times Treat$ are -1.388 and -1.652, respectively, and are both statistically significant at 1%. These suggest that treated firms exported around 1 product less to the EU post-CBAM announcement and, after CBAM implementation in 2023, treated firms exported around 2 products less.

Table 3: Regression estimates for impacts of CBAM on number of products exported by firms

	Number of exported products	
	(1)	(2)
Post[a] x Treat	-1.487***	-1.388***
	(0.179)	(0.179)
Post[im] x Treat		-1.652***
		(0.229)
Constant	Yes	Yes
Adjusted R^2	0.910	0.910
n	35,623	35,623
Firm FE	Yes	Yes
Year FE	Yes	Yes

***, **, * denote statistically significant at 1%, 5% and 10% respectively and robust standard errors are shown in the parentheses.

To complement the baseline difference-in-differences estimates above, we present event study plots that visualize the dynamic treatment effects of CBAM announcement and implementation over time on product diversification decisions. Figure 4 shows the event study plot for the number of products exported by firms.

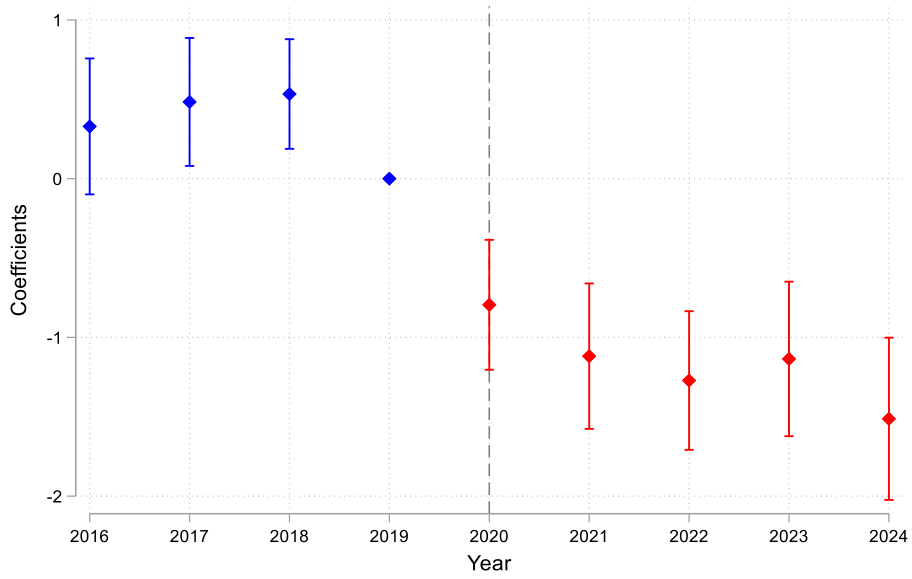


Figure 4: Event study plot - number of product exported by firms

Note: 2019 is the base year

Each point in Figure 4 represents the estimated effect for a given year relative to a pre-treatment base year and vertical lines represent 95% confidence intervals. The

pre-treatment coefficients (2016–2018) are close. Starting from 2020, the estimates become significantly negative, indicating that treated firms experienced a substantial decline in the number of product they exported.

Impacts on the number of export destination country

To assess how CBAM has affected firms' geographic diversification strategies, we examine the number of export destination countries served by firms. This analysis focuses on the count of unique destination countries to which CBAM-covered products are exported, capturing the extent of firms' exposure across international markets. Table 4 shows the estimation results for the impacts of CBAM announcement and implementation on the export destination diversification of the treated firms.

Table 4: Regression estimates for impacts of CBAM on number of export destination countries served by firms

	Number of export destination countries served by firms	
	(1)	(2)
$Post^a$ x Treat	-0.553***	-0.539***
	(0.085)	(0.080)
$Post^{im}$ x Treat		-0.575***
		(0.110)
Constant	Yes	Yes
Adjusted R^2	0.925	0.925
n	35623	35623
Firm FE	Yes	Yes
Year FE	Yes	Yes

***, **, * denote statistically significant at 1%, 5% and 10% respectively and robust standard errors are shown in the parentheses.

According to Table 4, the estimation results show that treated firms exhibit a lack of export destination diversification. The coefficients on $Post^a \times Treat$ are negative and statistically significant across both models (1) and (2). The regression results provide robust evidence that CBAM announcement had a negative and statistically significant impact on the number of export destination countries served by treated firms. This implies that, on average, treated firms reduced their number of export destinations by approximately 0.5 countries relative to non-treated firms following the CBAM announcement. Several factors may explain this response. First, carbon-intensive goods are often produced with scale-specific technology, making product adaptation for different markets costly. Second, some exporters may lack market access needed to pivot quickly to new trade partners, especially if they are highly reliant on the EU as a primary buyer. In model (2), which accounts for both CBAM

announcement and implementation, the coefficients for $Post^{a} \times Treat$ and $Post^{im} \times Treat$ are -0.539 and -0.575, respectively, and are both statistically significant at 1%. It is interesting to note that, after CBAM was implemented and effective in 2023, the negative causal effect on the number of export destinations served by treated firms is even deeper than CBAM announcement.

To complement the baseline difference-in-differences estimates above, we present event study plots that visualize the dynamic treatment effects of CBAM announcement over time in Figure 5. The pre-treatment coefficients (2016–2018), expressed relative to the baseline year 2019, are small and statistically insignificant, with no systematic pre-trend detected. This pattern provides supporting evidence for the validity of the parallel-trends assumption. During the post-CBAM announcement from 2020 onward, the coefficients become negative and statistically significant, indicating an immediate contraction in the number of export destination markets served by treated firms relative to control firms. The magnitude of the estimated treatment effects remains sizeable and persistent during 2021–2024. The results are consistent with the interpretation that heightened regulatory uncertainty and anticipated compliance costs associated with CBAM—such as emissions reporting requirements, administrative burdens, and potential carbon pricing adjustments—led firms to rationalize their export portfolios by exiting relatively marginal or high-cost markets, thereby reducing geographic diversification.

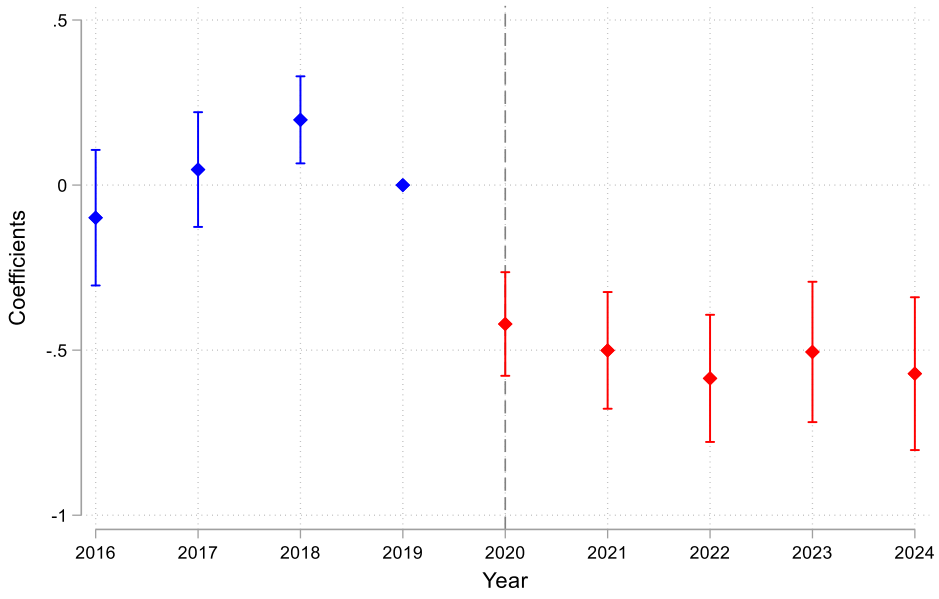


Figure 5: Event study plot - number of export destination countries served by treated firms

4.2.2 Analyses based on revenue-based export diversification

This subsection examines the impact of CBAM announcement on firms' diversification using revenue-based indicators. To be more specific, this subsection examines how the announcement of the CBAM influenced the composition of firms' export revenues across products (CBAM vs. non-CBAM goods) and export destinations (EU vs. non-EU markets). We construct four outcome variables to capture the composition of firms' export earnings: (i) the share of export revenue from CBAM goods to the EU; (ii) the share of export revenue from CBAM goods to non-EU countries; (iii) the share of export revenue from non-CBAM goods to the EU; and (iv) the share of export revenue from non-CBAM goods to non-EU countries. Using a difference-in-differences approach, we estimate the causal effects of the CBAM announcement on each of these export revenue shares to assess how firms reallocate their exports across products and destinations in response to the policy. Table 5 shows the difference-in-difference estimation results.

Table 5: Regression estimates for impacts of CBAM on exporting firms' revenue structure

	Composition of exporting firms' export earnings							
	Share of export revenue from CBAM goods to EU		Share of export revenue from CBAM goods to non-EU		Share of export revenue from non-CBAM goods to EU		Share of export revenue from non-CBAM goods to non-EU	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Post^a$ x Treat	-0.012***	-0.012***	-0.001	0.000	-0.015**	-0.016**	0.028***	0.028***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.005)	(0.005)	(0.005)	(0.005)
$Post^{im}$ x Treat		-0.011***		-0.003		-0.015*		0.029***
		(0.003)		(0.003)		(0.006)		(0.006)
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.725	0.725	0.868	0.868	0.797	0.797	0.808	0.808
n	52,443	52,443	52,443	52,443	52,443	52,443	52,443	52,443
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

***, **, * denote statistically significant at 1%, 5% and 10% respectively and robust standard errors are shown in the parentheses.

As shown in Table 5, first, the coefficient on the $Post^a \times Treat$ variable, which captures for the causal effect of CBAM announcement on treated firms' share of export revenue from CBAM goods to the EU, is negative and statistically significant across models (1) and (2). This indicates that, following the CBAM announcement, treated firms reduced the share of their export revenue from CBAM goods destined for the EU by approximately 1.2% relative to non-treated firms. This finding provides direct

evidence of a negative adjustment in firms' reliance on carbon-intensive product exports to the EU in anticipation of the policy. In model (2), it is interesting to highlight that the impact on the share of export revenue from CBAM goods to the EU is persistently negative after CBAM implementation.

Second, for the share of export revenue from CBAM goods to non-EU countries, even though the coefficients on the $Post^{a} \times Treat$ and $Post^{im} \times Treat$ variable is negative but not statistically significant. This suggests that treated firms did not compensate for the decline in export of CBAM goods to the EU by redirecting them to other markets both post CBAM announcement and implementation.

Third, for the impact on non-CBAM goods exported to the EU, the coefficient on the $Post^{a} \times Treat$ variable is negative and statistically significant. This indicates that, following the CBAM announcement, treated firms reduced the share of their export revenue from non-CBAM goods destined for the EU by approximately 1.6% relative to non-treated firms. Moreover, in model (6), the estimation results show that the impact on firms' revenue from export of non-CBAM goods to the EU is persistently negative around 1.5%. This result suggests that, after CBAM announcement and implementation, treated firms' revenue from the export of both CBAM and non-CBAM goods to the EU decline. This issue is further investigated in the next subsection.

Finally, models (7) and (8) in Table 5 show the causal effects of CBAM announcement and implementation on the share of non-CBAM goods exported to non-EU countries. The coefficients of the interaction terms, $Post^{a} \times Treat$ and $Post^{im} \times Treat$, are positive statistically significant at 1% under models (7) and (8). This suggests that treated firms responded to CBAM by increasing their exports of non-CBAM products to non-EU markets. This positive adjustment points to limited substitution away from CBAM exposure toward non-CBAM goods in alternative markets.

In what follows, we present the event study plots that visualize the dynamic treatment effects of CBAM announcement on the four outcome variables, namely the share of export revenue from CBAM goods to EU, the share of export revenue from CBAM goods to non-EU countries, the share of export revenue from non-CBAM goods to EU, and the share of export revenue from non-CBAM goods to non-EU countries, over time (Figures 6 to 9). According to Figure 6, prior to the CBAM announcement (2016–2018), there is no significant pre-trend, as the coefficients are close to zero and statistically insignificant. After the announcement of CBAM, the

coefficients became negative, which indicates that the share of export revenue from CBAM goods to the EU declined significantly among treated firms post-announcement of CBAM.

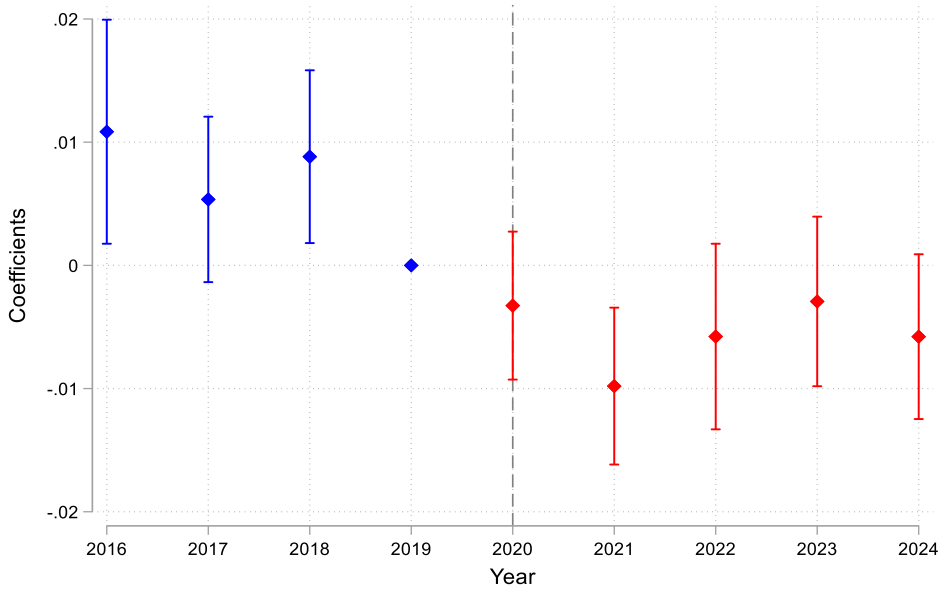


Figure 6: Event study plot - share of export revenue from CBAM goods to EU

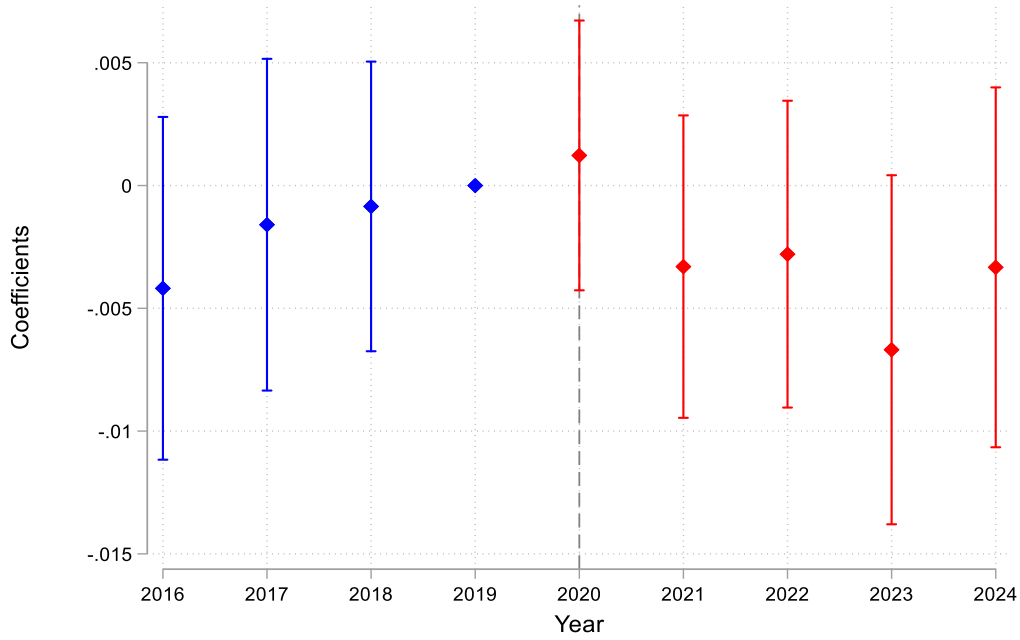


Figure 7: Event study plot - share of export revenue from CBAM goods to non-EU countries

According to Figure 7, which shows the event study plot for the share of export revenue from CBAM goods to non-EU countries, prior to the CBAM announcement, there is no significant pre-trend, as the coefficients are close to zero and statistically insignificant. After CBAM announcement in 2020, the coefficients remain close to zero. This suggests no statistically significant change in the share of CBAM goods exported to non-EU destinations following the CBAM announcement.

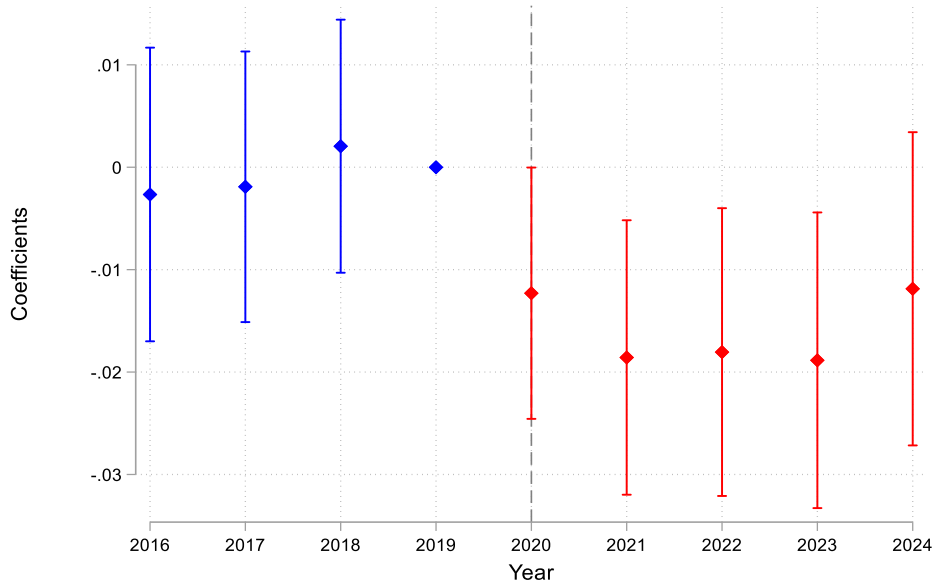


Figure 8: Event study plot - share of export revenue from non-CBAM goods to EU

For the event study plot for the share of export revenue from non-CBAM goods to EU shown in Figure 8, there is no significant pre-trend prior to CBAM announcement. After the CBAM announcement, the coefficients become slightly more negative, but the changes are small.

Finally, for the share of export revenue from non-CBAM goods to the non-EU countries, the event study plot shown in Figure 9 shows a positive post-CBAM announcement, which suggests a potential strategic shift by the treated firms. In other words, some treated firms may have responded to the CBAM announcement by increasing exports of non-CBAM goods to non-EU markets. The increase, although modest, points to a limited diversification response—treated firms appear to have slightly reoriented their product mix and destination away from CBAM exposure.

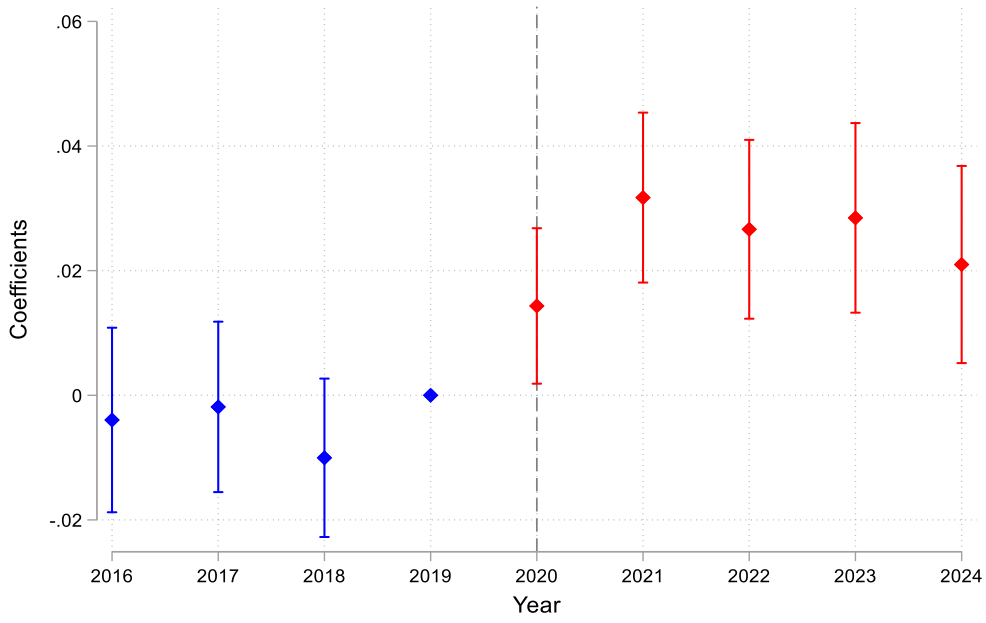


Figure 9: Event study plot - share of export revenue from non-CBAM goods to non-EU countries

4.2.3 Robustness checks

Impacts on firms' total export revenue

Given that the announcement of CBAM has a statistically significant adverse effect on the export performance of treated firms and provided that there is limited evidence of strategic diversification among treated firms in the period following the CBAM announcement, we expect that CBAM announcement would have adverse or statistically insignificant effect on treated firms' total export revenue. To verify this hypothesis, we conduct a regression analysis on the impact of CBAM announcement on the logarithm of total export revenue. The outcome variable considered here is the logarithm of firm's total export revenue. A difference-in-differences estimation strategy is employed to identify the causal effect of the CBAM policy announcement on logarithm of total export revenue. All specifications include firm fixed effects and year fixed effects. Table 6 shows the estimation results.

Table 6: Regression estimates for impacts of CBAM on total export revenue

	Logarithm of total export revenue	
	(1)	(2)
$Post^a$ x Treat	-0.010	0.032
	(0.028)	(0.028)
$Post^{im}$ x Treat		-0.079*
		(0.036)
Constant	Yes	Yes
Adjusted R^2	0.921	0.921
n	52,450	52,450
Firm FE	Yes	Yes
Year FE	Yes	Yes

***, **, * denote statistically significant at 1%, 5% and 10% respectively and robust standard errors are shown in the parentheses.

As shown in Table 6, the coefficient for $Post^a \times Treat$ in model (1) is negative but statistically insignificant, suggesting that the CBAM announcement does not have significant impact on treated firms' total export revenue. However, in model (2), which consider both CBAM announcement and implementation, the coefficient for $Post^{im} \times Treat$ is negative and statistically significant at 10%, which indicates that treated firms, on average, experienced a 7.9% decline in total export revenue following the CBAM announcement, relative to non-treated firms.

The event study plots for the case of logarithm of total export revenue is shown in Figures 10. According to Figure 10, in the pre-treatment period (2016–2018), the estimated coefficients are small and statistically insignificant, suggesting no evidence of pre=trend between treated and control firms prior to the CBAM announcement. After the CBAM announcement, during 2021-2023, although the coefficients are negative but not statistically different from zero. However, in 2024, the coefficient of the interaction term, $Post^a \times Treat$, becomes negative and statistically significant.

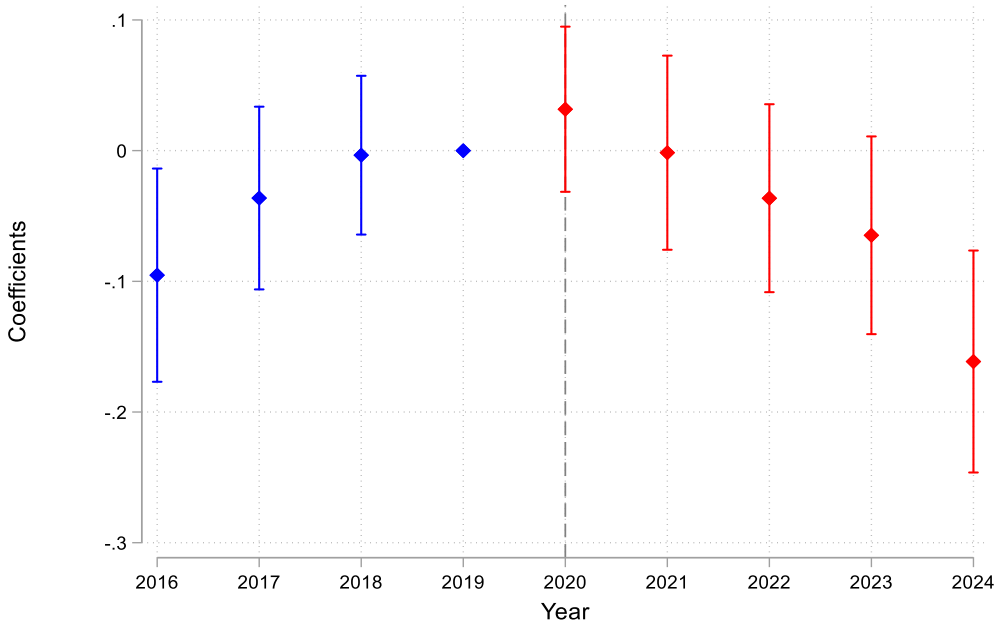


Figure 10: Event study plot - logarithm of total export revenue

Redirection of EU imports toward cleaner producers

The results from our main regression show that the announcement of the CBAM negatively affected Thai firms' ability to export goods in CBAM scope to the EU, and these adverse effects intensified following the CBAM implementation in 2023. Treated firms' export revenue to the EU decreased relative to the control group. For robustness check, in this sub-section, we examine whether the CBAM policy incentivizes a reallocation of import demand away from high-carbon-intensity producers toward cleaner exporters. To achieve this, we exploit variation in carbon emission intensities across exporting countries within CBAM-covered product categories and utilize a difference-in-differences framework.

Our analysis is conducted at the country-product-year level, focusing on CBAM-covered goods according to the EU. The treatment group comprises imports originating from countries classified as "high-emission" exporters for a given product. We classify exporters based on product-level carbon intensity (measured in ton of CO_2 per ton of product) using data from Vidovic et al. (2023). Countries with emission intensities above the EU benchmark values are designated as treated. The control group consists of low-emission exporters falling below the benchmark values. We designate a post-treatment period commencing from the announcement of CBAM (e.g., 2020

onwards). This temporal variation allows us to compare import flows before and after CBAM announcement across countries in treated and control groups.

(i) Empirical strategy

We estimate the following difference-in-difference regression specification:

$$Y_{gct} = \alpha + \beta(Treat \times Post_t^a) + \gamma_{gc} + \lambda_t + \varepsilon_{gct}$$

where Y is the EU's total demand for CBAM good g from country c in year t, $Post$ equals to 1 for 2020-2024, $Treat$ equals to 1 for high emitters, γ_{gc} is the fixed effects to control for time-invariant country-product characteristics, and λ_t is the year fixed effects to absorb common shocks affecting all trading partners.

Our identification strategy relies on the parallel trends assumption, i.e., in the absence of CBAM, import trends from high- and low-emission exporters would have evolved similarly. We test this assumption by conducting event-study analyses, estimating leads and lags of the treatment effect to examine pre-policy trends.

(ii) Data

With regards to the data used in the analysis, we use the international trade data from the UN Comtrade Database, which provides detailed bilateral trade statistics at the product level. Thus, the UN Comtrade allows for a comprehensive analysis of EU imports over time across a wide range of partner countries. The analysis focuses on EU imports of goods that are covered under the initial scope of CBAM—namely iron and steel, aluminum, cement, fertilizers, electricity, and hydrogen. Import data are analyzed at the level of the six-digit CN code, which is the EU's product classification system based on the international Harmonized System (HS) but with additional subdivisions for greater detail. This ensures consistency with the EU's tariff and regulatory reporting framework and allows for precise identification of CBAM-relevant products. The dataset dedicated for our analysis spans the period from 2016 to 2024. Import values are aggregated by partner country and CN product code to construct a panel dataset suitable for analyzing shifts in sourcing patterns.

To assess the role of carbon intensity in shaping these shifts, the trade data are merged with country-level CO_2 emission intensity indicators, measured as CO_2 emissions per unit of gross output in the relevant sectors. These emission intensities are sourced from JRC Technical Report by Vidovic et al. (2023). This allows for the classification of exporting countries into high- and low-carbon intensity groups.

The resulting dataset supports a panel analysis of EU import flows by CN code and country of origin, incorporating product-level and country-level controls. This empirical framework allows us to assess whether CBAM has prompted a reallocation of EU import demand—away from carbon-intensive producers and toward lower-emission countries—in line with the EU's climate objectives.

(iii) Results

Table 7 shows the regression results. As shown in Table 7, the coefficient for the interaction term $Post^{a} \times Treat$ is -0.061**, suggesting a negative association between the CBAM policy period and imports from high-emission countries. This implies that, on average, imports from "dirty" countries declined slightly relative to those from "clean" countries following the CBAM announcement. The estimated effect is statistically significant at 5%; thus, there is robust evidence that the CBAM policy has induced a reallocation of EU import demand away from higher-emission countries, including Thailand, whose emission intensities exceed the EU benchmark values. This pattern is consistent with the incentive structure faced by EU importers: holding other factors constant, sourcing from countries with lower emission intensities reduces the cost of acquiring CBAM certificates. Consequently, if Thailand is classified among the higher-emission countries, Thai exporting firms are likely to lose orders from EU importers, causing their revenues from the export of CBAM goods to the EU decline. This result supports our main results discussed in Section 4.1.

Table 7: Regression estimates on redirecting of EU imports towards cleaner production

	Log of export values of CBAM goods to EU
Post^{a} x Treat	-0.061**
	(0.022)
Constant	Yes
Adjusted R^2	0.743
n	152,095
Firm FE	Yes
Year FE	Yes
Country x Commodity FE	Yes

***, **, * denote statistically significant at 1%, 5% and 10% respectively and standard errors are clustered by commodity.

The event study plot is shown in Figure 11. According to Figure 11, in the pre-treatment period (2016–2018), the estimated coefficients are small and statistically insignificant, suggesting no evidence of pre=trend between treated and control firms

prior to the CBAM announcement. After the CBAM announcement, the coefficient of the interaction term, $Post^a \times Treat$, becomes negative and statistically significant.

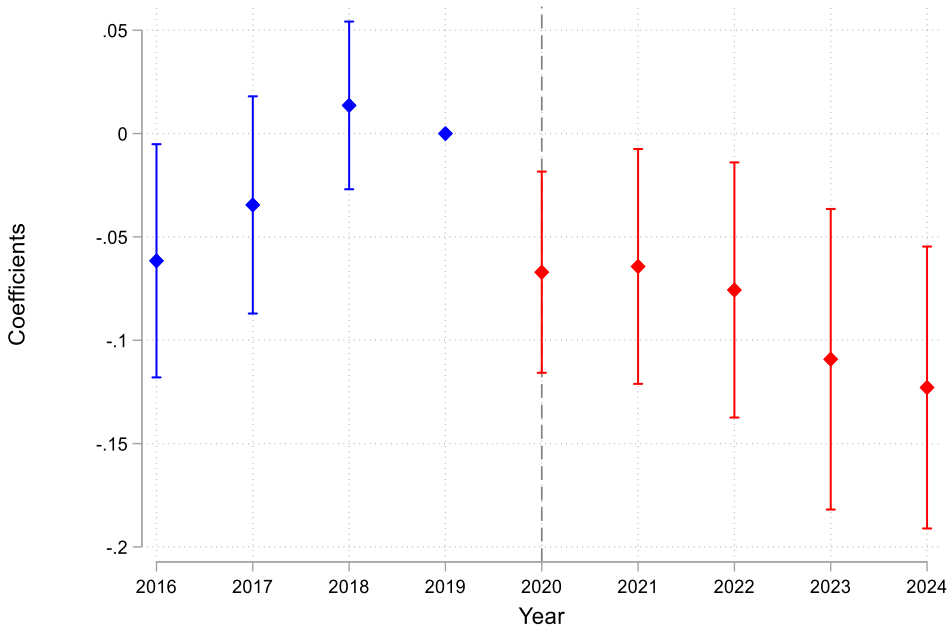


Figure 11: Event study plot - logarithm of total export revenue of CBAM goods to EU (country-product-year level)

Spillover effects on the export of non-CBAM goods to the EU - economies of scale from shipment consolidation

In Section 4.2.2, which analyzed the causal effects of CBAM on exporting firms' export revenue structure, it is quite striking to see that the share of revenue from export of non-CBAM goods to the EU also declines during the periods after CBAM announcement and implementation. One plausible explanation is related to firms' export logistics strategies. Specifically, exporting firms might consolidate shipments by pooling CBAM and non-CBAM products into bulk consignments to exploit economies of scale and reduce per-unit transportation and handling costs. Consequently, adjustments in export volumes of CBAM-covered products in response to the regulation may generate spillover effects on the shipment of non-CBAM goods to the EU, leading to a synchronized contraction in exports across product categories.

To empirically assess this hypothesis, we construct a variable $Bulk$, which reflect the intensity of bulk consignment, i.e. intensity of firm consolidating CBAM and non-CBAM goods into bulk shipments. We then incorporate this variable into a difference-

in-differences framework to test whether firms' reliance on bulk consignment mediates the observed export response to CBAM.

To examine whether firms' reliance on bulk consignments mediates the impact of CBAM on export outcomes, we estimate the following extended difference-in-difference model:

$$Y_{it} = \alpha + \beta_1 \text{Treat}_i + \beta_2 Post_t^a + \beta_3 \text{Bulk}_{it} + \beta_4 (\text{Treat}_i \times Post_t^a) + \beta_5 (\text{Treat}_i \times \text{Bulk}_{it}) + \beta_6 (Post_t^a \times \text{Bulk}_{it}) + \beta_7 (\text{Treat}_i \times Post_t^a \times \text{Bulk}_{it}) + \gamma_i + \delta_t + \varepsilon_{it},$$

where

Y_{it} denotes the share of export revenue from non-CBAM goods to the EU for firm i in period t,

Treat_i is an indicator equal to 1 for CBAM-affected firms and 0 otherwise,

$Post_t^a$ equals 1 in periods after the CBAM announcement (or implementation) and 0 otherwise.

Bulk_{it} is a continuous measure of bulk-consignment intensity (e.g. share of number of months in a year that firm shipped in bulk consignments or the average of bulk-consignment intensity during pre- and post-CBAM announcement periods),

γ_i and δ_t denote firm fixed effects and time fixed effects, respectively.

In this specification, the coefficient, β_7, captures the heterogeneous treatment effect of CBAM among firms that rely on bulk consignments. A statistically significant β_7 would indicate that the export response to CBAM differs systematically between bulk-shipping firms and non-bulk-shipping firms, consistent with the hypothesized spillover mechanism arising from economies of scale in logistics.

If one estimates the above regression with firm and year fixed effects, the regression equation becomes

$$Y_{it} = \alpha + \beta_1 (\text{Treat}_i \times \text{Post}_t) + \beta_3 (\text{Post}_t \times \text{Bulk}_{it}) + \gamma_i + \delta_t + \varepsilon_{it},$$

where the term $\text{Treat}_i \times \text{Post}_t \times \text{Bulk}_{it}$ is dropped due to collinearity with the term $\text{Post}_t \times \text{Bulk}_{it}$ since, in our sample, only treated firms have $\text{Bulk}_{it} > 0$ and for control firms, $\text{Bulk}_{it} = 0$for all t.

To estimate the treatment effects as a function of bulk intensity, we compute the post–pre change in Y for treated and control at different levels of bulk intensity b.

For control firms, $\text{Treat}_i = 0$ and, by the support assumption, $\text{Bulk}_{it} = 0$ for all t. For pre-CBAM announcement period ($\text{Post}_t = 0$),

$$Y_{it}^{\text{control, pre}} = \alpha + \gamma_i + \delta_t + \varepsilon_{it}.$$

For post-CBAM announcement period ($\text{Post}_t = 1$),

$$Y_{it}^{\text{control, post}} = \alpha + \gamma_i + \delta_t + \varepsilon_{it}.$$

So the post–pre change in Y for control firms is

$$\Delta Y^{\text{control}} = 0$$

For treated firms, $\text{Treat}_i = 1$and $\text{Bulk}_{it} = b$(some positive continuous value). It follows that the pre-CBAM announcement period ($\text{Post}_t = 0$),

$$Y_{it}^{\text{treated, pre}}(b) = \alpha + \gamma_i + \delta_t + \varepsilon_{it}.$$

For post-CBAM announcement period ($\text{Post}_t = 1$),

$$Y_{it}^{\text{treated, post}}(b) = \beta_1 + \beta_3 b + \gamma_i + \delta_t + \varepsilon_{it}$$

So the post–pre change in Y for treated firms at bulk intensity $b$is given by

$$\Delta Y^{\text{treated}}(b) = \beta_1 + \beta_3 b.$$

Therefore, the difference-in-difference treatment effect at bulk intensity $b$is:

$$TE(b) = \Delta Y^{\text{treated}}(b) - \Delta Y^{\text{control}} = \beta_1 + \beta_3 b.$$

At zero bulk intensity ($b = 0$), the effect of CBAM announcement is given by

$$TE(0) = \beta_1,$$

which is the treatment effect for firms that do not use bulk consignments.

At positive bulk intensity $b > 0$, the effect of CBAM announcement is given by

$$TE(b) = \beta_1 + \beta_3 b.$$

Therefore, the incremental effect of bulk intensity is

$$\frac{\partial TE(b)}{\partial b} = \beta_3.$$

When the triple interaction $\text{Treat}_i \times \text{Post}_t \times \text{Bulk}_{it}$ is dropped as collinear with $\text{Post}_t \times \text{Bulk}_{it}$, the heterogeneity of CBAM's impact with respect to bulk intensity is captured by the coefficient of $\text{Post}_t \times \text{Bulk}_{it}$ or β_3.

Table 8 shows the estimation results. Two model specifications are considered. In model (1), Bulk_{it} is a continuous variable capturing the bulk-consignment intensity (e.g. share of number of months in a year that firm shipped in bulk consignments) or denoted by $\text{Bulk\_}intensity$. In model (2), Bulk_i is an average bulk-consignment intensity during the pre- and post-CBAM announcement periods denoted by $\text{Bulk\_}average$.

As mentioned earlier, because the triple interaction term $\text{Treat}_i \times \text{Post}_t \times \text{Bulk}_{it}$ is not separately identified in the presence of firm and year fixed effects, the coefficient on $\text{Post}_t \times \text{Bulk}_{it}$ captures heterogeneity in the CBAM-related adjustment among treated firms along the intensive margin of bulk-shipment behavior. The estimation results shown in Table 8 show a consistently negative and statistically significant coefficient on the interaction term $\text{Post}_t \times \text{Bulk}_{it}$ in both specifications. Specifically, the estimated coefficient is -0.022 in model (1) and -0.023 in model (2), with both estimates statistically significant at the 10 percent level. These results indicate that, following the CBAM announcement, firms with greater reliance on bulk consignments experience a larger decline in the share of export revenue from non-CBAM goods shipped to the EU. This result partly explains why the share of export revenue from non-CBAM goods shipped to the EU also decline after CBAM announcement as presented in Section 4.2.2. This pattern is consistent with a logistics-driven spillover mechanism, whereby disruptions or cost increases affecting CBAM-covered products propagate to non-CBAM exports through shared shipment arrangements.

The similarity of the estimated coefficients across the two alternative bulk-consignment measures further reinforces the robustness of this finding. Whether bulk behavior is measured contemporaneously or as a firm-specific average across periods, the results point to a modest but systematic amplification of the decline in non-CBAM export shares among firms with higher bulk-shipment intensity. While the magnitude of the effect is economically moderate and statistically significant only at the 10 percent level, the findings provide suggestive evidence that export logistics practices constitute an important channel through which CBAM reshapes firms' export revenue composition beyond the set of directly regulated products.

Table 8: Heterogeneous effects of CBAM by bulk consignment strategy

	Share of export revenue from non-CBAM goods to EU to total export revenue	
	(1)	(2)
Bulk_intensity	0.035***	
	(0.013)	
Bulk_average		0.004
		(0.023)
Post[a] x Treat	-0.011*	-0.011*
	(0.006)	(0.006)
Treat x Bulk		
Post[a] x Bulk	-0.022*	-0.023*
	(0.013)	(0.015)
Post[a] x Treat x Bulk		
Constant	Yes	Yes
Adjusted R^2	0.7938	0.7975
n	52,450	52,443
Firm FE	Yes	Yes
Year FE	Yes	Yes

***, **, * denote statistically significant at 1%, 5% and 10% respectively and robust standard errors are shown in the parentheses.

4.3 Heterogeneous Impacts on Treated Firms

To explore whether the impact of CBAM varies across different types of firms, we extend the baseline difference-in-difference specification by interacting $Post \times Treat$ with firm-level characteristics that capture heterogeneity in size, age, financial health, financial constraints, and leverage. This allows us to examine whether firms with different structural or financial profiles are differentially affected by CBAM. Specifically, we estimate the following regression specification:

$$Y_{it} = \alpha_i + \gamma_t + \beta_1(Treat_i \times Post_t) + \sum_k \beta_{2k}(Treat_i \times Post_t \times D_{ik}) + \varepsilon_{it}$$

where Y_{it} is the outcome variable of interest (either log of export value to the EU or the share of export value to the EU to total export revenue), α_i is firm fixed effect, γ_t is year fixed effect, D_{ik} are binary indicators for firm characteristics, such as small firm size, young firm age, poor financial health (low Altman z-score), financially constrained (high RBI), and high leverage. The coefficient, β_{2k}, captures the differential treatment effect for firms in subgroup k relative to the baseline.

The results of heterogeneity analysis are shown in Table 9.[3] According to Table 9, the negative impact of CBAM on export performance is more pronounced among small firms, as reflected by a statistically significant and negative coefficient on the triple interaction term for firm size. This suggests that smaller firms are less able to absorb or adapt to the additional compliance costs associated with CBAM. In contrast, the interaction terms for firm age, financial health, financial constraint and leverage are not statistically significant in most specifications, suggesting that these characteristics are not systematically associated with differential CBAM impacts. Overall, these results highlight that the costs of CBAM are not evenly distributed across firms. Vulnerable subgroups -- particularly small exporters – bear a disproportionate burden, raising important policy considerations for targeted support measures aimed at facilitating low-carbon transitions among these firms.

Table 9: Results for the heterogeneity analysis on impacts of CBAM on exporting firms

	log of export values to the EU				
	(1)	(2)	(3)	(4)	(5)
Post x Treat	-0.167*	-0.205**	-0.241***	-0.179*	-0.223*
	(0.069)	(0.071)	(0.065)	(0.078)	(0.101)
Post x Treat x d_small	-0.197*				
	(0.094)				
Post x Treat x d_young		-0.018			
		(0.094)			
Post x Treat x d_poor_fin_health			0.069		
			(0.091)		
Post x Treat x d_fin_constrained				-0.031	
				(0.092)	
Post x Treat x d_high_leverage					0.255
					(0.135)
Constant	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.807	0.807	0.811	0.810	0.800
n	44,956	45,319	42,385	42,773	22,476
Firm FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Industry x Year FE	Yes	Yes	Yes	Yes	Yes

***, **, * denote statistically significant at 1%, 5% and 10% respectively and robust standard errors are shown in the parentheses.

[3] It is important to remark that the heterogeneity analysis is based on the data during 2016-2023 according to the currently available financial statement data of firms in the CPFS database.

5. Conclusion

This paper provides firm-level evidence on the impacts of the European Union's Carbon Border Adjustment Mechanism (CBAM) on exporting firms in Thailand. Using detailed firm-level export data and a difference-in-differences framework that exploits variation across products, destinations, and time, we document how CBAM has reshaped firms' export performance, export composition, and adjustment margins.

We show that the announcement of CBAM exerted a statistically significant negative effect on treated firms' ability to export CBAM-covered goods to the EU. These adverse effects intensified following the CBAM implementation phase beginning from 2023, indicating that initial announcement effects were reinforced once compliance obligations became binding. Our results show that, while some treated firms attempted to cushion this negative shock by expanding their exports of non-CBAM goods to destinations outside the EU, such adjustments were only partial and insufficient to fully offset the loss in EU market access. More broadly, the results point to limited diversification capacity among treated firms, both in terms of product scope and export destinations, which constrains their ability to reallocate exports in response to CBAM policies.

Robustness checks examining shifts in EU import sourcing before and after CBAM provide supporting evidence that CBAM has induced a reallocation of EU import demand away from higher-emission exporting countries. Thai exporters, whose emission intensities exceed EU benchmark values in CBAM-covered sectors, experienced a relative contraction in EU demand. These findings are consistent with the policy's stated objective of internalizing carbon costs at the border and confirm that CBAM has begun to influence international trade patterns along emissions-intensity lines.

This paper also uncovers evidence of a logistics-driven spillover mechanism. Our results indicate that disruptions or cost increases affecting CBAM-covered products can propagate to non-CBAM exports through shared shipment arrangements, particularly among firms that consolidate CBAM and non-CBAM goods into bulk consignments. This mechanism highlights that the effects of CBAM extend beyond the products in CBAM scopes.

Finally, we document a heterogeneity in firms' responses to CBAM. The negative impact on export performance is more pronounced among smaller exporting firms, suggesting that these firms face greater challenges in absorbing or adapting to the additional compliance, reporting, and adjustment costs associated with CBAM. Larger

firms appear better positioned to manage these costs, either through greater financial capacity, more diversified export portfolios, or superior access to low-emission production technologies.

This study is still subject to some limitations. First, while firm-level customs data allow for a granular analysis of export outcomes, they do not directly observe firms' actual CBAM compliance costs, emissions abatement investments, or contractual arrangements with EU importers. As a result, the estimated effects capture reduced-form responses to CBAM rather than the precise structural channels through which compliance costs and regulatory burdens operate. Second, the analysis focuses on short- to medium-term adjustment following the CBAM announcement and early implementation phases; longer-run responses, such as production relocation, technology upgrading, or entry and exit dynamics, may not yet be fully realized within the sample period. Finally, measurement of logistics strategies—particularly bulk consignment behavior—relies on proxy variables constructed from shipment-level information, which may not fully capture firms' internal logistical decision-making or contractual shipping arrangements. These limitations suggest several avenues for future research. First, further work on the mechanisms underlying firms' adjustment to CBAM is necessary. Second, extending the analysis to longer horizons would allow for assessment of firms' adaptation behavior, i.e., whether firms adopt technological upgrading, changes in sourcing strategies, or deeper export diversification.

The empirical results in this paper have some policy implications. For exporting countries such as Thailand, the findings underscore the need for targeted support to help firms—particularly small and less diversified exporters—cope with CBAM-related compliance costs. Policies that facilitate access to emissions measurement, verification infrastructure, and financing for adoption of low-carbon technology could reduce firms' vulnerability to climate-related trade barriers. Promoting export diversification, both across products and destinations, may also enhance firms' resilience to external policy shocks. From the EU's perspective, the evidence that CBAM induces reallocation of import demand along emissions-intensity lines suggests that the policy is beginning to operate as intended; however, the presence of logistics-driven spillovers implies that CBAM may have broader trade effects beyond covered products. Complementary measures—such as technical assistance or transitional support for developing-country exporters—may help mitigate unintended distributional consequences while preserving the environmental integrity of the policy.

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