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# Does Carbon Pricing Affect International Competitiveness? Implications for Carbon Leakage

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**Abstract**

This study explores the impacts of carbon pricing on the international competitiveness of manufacturing sectors. We develop a simple theoretical framework to examine the link between carbon pricing and changes in market shares that may lead to carbon leakage. The framework distinguishes between direct and indirect impacts by considering shifts from domestic to foreign inputs in the production of final goods. Using the European Union Emissions Trading System as an empirical setting, we estimate the effects of carbon pricing on the home country's market share in both targeted input sectors and non-targeted output sectors. Our results show that unilateral carbon pricing slightly weakens the competitiveness of the home country in the markets of the targeted sectors, potentially increasing the risk of carbon leakage. In contrast, competitiveness in non-targeted sectors is largely unaffected. Overall, the findings suggest that unilateral carbon pricing primarily influences the targeted sectors, with no compelling evidence of spillover effects on non-targeted sectors.

**Keywords:** Carbon pricing, Competitiveness, Carbon leakage, Trade
**JEL Classification Numbers:** F18, H23, Q54, Q56

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# 1 Introduction

Various countries have introduced carbon pricing as a strategy to mitigate climate change. As of 2024, over 40 countries have adopted Emissions Trading Systems (ETS) and/or carbon taxes (World Bank, 2024). Alongside these policies, concerns have grown regarding their potential impacts on international competitiveness and carbon leakage. These concerns have motivated the EU to introduce the Carbon Border Adjustment Mechanism (CBAM), which aims to impose a fair price on the carbon emissions embodied in carbon-intensive goods imported into the EU. Although a growing body of research has examined the effects of carbon pricing on competitiveness and/or carbon leakage in targeted sectors, the literature has not yet reached a consensus on whether these impacts are sufficiently large to justify countermeasures. The present study investigates this question by developing a simple theoretical framework for international trade and empirically examining its direct and indirect effects.

Loss of competitiveness and carbon leakage are the two major concerns of the carbon pricing. These are closely connected and a comprehensive assessment of carbon pricing is difficult without simultaneously considering both issues. When carbon pricing is introduced in a country, international competitiveness may weaken, leading to increased consumption of goods from countries without such regulations; this shift in competitiveness can result in carbon leakage. However, detailed sector-country emission data are often limited due to measurement challenges.[1] To address such limitations, we develop a theoretical framework enabling us to analyze the impact of carbon pricing on carbon leakage using available data on international competitiveness. In other words, we assess the risk of carbon leakage by examining how carbon pricing affects competitiveness.

This study extends the literature on competitiveness and carbon leakage by distinguishing between sectors directly targeted by carbon pricing and those that are not. Most carbon pricing schemes worldwide apply to sectors that primarily produce intermediate goods used as inputs in other sectors. Accordingly, we define targeted sectors producing intermediate goods as intermediate input (IM) sectors and non-targeted sectors producing final goods as final goods (FN) sectors. Based on this distinction, we investigate not only the direct effects of carbon pricing on IM sectors but also the indirect effects on FN sectors. These indirect effects may arise through price changes in IM sectors, which can transmit to FN sectors via production linkages. A comprehensive understanding of both direct and indirect effects is crucial for policymakers to avoid unintended consequences and improve the effectiveness of

[1]For example, Naegele and Zaklan (2019) and Aichele and Felbermayr (2015) explore carbon leakage using country-by-sector data, but their datasets cover at the most 13 time points. Eskander and Fankhauser (2023) compiles emission data spanning 23 years, but only at the country level. Misch and Wingender (2024) examine carbon leakage using OECD country-by-sector data, covering both direct carbon emissions and carbon embodied in goods and services. Yet, the detailed dataset spans only 11 years.

carbon pricing.

To answer our research question, we use the EU ETS as a case study of carbon pricing. Since its launch in 2005, the EU ETS has aimed to reduce greenhouse gas (GHG) emissions by requiring plants in carbon-intensive sectors to pay for emissions exceeding their allowances. Three key features of this policy make it suitable for our research. First, the EU ETS primarily targets sectors that produce intermediate inputs widely used in other sectors.[2] This feature enables us to estimate the indirect effects on FN sectors, as carbon pricing in one sector can influence other sectors through supply chains. Second, carbon price in EU countries is generally higher than in most other countries,[3] alleviating concerns that carbon pricing elsewhere may distort the estimated impact of the EU ETS. Third, the availability of long-term data allows us to examine trends before and after implementing the EU ETS. Trade data sources such as the OECD and UN Comtrade provide records dating back to the mid-1990s. As the EU ETS was introduced in 2005, we can observe roughly 10 years before and 15 years after its implementation, ensuring a robust time frame for analysis.

Our empirical strategy is guided by a simple theoretical framework in the context of international trade, which illustrates how carbon pricing can affect competitiveness and increase carbon leakage risk. The framework assumes that only the home country implements carbon pricing, while the foreign country does not. We focus on the markets of a sector in a home country. For IM sectors, the model shows that the home country's market share may decline, suggesting a potential loss of competitiveness. This outcome arises because the cost of carbon pricing is passed on to domestic prices, shifting demand from domestically produced goods to imported alternatives. Next, the risk of carbon leakage in IM sectors is expected to rise as a result of this demand shift, based on our assumption that only the home country imposes carbon pricing, implying that goods produced domestically emit fewer GHGs than those produced abroad. The magnitude of the impacts on competitiveness and carbon leakage increases in sectors with higher elasticity of substitution. For FN sectors, the effects on competitiveness and carbon leakage are less straightforward and depend on sector-specific conditions. Nonetheless, both the degree of elasticity and the increase in input costs in IM sectors play a critical role in shaping the expected impacts.

This study employs two empirical methodologies to examine the impacts of carbon pricing. We apply a difference-in-differences (DiD) design to identify the causal effects of carbon

[2]The sectors targeted by the EU ETS in Phase 1 include power stations and other combustion plants, oil refineries, coke ovens, iron and steel plants, cement clinker, glass, lime, bricks, ceramics, pulp, and paper and board. Phases 2 and 3 include sectors such as aviation, aluminum, and petrochemicals (Climate Action, 2015).

[3]According to World Bank (2024), as of April 1, 2024, among the 33 countries with national carbon taxes or ETS, only Finland, Liechtenstein, Norway, Sweden, and Switzerland had higher carbon taxes than the EU ETS. Liechtenstein and Norway are not included in our dataset.

pricing on competitiveness and carbon leakage, and complement this analysis with the Poisson pseudo-maximum likelihood (PPML) estimator (Silva and Tenreyro, 2006). PPML is particularly suitable for our analysis, which applies the gravity model to assess trade effects, for two main reasons. It accommodates zero trade flows in a natural way,[4] and remains fully consistent with the gravity framework that is widely used to evaluate trade impacts. To implement both DiD and PPML, we follow Aichele and Felbermayr (2015) and construct a dummy variable capturing differences in EU ETS participation between home and foreign countries.

Our findings are summarized as follows. First, unilateral carbon pricing reduces the competitiveness of IM sectors in the home country. Under the EU ETS, its introduction is associated with a 0.2 percentage-points decline in the representative market share for the regulated country. This loss of competitiveness stems from trade reallocation, whereby goods previously sourced domestically are replaced with imports from countries without carbon pricing. Second, unilateral carbon pricing does not significantly affect the competitiveness of FN sectors. Third, the impacts on carbon leakage depends on sectoral demand shifts. Carbon leakage is likely to arise in IM sectors, as carbon pricing diverts demand toward imports, but not in FN sectors, where demand remains largely unchanged. Finally, elasticity plays only a limited role in shaping competitiveness and leakage outcomes, whereas government protection in certain sectors may help mitigate the adverse impacts of carbon pricing.

This study contributes to the literature in several ways. One contribution is that while various studies on carbon pricing have examined its impacts on competitiveness and/or carbon leakage, most focus solely on the direct effects on targeted IM sectors (e.g., Aichele and Felbermayr, 2015; Anger and Oberndorfer, 2008; Chan et al., 2013; Demailly and Quirion, 2008; He and Chen, 2023; Naegele and Zaklan, 2019; Petrick and Wagner, 2014; Qi et al., 2021; Sadayuki and Arimura, 2021). By contrast, little attention has been paid to the indirect effects on non-targeted FN sectors, although changes in IM sectors induced by carbon pricing may spill over and influence FN sectors. Feenstra (1998) and Grossman and Rossi-Hansberg (2008) suggest that policy-driven cost changes in IM sectors can alter production conditions such as cost structures in FN sectors, potentially affecting their competitiveness. To our knowledge, this study is the first to analyze both direct and indirect effects in a systematic manner, explicitly accounting for the relationship between IM and FN sectors.

We further contribute to the literature by examining the long-term global dynamics of carbon pricing, this study adds to the rapidly expanding work on its effects on competitiveness and carbon leakage. Previous studies have predominantly relied on firm- or plant-level data

[4] While PPML allows us to retain zero-valued trade flows, it does not by itself resolve economic selection at the extensive margin. Our interpretation therefore focuses on intensive-margin responses among existing trade relationships.

within single countries or integrated regions such as the EU, providing valuable insights into direct regulatory costs and firm-level responses (see Martin et al. (2016) and Verde (2020) for a review). For example, firm-level comparisons within a given region are useful for isolating direct regulatory costs faced by regulated versus non-regulated firms (Chan et al., 2013; Colmer et al., 2025; Cui et al., 2021; Dechezleprêtre et al., 2023). Nevertheless, such analyses are confined to intra-region contexts and have not captured cross-border adjustments through global value chains. Some studies have investigated cross-border implications, including short-term competitiveness and leakage effects between regulated and unregulated regions (Branger et al., 2016; Naegele and Zaklan, 2019). Global analyses have emerged recently (Roy, 2025; Teusch et al., 2024), but they tend to focus on specific aspects, such as emissions in a few sectors. To advance this line of research, our study adopts a long-term, cross-regional, and broad cross-sectoral perspective, integrating both direct and indirect sectoral effects to assess how carbon pricing reshapes international competitiveness and carbon leakage.

Finally, this study extends the literature on carbon leakage by advancing its measurement. Identifying leakage and inferring the causal impacts of policy on emissions require extensive data (Verde, 2020). Although several studies have attempted to empirically assess carbon leakage (e.g., Aichele and Felbermayr, 2015; Dechezleprêtre et al., 2022; Eskander and Fankhauser, 2023; Misch and Wingender, 2024; Naegele and Zaklan, 2019), the lack of sufficiently detailed emission data, particularly at the disaggregated sector-country level, remains a major challenge (Martin et al., 2014). To address this limitation, we develop a simple theoretical framework that links changes in prices and quantities. This approach offers two key advantages: insights into the risk of carbon leakage even when emission data are scarce, and capturing the indirect effects of changes in targeted IM markets on leakage in non-targeted FN markets.

The remainder of this paper is structured as follows. Section 2 reviews carbon pricing policies and defines the concepts of competitiveness and carbon leakage. Section 3 constructs a theoretical framework to examine how carbon pricing influences competitiveness and the risk of carbon leakage. Section 4 describes our empirical strategies and data. Section 5 presents the empirical results and robustness checks and Section 6 discusses the main findings and concludes the paper.

# 2 Background

## 2.1 Carbon Pricing Policy

Carbon pricing is a policy instrument that requires emitters to pay for the external costs of GHG emissions. Explicit instruments include ETS and carbon taxes, while fuel taxes function as implicit instruments.[5] Although these mechanisms differ in design, they generally increase costs in the targeted sectors.[6] As Green (2021) notes, carbon taxes direclty set the price of emissions, whereas ETS specifies the total allowable GHG emissions for regulated entities. In this sense, carbon taxes inherently raise production costs, which may then be passed onto consumers, while ETS does not necessarily have this effect. Nonetheless, several sectors have been able to pass ETS-related costs to consumers, even when emission allowances were sufficient (Branger et al., 2016). For example, pass-through rates have been estimated at 30–40% for ceramic bricks, over 100% for ceramic goods (Oberndorfer et al., 2010), and more than 100% for iron and steel (de Bruyn et al., 2010). The ability to shift costs allows producers to avoid bearing the full burden of carbon pricing (Arlinghaus, 2015), and in some cases, this has resulted in windfall profits (Cludius et al., 2020; Joltreau and Sommerfeld, 2019). In summary, although our empirical analysis focuses on the ETS, the findings can be broadly generalized to carbon pricing. Both ETS and carbon taxes share the feature that firms may pass carbon costs on to consumers, and this cost pass-through is the channel through which production costs are transmitted into higher consumer prices. By focusing on price changes, we capture these common impacts of carbon pricing within a unified theoretical framework.

## 2.2 International Competitiveness and Carbon Leakage

Competitiveness is defined as a company's or sector's ability to thrive and grow in terms of market share, profits, or productivity (Dechezleprêtre and Sato, 2017). This study uses market share as a measure of international competitiveness and examines its relationship with carbon leakage. This choice is motivated by several reasons. First, while we sought to analyze global trade dynamics through changes in both prices and quantities, datasets providing disaggregated information on each component are limited. Market share, however, can be derived from trade-flow values, which are relatively accessible. Second, market share directly captures the link between competitiveness and carbon leakage, as it reflects the relative preference for domestic versus imported goods. In the context of carbon pricing, a shift in market share may indicate that demand moves from goods produced in countries with stricter emission regulations to those produced in countries with more lenient policies, resulting in

[5]Explicit carbon pricing directly sets a price on GHG emissions, whereas implicit carbon pricing does so indirectly by imposing costs on emission-related factors.

[6]Porter and Linde (1995) discusses the possibility that stricter environmental regulations can reduce production costs and enhance competitiveness through policy-induced technological innovation. However, empirical studies testing the Porter hypothesis have found that the positive effect of innovation does not fully offset the negative impact of regulatory costs (Dechezleprêtre and Sato, 2017; Lanoie et al., 2011).

GHG emissions relocation and carbon leakage.[7] Accordingly, changes in competitiveness are closely connected to risk of carbon leakage, as both reflect the shifts in demand between domestic and foreign goods induced by carbon pricing policies.

# 3 Theoretical Framework

## 3.1 Model Setup

Focusing on changes in consumption value, measured by price ($p$) and quantity ($q$), we develop a simple theoretical framework, using bilateral trade relationships among countries $N$, to predict shifts in market share and carbon leakage induced by carbon pricing. We begin by analyzing the direct effects on targeted sectors that supply intermediate inputs, moving on to indirect effects on non-targeted output sectors whose goods are consumed as final goods, through price changes in targeted sectors. The former sectors are IM sectors, denoted by $L$, and the latter are FN sectors, denoted by $K$. Each sector in each country is assumed to produce a single variety of goods, with goods from the same sector in different countries treated as distinct. To examine the impacts of unilateral carbon pricing, we use the market share of the IM or FN sector in the home country $i$. In this framework, carbon pricing is one-sided, meaning only the home country implements it,[8] and we focus on the home country's markets. We also assume that all determinants of trade flows remain constant except for carbon pricing, allowing certain import-related variables to be treated as time-invariant and denoted with an overline (e.g., $\bar{p}_{l'}$).[9]

## 3.2 Markets for Intermediate Inputs: Targeted Sectors

Our analysis starts with IM markets in a country $i \in N$ that introduces carbon pricing, assuming within-sector substitution.[10] In the IM markets, the market share of sector $l$ is measured using the consumption value of domestic goods and that of foreign goods from country $j \in N$, both consumed as intermediate inputs in the home country. We use apostrophe to indicate foreign variables. For example, $l_i$ denotes sector $l$ in the home country $i$, while $l'_j$ (sector $l$ with an apostrophe) denotes the corresponding sector in foreign country $j$.

[7] Carbon leakage can occur through several channels, including changes in international fossil fuel markets, production, and market share (see Beck et al. (2023) and Naegele and Zaklan (2019) for details). This study focuses on the market-share channel.

[8] This assumption reflects real-world conditions, capturing relative differences in policy stringency.

[9] Although this assumption may be restrictive, we address it in the empirical analysis by using time-variant fixed effects to absorb general price trends.

[10] The within-sector substitution assumption is consistent with the Armington framework, where the elasticity of substitution measures how interchangeable goods are across countries of origin within a sector.

Before the implementation of carbon pricing, the domestic and foreign consumption values in country $i$ are given by $D_l^0 = p_l q_l$ and $I_{l'}^0 = \bar{p}_{l'} q_{l'}$, respectively. For brevity, we omit the country indices $i$ and $j$ from the equations. The total consumption value in a market, where $l$ and $l'$ compete, is then expressed as $T_{ll'}^0 = D_l^0 + I_{l'}^0$.

After the introduction of carbon pricing, domestic goods price rises by $\tau_l \geq 0$. This term captures the increase in cost attributable to carbon pricing, including the cost pass-through rate, changes in margins, and carbon intensity of the sector $l$.[11] Consequently, the domestic and import consumption values, as well as total market value, are adjusted as follows:

$$\begin{aligned} T_{ll'}^1 = D_l^1 + I_{l'}^1 &= (1+\tau_l) p_l \sum_{k_i \in K} (1 - \gamma_{k_i,l}) q_{k_i,l} + \bar{p}_{l'} \sum_{k_i \in K} (1 + \gamma_{k_i,l'}) q_{k_i,l'} \\ &= (1+\tau_l) p_l (1-\gamma_l) q_l + \bar{p}_{l'} (1+\gamma_{l'}) q_{l'}, \end{aligned} \tag{1}$$

where $k_i \in K$ denotes the FN sector in the home country $i$, and $q_{k_i,l}$ represents the quantity of inputs from domestic IM sector $l$ consumed by FN sector $k_i$. The parameter $\gamma_{k_i,l} \in [0,1]$ indicates the rate of change in this consumption due to carbon pricing. We define the aggregated change rate in domestic IM consumption as $(1-\gamma_l) q_l \equiv \sum_{k_i \in K} (1-\gamma_{k_i,l}) q_{k_i,l}$, so that $\gamma_l \in [0,1]$ reflects the overall adjustment for domestic goods from $l$. Analogous definitions apply for $l'$. We expect that the demand for domestic goods from $l$ decreases because carbon pricing makes them costlier, while demand for imports from $l'$ increases as they substitute for domestic goods. The elasticity of substitution between domestic and foreign goods can then be approximated by $\frac{\gamma_l + \gamma_{l'}}{\tau_l}$. Since domestic and foreign goods are not perfect substitutes, we assume that the increase in imports does not fully offset the reduction in domestic demand ($\gamma_{k_i,l} q_{k_i,l} \geq \gamma_{k_i,l'} q_{k_i,l'}$ and $\gamma_l q_l \geq \gamma_{l'} q_{l'}$). Based on this setup, the change in market share can be expressed as:

$$\Delta MS_{ll'} = \frac{D_l^1}{T_{ll'}^1} - \frac{D_l^0}{T_{ll'}^0} = (\omega_{ll'} - 1) \frac{D_l^0}{T_{ll'}^0}, \tag{2}$$

where $\omega_{ll'}$ is the ratio of the post-policy market share to the pre-policy market share and lies between 1 and $\frac{(1+\tau_l)(1-\gamma_l)}{1+\gamma_{l'}}$. Thus, market share is expected to decline whenever $\omega_{ll'} \leq 1$. The likelihood of such a loss in competitiveness rises with the elasticity of substitution, underscoring its central role in determining the impact of carbon pricing.

We also discuss the linkage between changes in market shares and the risk of carbon leakage. As shown in Appendix A, sectors with higher substitutability or higher emissions intensity face a greater risk of carbon leakage under carbon pricing, as demand shifts toward

[11] Even if the nominal carbon price is identical across sectors and countries, $\tau_l$ may vary due to differences in cost pass-through rates, production technologies, or sector-specific margins. $\tau_l = 0$ indicates that sector $l$ has either reduced its carbon intensity through technological improvements or adjusted margins to fully absorb the additional costs.

foreign goods. This highlights the role of both the elasticity of substitution and emissions intensity in shaping changes in market shares and leakage risk.

To connect the theoretical predictions to the empirical analysis, we operationalize market share. We define import share as $IS_{ll'} = \frac{I_l}{T_{ll'}} = 1 - \frac{D_l}{T_{ll'}} = 1 - MS_{ll'}$, a monotonic transformation of the theoretical market share, implying $\Delta IS_{ll'} = -\Delta MS_{ll'}$. This specification facilitates valid estimation under the PPML method (see Section 4), and the theoretical predictions carry over once the results are mapped back to the theoretical market share.

### 3.3 Markets for Final Goods

Studies on global supply chains suggest that carbon pricing in IM markets may spill over to FN markets. Feenstra (1998) and Grossman and Rossi-Hansberg (2008) indicate that cost variations in IM sectors can influence FN sectors through input-output linkages, thereby altering competitiveness in FN sector markets. Therefore, FN sectors in a country $i$ that are subject to carbon pricing may face higher input costs.[12] These changes in cost structure can affect input portfolios, final-good pricing, and ultimately competitiveness. The average input cost for FN sector $k$ in the home country $i$ before carbon pricing is:

$$C_k^0 = \frac{1}{Q_k}\left[\sum_{l_i \in L} p_{l_i} q_{k,l_i} + \sum_{j \neq i} \sum_{l'_j \in L} p_{l'_j} q_{k,l'_j} + \bar{c}_k\right], \tag{3}$$

where $\bar{c}_k$ denotes costs of intermediate inputs not included in $L$. After carbon pricing, the cost becomes:

$$C_k^1 = \frac{1}{(1+\Gamma_k)Q_k}\left[\sum_{l_i \in L}(1+\tau_{l_i})p_{l_i}(1-\gamma_{k,l_i})q_{k,l_i} + \sum_{j \neq i} \sum_{l'_j \in L} \bar{p}_{l'_j}(1+\gamma_{k,l'_j})q_{k,l'_j} + \bar{c}_k\right]. \tag{4}$$

where $\Gamma_k \in (-1, 1]$ is the rate of change in output. We recall that $\gamma_{k,l_i} q_{k,l_i} \geq \gamma_{k,l'_j} q_{k,l'_j}$ for all $l_i$ and $l'_j$. The substitution possibilities across inputs determine whether input costs rise or fall after carbon pricing. For a foreign FN sector $k'$ in a country without carbon pricing, we assume unchanged input costs and prices: $\bar{C}_{k'} = C_{k'}^0 = C_{k'}^1$ and $\bar{p}_{k'} = \bar{\mu}_{k'} \bar{C}_{k'}$, where $\bar{\mu}_{k'} \geq 0$ is the markup of $k'$. This assumption is justified by the very low share of imported input in total input use (about 0.4-1.5%; see Table 4), which makes foreign costs essentially unaffected by carbon pricing abroad. The total value of each FN market, before and after the policy, is then:

$$T_{kk'}^0 = D_k^0 + I_{k'}^0 = \mu_k C_k^0 q_k + \bar{p}_{k'} q_{k'}, \tag{5}$$

$$T_{kk'}^1 = D_k^1 + I_{k'}^1 = (1+\rho_k)\mu_k C_k^1 (1-\gamma_k) q_k + \bar{p}_{k'}(1+\gamma_{k'}) q_{k'}, \tag{6}$$

[12] We do not consider inputs other than intermediate inputs, such as labor and capital, because all other factors are assumed constant for simplicity.

where $\rho_k \in [-1, 1]$ is the markup adjustment following input cost changes. The elasticity of substitution for $k$ can be approximated by $\frac{\gamma_k + \gamma_{k'}}{\rho_k + (C_k^1 / C_k^0 - 1)}$. The market share of the domestic FN sector $k$ is measured by the ratio of its domestic consumption value to the total market value. Using equations 5 and 6, the change in market share, or import share, comes to:

$$\Delta MS_{kk'} = \frac{D_k^1}{T_{kk'}^1} - \frac{D_k^0}{T_{kk'}^0} = (\omega_{kk'} - 1)\frac{D_k^0}{T_{kk'}^0} = -\Delta IS_{kk'}, \tag{7}$$

where $\omega_{kk'}$ takes a value between 1 and $\frac{(1+\rho_k)(C_k^1/C_k^0)(1-\gamma_k)}{1+\gamma_{k'}}$. As in IM markets, carbon pricing raises domestic prices and may induce substitution toward imports. Although FN market adjustments are more complex, input costs and exposure to IM sectors remain central for price transmission.[13] An additional key insight from the equation is that the effects vary with the elasticity of substitution, depending on the value of $\omega_{kk'}$.[14]

In light of the discussion on FN market shares and the mechanism of carbon leakage (see Appendix A), two main implications emerge. First, while the effect of carbon pricing on FN input costs via IM sectors is ambiguous, the combination of exposure to IM markets and sectoral elasticities is central to competitiveness and carbon leakage. Second, carbon leakage rises when FN sectors lose competitiveness and demand shifts toward foreign goods; it remains unchanged when competitiveness is preserved. This applies to both high- and low-elasticity sectors, through different channels.

# 4 Empirical Strategies and Data

## 4.1 Specification

We present econometric specifications to analyze the direct effects of the EU ETS on IM markets and the indirect effects on FN markets. While the theoretical framework in Section 3 provides a basis for the mechanisms, it abstracts from core empirical trade structures, such as multilateral resistance terms. To address this limitation, we incorporate a gravity model into our econometric design, estimated using PPML (Silva and Tenreyro, 2006).

Our main variable of interest is the market share, defined as the ratio of domestic consumption value to total consumption value (domestic and imports) within the home country $i$. For empirical implementation under PPML, we restate the market share as one minus the ratio of import value to total value. This formulation is preferable for the gravity model, as

[13]Firms in FN markets can partly buffer input-cost shocks through changes in markups or input sourcing.

[14]The heterogeneity of effects in FN markets reflects differences in substitution elasticities across sectors. In high-elasticity sectors, greater substitutability limits cost pass-through and raises import shares, while in low-elasticity sectors firms can pass costs onto prices with modest market-share changes. Additionally, price rigidity may lead firms to maintain prices when input costs fall, dampening market-share responses.

import values are directly tied to cross-border trade dynamics. In the subsequent analysis, we use the share of import value in place of market share.

**Direct impacts on IM markets.** To examine the direct impact of the EU ETS on IM markets, we estimate the following model:

$$IS_{ijlt} = exp\left[\beta_0 + \beta_1(EUETS_{ijlt} \times EI_{il}) + \boldsymbol{\beta}'\mathbf{X}_{ijt} + \text{FEs}\right] \times \epsilon_{ijlt}, \quad \textbf{(8)}$$

where the dependent variable is the import share of foreign country $j$ in the market of the IM sector $l$ in the home country $i$ in year $t$.[15] To assess which component drives changes in import share, we also estimate specifications using import value ($I_{ijlt}$) and total value ($T_{ijlt}$) as dependent variables.

Following Aichele and Felbermayr (2015), the key explanatory variable is the interaction term, $EUETS_{ijlt} \times EI_{il}$. $EUETS_{ijlt}$ equals one if the EU ETS is implemented in the home country $i$ but not in the foreign country $j$ in sector $l$ at time $t$, and zero if neither country has implemented it.[16] $EI_{il}$ denotes the $CO_2$ emission intensity ($tCO_2eq$/thousand USD) of sector $l$ in country $i$ in 2004, just before the EU ETS implementation, to capture differential exposures across sectors. $\mathbf{X}_{ijt}$ is a vector of control variables ($JointFTA_{ijt}$, $JointCP_{ijt}$ and $JointWTO_{ijt}$) with the corresponding coefficients $\boldsymbol{\beta}$. These dummy variables control for trade-related policies: $JointFTA_{ijt}$ equals one if both countries have a free trade agreement, $JointCP_{ijt}$ equals one if both have carbon pricing policies (ETS or carbon taxes), and $JointWTO_{ijt}$ equals one if both are WTO members. The variable $JointCP_{ijt}$ simply indicates whether both countries are subject to carbon pricing, allowing us to account for situations in which carbon pricing is in place on both sides of a trade partnership, which is increasingly relevant for policymakers and central to discussions of carbon border adjustments. The specification includes home country-year, foreign country-year, IM sector-year, and country pair-IM sector fixed effects, consistent with the gravity model structure. The error term is denoted by $\epsilon_{ijlt}$.

**Indirect impacts on FN markets.** We next examine the indirect effects of the EU ETS on competitiveness in FN sectors using the following model:

[15] Although PPML is usually not applied to shares because the dependent variable is bounded between zero and one, the mean import share in our data is below 0.015, making predictions above one practically irrelevant. Moreover, as the import share mechanically equals one for intra-national trade by construction, under the definition we have adopted, including such observations will be rather problematic in a PPML framework. We therefore exclude intra-country observations from the estimation sample.

[16] The EU ETS dummy is indexed by the home country $i$, foreign country $j$, IM sector $s$, and year $t$. However, in our sample, its identifying variation arises solely at the home country-year level. This is because all IM sectors are covered by the EU ETS and the EU ETS status of the foreign country is time-invariant. Indexing by the foreign country and sector reflects the construction of the dummy variable rather than additional sources of variation.

$$IS_{ijkt} = exp\left[\gamma_0 + \gamma_1(EUETS_{ijt} \times E_{ik}) + \boldsymbol{\gamma'}\mathbf{X}_{ijt} + \text{FEs}\right] \times \epsilon_{ijkt}. \quad \mathbf{(9)}$$

The dependent variable is defined analogously to the model of direct effects as the share of import value of sector $k$ from foreign country $j$ in the total consumption value of country $i$ in year $t$. We also estimate versions using import value ($I_{ijkt}$) and total value ($T_{ijkt}$) as dependent variables. The key distinction from equation 8 lies in the construction of the explanatory variables, which reflect the indirect impacts of the EU ETS through the FN sectors' exposure to IM sectors. We define $E_{ik} = \left(\sum_{l\in L}\theta_{ikl}\right) \times EI_{ik}$, where $\theta_{ikl}$ denotes the share of inputs sourced from IM sector $l$ and used by the FN sector $k$ in home country $i$ in 2004, relative to the total input use of FN sector $k$.[17] Thus, the summation over $l \in L$ captures the FN sector $k$'s overall reliance on inputs from IM sectors. $EI_{ik}$ is defined as the weighted average of emission intensity of EU IM sectors, with weights given by the input shares in the FN sector $k$. This term scales exposure by the magnitude of the cost shock induced by the EU ETS.

## 4.2 Identification

To identify EU ETS impacts clearly, the sample is restricted to pairs consisting of an EU home country and a non-EU foreign country as the treatment group, and non-EU country pairs as the control group. Accordingly, we exclude cases where the EU ETS is implemented in the foreign country but not in the home country, as well as cases where both countries participate in the EU ETS. Although the EU ETS imposes a common carbon price across participating countries, differences in sectoral emission intensities create heterogeneous effective cost shocks, making it difficult to treat trade between EU member states as unaffected by the policy. This sample restriction therefore aims to improve the clarity of EU ETS effect identification.

Our specification nonetheless raises the potential concern that the control group (non-EU country pairs) may also be affected by the EU ETS through changes in the relative competitiveness of EU producers in third markets. For example, following the introduction of the EU ETS, non-EU importers may substitute away from EU suppliers toward domestic producers or alternative third-country exporters. Such spillover effects could, in principle, influence import shares even among country pairs classified as controls in our baseline specification. The direction of the resulting bias is ambiguous. If substitution away from EU suppliers primarily benefits other foreign producers, import shares in the control group would increase, biasing our estimates toward zero and implying that the estimated treatment effects represent a

[17] For computing $E$, $\theta_{ikl}$ is expressed in percentage units rather than in the 0-1 scale; this adjustment facilitates interpretation.

lower bound. Conversely, if substitution occurs mainly toward domestic production, import shares in the control group would decline, potentially leading to an overestimated treatment effect. In practice, however, imports from EU countries account for only a very small share of total imports in non-EU countries (approximately 0.4% on average). This limited exposure suggests that any contamination of the control group arising from third-market effects of the EU ETS is likely to be quantitatively small and unlikely to materially affect our main conclusions.

## 4.3 Data

We construct a panel dataset covering 76 countries over the period from 1995 to 2020. The main data source is the OECD Inter-Country Input-Output (ICIO) tables.[18] From this source, we obtain total and import values (trade flows) for all countries, excluding five countries that joined the EU ETS after 2006.[19] Out of 17 manufacturing sectors, we retain three IM sectors and eight FN sectors. The IM sectors covered by the EU ETS are identified by manually mapping industries in the ICIO table, classified according to two-digit ISIC Rev.4 divisions, to the activities regulated under the EU ETS (Directive 2003/87/EC and Directive 2009/29/EC).[20] A summary of sectoral mapping is presented in Table B1. In addition to *C19*, *C23* and *C24*, the ICIO sector *C20* is also regulated. However, we exclude *C20* because it does not fall within the the EU ETS regulatory scope during Phase 1.[21] Moreover, although *C17_18* partially includes activities covered by the EU ETS, we do not treat it as a targeted IM sector because its overall carbon intensity is relatively low (see Table B2).

As described in Section 3, this study distinguishes between IM sectors (directly affected by carbon pricing) and FN sectors (indirectly affected). To capture these distinctions empirically, we restrict the sample to country-sector pairs that meet a specific criterion. Following the approach of Saito (2004), we include only IM sectors where the share of intermediate input consumption exceeds two-thirds of total consumption in 2004, the year immediately preceding the EU ETS. Similarly, we include only FN sectors where the share of final goods consumption

[18]https://www.oecd.org/en/data/datasets/inter-country-input-output-tables.html

[19]These countries are Bulgaria, Romania, Norway, Iceland, and Croatia. The exclusion helps maintain analytical simplicity. The EU ETS comprises three phases up to 2020: Phase 1 (2005–2007), Phase 2 (2008–2012), and Phase 3 (2013–2020). Including all countries that adopted the EU ETS at different times would make the estimation models more appropriate for a staggered DiD approach but would complicate interpretation, especially because we also employ PPML methods.

[20]One regulated activity, "Combustion of fuels in installations with a total rated thermal input exceeding 20 MW (except in installations for the incineration of hazardous or municipal waste)," is excluded because it spans a wide range of sectors. However, all major carbon-intensive manufacturing sectors are included in our data, alleviating concerns about omission.

[21]See Footnote 19.

exceeds two-thirds of total consumption in the same year. Table 1 lists the sectors included in the analysis.

**Table 1:** Sectoral classification

| | Elasticity | Sector | Description |
|---|---|---|---|
| ***IM sector*** | High | C19 | Coke and refined petroleum products |
| | Low | C23 | Other non-metallic mineral products |
| | | C24 | Basic metals |
| ***FN sector*** | High | C13T15 [a] | Textiles, textile products, leather and footwear |
| | | C28 | Machinery and equipment, nec |
| | | C29 [a] | Motor vehicles, trailers and semi-trailers |
| | | C30 | Other transport equipment |
| | Low | C10T12 | Food products, beverages and tobacco |
| | | C21 | Pharmaceuticals, medicinal chemical and botanical products |
| | | C26 | Computer, electronic and optical equipment |
| | | C31T33 | Manufacturing nec; repair and installation of machinery and equipment |

*Notes*: The table displays the sectoral classification used in this study, based on ISIC Rev.4. We first distinguish between IM and FN sectors and then further divide each group into two categories, sectors with high elasticity of substitution and those with low elasticity.

[a] Sector with protection.

The ICIO table covers 71 countries—comprising 38 OECD and 33 non-OECD members. Among the 38 OECD members, 22 are EU countries that constitute the treatment group.[22] Considering this composition, substantial differences in economic size and trade volume may exist between the home countries in the treatment and control groups, potentially influencing the likelihood of treatment assignment. To mitigate selection bias, we employ propensity score matching (PSM).[23] PSM is applied to the processed dataset described earlier.

Following Austin (2011) and Rosenbaum and Rubin (1985), we perform one-to-one nearest

[22]In practice, the EU ETS has also been implemented outside the EU, such as in Norway, Iceland, and Liechtenstein. In this study, these countries are excluded during data processing. Norway and Iceland are omitted for simplicity (details are in Section 4.3), and Liechtenstein is not included in the original dataset. Hence, cases of the EU ETS outside the EU are excluded here.

[23]PSM is conducted using the average data from the first year of the study period up to the year before the publication of Directive 2003/87/EC (1995–2002). The choice of 2002 is motivated by the fact that the Directive, published in 2003, determined the activities covered by the EU ETS. Therefore, we assume that sector selection was based on factors such as carbon intensity during the years preceding 2003.

neighbor matching with a caliper of 0.25 standard deviations, as defined by the propensity score. We use the logarithm of GDP, manufacturing share, total import share (including all sectors), and WTO membership dummy ($JointWTO$) as covariates for PSM.[24] Data on these covariates are obtained from the World Bank DataBank[25] and World Trade Organization.[26]

After applying the matching procedure, 19 home countries remain in each of the treatment and control groups (Table 2). The results of the matching are presented in Table 3. The absolute standardized mean difference (SMD) of each covariate is below 0.25, indicating that the balance of most covariates has improved.[27] The negative balance improvement for the logarithm of GDP and manufacturing share suggests that the difference between the treatment and control groups slightly increased after PSM. However, since their absolute SMDs remain within the 0.25 threshold, these covariates are still considered well-balanced. Fig. 1 illustrates the distribution of propensity scores before and after PSM, showing that importing countries in both groups have similar propensity scores, further confirming improvement in balance.

**Table 2:** Home countries remaining after PSM

| Group | Home countries |
|---|---|
| ***Treatment*** | Austria, Cyprus, Czech, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Lithuania, Latvia, Poland, Portugal, Slovakia, Slovenia, Sweden, United Kingdom |
| ***Control*** | Australia, Brazil, Brunei, Canada, Switzerland, Chile, Costa Rica, Israel, Jordan, Korea, Malaysia, New Zealand, Pakistan, Philippines, Russian, Thailand, Tunisia, Ukraine, United States |

*Notes*: The United Kingdom is included in the treatment group, as the analysis period ends in 2020, prior to its withdrawal from the EU.

[24] These covariates are chosen to align the economic and trade scales between importing countries (Eskander and Fankhauser, 2023). Although it is common to use all control variables as covariates, we exclude $jointFTA$ and $jointCP$ because both take the value of zero for all importing countries in the data from 1995 to 2002.

[25] https://databank.worldbank.org/source/world-development-indicators

[26] https://www.wto.org/english/thewto_e/whatis_e/tif_e/org6_e.htm

[27] Various SMD cutoffs have been proposed, such as 0.1 and 0.25 (e.g., Austin, 2009; Normand et al., 2001; Stuart, 2010). We adopt the more lenient threshold of 0.25, as small sample sizes make it challenging to achieve a well-balanced outcome through PSM, even when the model is properly specified (Austin, 2009).

**Table 3:** Balancing test results

| | Status | Mean | | SMD | Balance improvement (%) |
|---|---|---|---|---|---|
| | | Treatment | Control | | |
| Ln GDP | U | 25.40 | 25.32 | 0.043 | -160.5 |
| | M | 25.48 | 25.65 | -0.112 | |
| Manufacturing share | U | 0.170 | 0.171 | -0.086 | -18.70 |
| | M | 0.170 | 0.173 | -0.102 | |
| Total import share | U | 0.472 | 0.375 | 0.452 | 66.87 |
| | M | 0.407 | 0.375 | 0.150 | |
| WTO membership | U | 0.880 | 0.805 | 0.231 | 100.00 |
| | M | 0.842 | 0.842 | 0.000 | |

*Notes*: The table shows the results of nearest-neighbor PSM with a caliper of 0.25 standard deviations. Status "U" and "M" refer to unmatched and matched samples, respectively. SMD denotes the standardized mean difference.

Table 4 reports the descriptive statistics of the main outcome variables after applying the PSM procedure. Although notable differences exist between the treatment and control groups in both the IM and FN sectors in terms of the absolute levels of import value, total value, and import share, these differences are unlikely to pose serious concerns for the regression analysis. Because the estimation employs PPML, which uses a log-link specification and accounts for the multiplicative nature of trade flows, it is less sensitive to differences in absolute scale across groups. Therefore, while the descriptive statistics reveal heterogeneity in trade volumes, such variations are not expected to bias the causal estimates. Note that, for EU ETS-regulated countries, the aggregated import share from non-EU countries averages approximately 28% for the IM sector and about 63% for the FN sector. This suggest that, although intra-EU trade remains dominant in the IM sector, both sectors source a substantial portion of imports from outside the EU. Given that the post-PSM sample includes trade flows between EU countries and only 19 non-EU countries, the actual exposure to imports from non-EU countries in the broader dataset is likely to be even higher.

Data on carbon pricing and FTA are obtained from the World Bank[28] and the Japan External Trade Organization (JETRO),[29] respectively. $CO_2$ emission intensity is calculated using World Input-Output Database (WIOD) Environmental Accounts[30] and ICIO table (see Appendix B.2 for more details).

[28]https://carbonpricingdashboard.worldbank.org/about#download-data

[29]https://www.jetro.go.jp/theme/wto-fta/ftalist.html

[30]The data can be obtained from the Joint Research Centre of the European Commission.

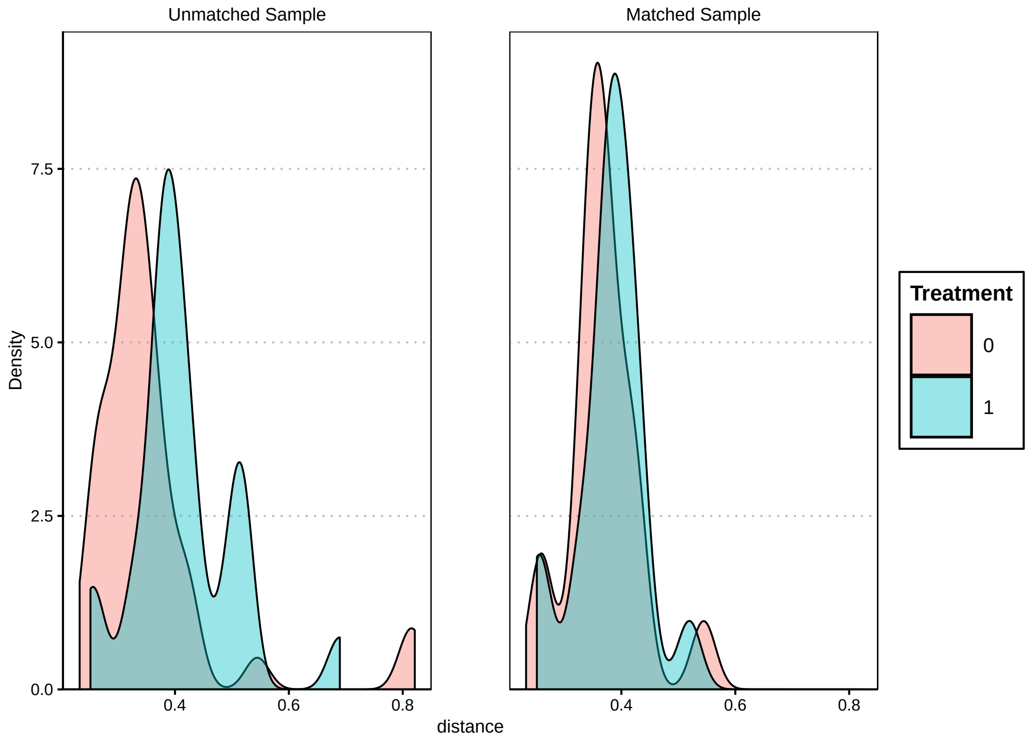


**Fig. 1.** Distribution of propensity scores by treatment and control groups

*Notes*: The figure illustrates the distribution of propensity scores for the control (pink) and treatment (blue) groups. The panels on the left and right display the distribution before and after the PSM procedure, respectively.

**Table 4:** Descriptive statistics

| Statistic | Observations | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| ***IM sector*** | | | | | |
| *Treatment Group:* | | | | | |
| Import value | 30,416 | 30,715 | 178,692 | 0 | 6,249,556 |
| Total value | 30,416 | 8,163,844 | 13,772,914 | 56 | 101,490,721 |
| Market share | 30,416 | 0.990 | 0.062 | 0 | 1 |
| Bilateral import share | 30,416 | 0.010 | 0.062 | 0 | 1 |
| Aggregated import share (non-EU) | 30,416 | 0.284 | 0.210 | 0.038 | 0.975 |
| Emission intensity | 30,416 | 3.979 | 2.819 | 0.017 | 11.531 |
| *Control Group:* | | | | | |
| Import value | 68,930 | 62,231 | 521,845 | 0 | 29,138,760 |
| Total value | 68,930 | 13,907,212 | 30,121,403 | 359 | 274,073,542 |
| Market share | 68,930 | 0.993 | 0.038 | 0.002 | 1 |
| Bilateral import share | 68,930 | 0.007 | 0.038 | 0 | 0.998 |
| Aggregated import share (non-EU) | 68,930 | 0.451 | 0.272 | 0.019 | 0.995 |
| ***FN sector*** | | | | | |
| *Treatment Group:* | | | | | |
| Import value | 21,866 | 17,694 | 140,415 | 0 | 3,922,324 |
| Total value | 21,866 | 7,508,333 | 20,071,062 | 7,093 | 145,611,443 |
| Market share | 21,866 | 0.996 | 0.021 | 0.355 | 1 |
| Bilateral import share | 21,866 | 0.004 | 0.021 | 0 | 0.645 |
| Aggregated import share (non-EU) | 21,866 | 0.626 | 0.249 | 0.016 | 0.987 |
| Exposure | 21,866 | 2.423 | 4.936 | 0.002 | 23.392 |
| *Control Group:* | | | | | |
| Import value | 21,268 | 53,834 | 1,116,273 | 0 | 60,494,441 |
| Total value | 21,268 | 28,225,850 | 87,056,643 | 0 | 610,888,046 |
| Market share | 21,268 | 0.984 | 0.105 | 0 | 1 |
| Bilateral import share | 21,268 | 0.015 | 0.100 | 0 | 1 |
| Aggregated import share (non-EU) | 21,268 | 0.647 | 0.285 | 0.004 | 1 |

*Notes*: This table presents the descriptive statistics of the main variables after PSM. The units of import and total values are in thousands of USD, and emission intensity is based on 2004 data.

## 4.4 Elasticity of Substitution

In the theoretical framework, we suggest that the effects of carbon pricing may vary depending on the elasticity of substitution in international trade. We classify goods in the three IM sectors and eight FN sectors according to whether they exhibit high elasticity, based on estimates reported in previous studies (Imbs and Mejean, 2017; Saito, 2004; Welsch, 2008). Consequently, within the IM sectors, *C19* is classified as high elasticity, while within the FN sectors, *C13T15* and *C28* through *C30* are classified as high elasticity (Table 1). The detailed procedure for defining high elasticity is provided in Appendix B.3.

# 5 Results

## 5.1 Markets for Intermediate Inputs

The results indicate that the introduction of the EU ETS led to a reallocation of demand toward imports in regulated IM sectors. Specifically, following the introduction of the EU ETS, sectors with a one-unit higher emission intensity ($tCO_2eq$ per thousand USD) experienced, on average, a 5.2% larger increase in import share relative to the less emission-intensive sectors.[31] For example, IM sector *C24* in EU countries has an emission intensity of 3.8 (see Table B2 for the median emission intensity of the three targeted sectors). Using a representative emission intensity of non-targeted manufacturing sectors (around 0.06),[32] the estimated semi-elasticity suggests that the EU ETS introduction is associated with an approximately 20% larger increase in import share for *C24*. Given that the average bilateral import share in treated IM sectors is about 1% (Table 4), this relative effect corresponds to an absolute increase of roughly 0.2 percentage points in the post-EU ETS change in import share.

For reference, column (1) reports the results of an OLS estimation using the import share as the dependent variable. The findings are consistent, indicating that the EU ETS increases import share. Columns (3) and (4) present results using import value and total value as dependent variables, respectively. These results show that import value rises more than total value,[33] in line with the earlier finding of an increase in the import share. Overall, the IM markets results reveal that carbon pricing slightly weakens the international competitiveness of carbon-priced sectors and heightens the risk of carbon leakage, as demand shifts from EU to non-EU countries.

[31] The change is calculated as $(e^{\beta_1} - 1) \times 100$, where $\beta_1 \approx 0.051$, as shown in Table 5.

[32] Because the distribution of emission intensity is right-skewed, we interpret effects relative to the median intensity (0.06), which better reflects a representative non-targeted manufacturing sector. Similarly, for the FN sectors, exposure is also right-skewed, and therefore we report effects using median exposure.

[33] Increases in total value can arise when the price of domestic goods rises sufficiently to outweigh the associated decline in quantities.

**Table 5:** Impacts on the competitiveness of IM markets

| | OLS | PPML | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | |
| EUETS × EI | 0.122*** | 0.051*** | 0.065*** | 0.008** |
| | (0.029) | (0.018) | (0.014) | (0.004) |
| JointFTA | -0.097 | -0.010 | 0.023 | -0.001 |
| | (0.093) | (0.060) | (0.062) | (0.007) |
| JointCP | -0.103 | -0.023 | 0.002 | 0.001 |
| | (0.157) | (0.091) | (0.100) | (0.010) |
| JointWTO | 1.631*** | -0.634** | -0.597** | -0.017 |
| | (0.313) | (0.258) | (0.277) | (0.027) |
| *Fit statistics* | | | | |
| Observations | 99,346 | 99,346 | 99,346 | 99,346 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.80459 | 0.97670 | 0.97572 | 0.99492 |

*Notes*: The coefficients reported in this table are estimated using equation 8. The specification includes home country-year, foreign country-year, IM sector-year, and country pair-IM sector FEs. Standard errors, shown in parentheses, are clustered at the country pair-IM sector level. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

To provide graphical evidence of the results, we estimate equation 8 including 10 leads and 15 lags. Fig. 2(a) illustrates the evolution of the import share in IM markets. First, we confirm the validity of the parallel trends assumption, as no statistically significant pre-trend is observed, indicating no difference between treated and control groups before the introduction of the EU ETS. Second, the figure shows that the import share augments after the EU ETS is introduced in 2005 (time of treatment = 0), but the increase gradually dissipates over time, returning to approximately its pretreatment level. This pattern suggests that the impact of the EU ETS on import shares was economically meaningful for several years but not persistent in the long run. Third, Fig. 2(a) shows that IM sectors experience a statistically significant increase in import shares starting in 2008, three years after the introduction of the EU ETS. While this timing coincides with a sharp increase in the futures price of European Union Allowances (EUA) at the start of Phase 2 (Huang et al., 2022), allowance prices declined in subsequent years. However, the estimated import share effects remain statistically significant for several periods. This delayed emergence suggests that firms' responses to carbon pricing may have been gradual, reflecting adjustment frictions such as the renegotiation of long-term supply contracts, learning about the effective stringency of the ETS, or irreversible investment decisions, rather than a contemporaneous response to allowance price movements.

Overall, our analysis of the IM sectors highlights that unilateral carbon pricing can affect market shares and modestly weaken the international competitiveness of the implementing country, increasing carbon leakage risk.

**(a) IM markets** **(b) FN markets**

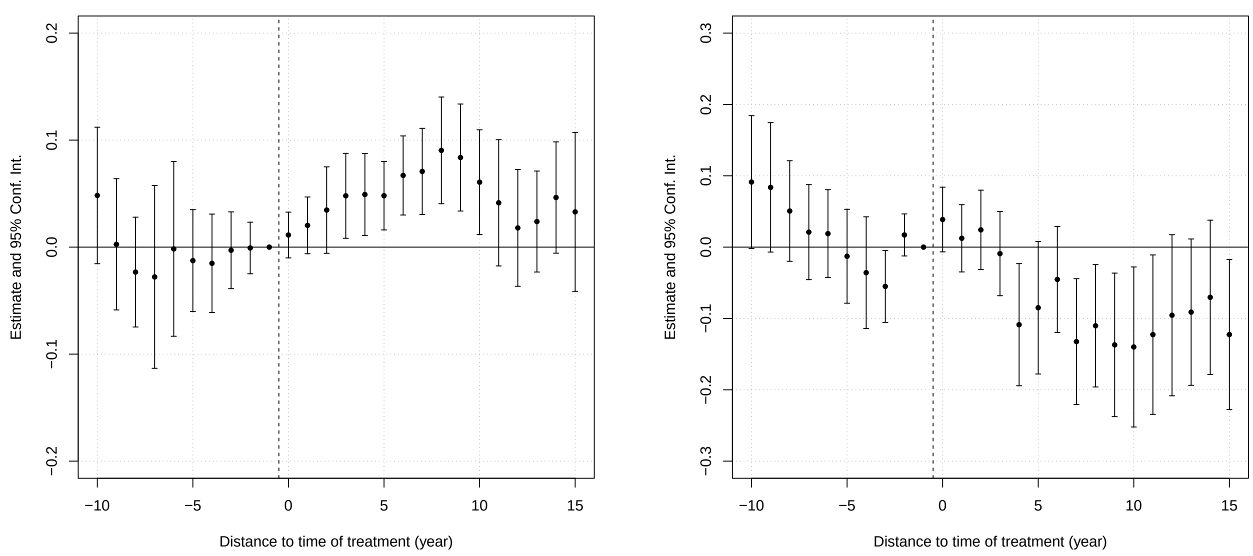


**Fig. 2.** Transition of the import share in IM and FN markets

*Notes*: The figure plots the evolution of import and total values in IM sectors from 1995 to 2020, estimated using equation 8 for panel (a) and equation 9 for panel (b), with 10 leads and 15 lags. The time distance to treatment = 0 represents the year the EU ETS was introduced (2005).

Few studies have examined the global impacts of the EU ETS. For instance, Naegele and Zaklan (2019) analyze the effects of carbon pricing on bilateral trade using net imports and find only a modest and statistically insignificant increase in import values. Our findings partially align with theirs because we also observe a potential increase in imports. However, the effect in our analysis becomes more pronounced for sectors with higher emission intensity, implying that carbon leakage tends to occur when intensity is elevated. Several factors may explain the differences between our results and those of the previous study. First, the study periods differ. We use consecutive annual data from 1995 to 2020, whereas Naegele and Zaklan (2019) analyze data from only three points in time (2004, 2007, and 2011). As Piermartini and Yotov (2016) note, estimations based on pooled annual data can yield results that are not identical to those using interval data. In Section 5.5, we assess the impacts of the EU ETS on competitiveness using interval data and find that a longer interval between observations leads to slightly smaller estimated effects on import values (see column (2) in Table C1). Therefore, their conclusion of no carbon leakage does not necessarily contradict our framework. Consistent with our theoretical framework, the magnitude of the effect of carbon pricing determines the level of carbon leakage risk. Another explanation for the differences in magnitude lies in research design and objectives. Naegele and Zaklan (2019) analyze country pairs in which at least one trading partners has implemented the EU ETS, thereby examining its effects on both imports and exports from ETS countries.[34] By contrast, our study focuses specifically on imports to clearly isolate the effects of carbon pricing.

## 5.2 Markets for Final Goods

We analyze the indirect impacts of the EU ETS on FN sectors through changes in input costs by estimating equation 9. The results are reported in Table 6. The PPML estimate in column (2) shows that the estimate of interaction between the EU ETS and exposure to IM sectors is negative and statistically significant when import share is used as the dependent variable. This suggests that demand reallocation toward imports appears to be minimal in production networks with greater exposure to IM sectors following the introduction of the EU ETS. Columns (3) and (4) also confirm this limited reallocation, as the decreases in import shares appear to be driven by increases in total value. To illustrate the magnitude of this effect, consider a production network with a median IM exposure level, 0.3. Compared to a FN sector with no exposure ($E = 0$), this typical level implies a reduction in import share of approximately 2.7% post-ETS. Given that the average bilateral import share is about 0.4%, this implies an absolute decrease of roughly 0.011 percentage points. The modest magnitude of this effect indicates that FN sectors have largely preserved their competitiveness even after the EU ETS, and that the risk of carbon leakage has not increased. However, this average effect may obscure a significant variation within the FN sector, where industries differ in substitution elasticities and protection status, potentially masking the true impact of the EU ETS when sectors are pooled. The following subsection therefore explores heterogeneity across sectors in more detail.

From Fig. 2(b), we observe almost no significant pre-trends, indicating that in the absence of treatment, the import share of the treated and control groups would have followed parallel paths over time. Furthermore, when FN sectors are considered in aggregate, there is no evidence that the EU ETS adversely affect import shares, implying that FN sectors in EU countries might not experience a loss of competitiveness. These results are in line with those shown in Table 6.

[34] While the empirical approach proposed by Naegele and Zaklan (2019) is valuable, we did not implement a robustness check based on their method because our PSM procedure targets only home countries. Using their approach could lead to selection bias related to foreign countries unaddressed.

**Table 6:** The impacts on competitiveness of FN markets

| | OLS | PPML | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | |
| EUETS × E | -0.006 | -0.088*** | -0.044 | 0.119*** |
| | (0.032) | (0.025) | (0.028) | (0.006) |
| JointFTA | -0.053 | -0.131 | -0.107 | 0.001 |
| | (0.135) | (0.082) | (0.085) | (0.005) |
| JointCP | -0.056 | -0.101 | -0.220 | -0.013 |
| | (0.200) | (0.167) | (0.163) | (0.009) |
| JointWTO | 0.577** | 0.271 | 0.346 | 0.021 |
| | (0.247) | (0.223) | (0.233) | (0.017) |
| *Fit statistics* | | | | |
| Observations | 43,134 | 43,134 | 43,134 | 43,134 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.84338 | 0.99469 | 0.99457 | 0.99933 |

*Notes*: The coefficients in this table are estimated using equation 9. The specification includes home country-year, foreign country-year, FN sector-year, and country pair-FN sector fixed effects. Standard errors, shown in parentheses, are clustered at the country pair-FN sector level. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

## 5.3 Sectoral Heterogeneity

Sector-specific differences in elasticity of substitution and protection may contribute to heterogeneous impacts of carbon pricing. To examine this, we build on the sectoral classification in Section 4.3 (Table 1) and additionally label two sectors as "protected". *C13T15* (textiles) and *C29* (vehicles), which face higher tariff rates at the borders of EU member states. To capture the combined characteristics of high elasticity and protection, we define a categorical dummy variable with three levels ("Low elasticity", "High elasticity", "Protection"), where "Low elasticity" group serving as the reference category. This variable is incorporated into equations 8 and 9 as an interaction term with the explanatory variables. Both *C13T15* and *C29* are FN protected sectors, meaning that no IM sectors are classified as protected. As such, in the IM markets, the dummy variable only distinguishes between low and high elasticities.[35]

Table 7 reports the results for IM markets. Based on the coefficients of $EUETS \times EI$ in

[35]This also implies that the "Protection" category comprises solely sectors that are both protected and highly elastic, with no protected sectors in "Low elasticity".

the first row, we observe that the EU ETS negatively affects competitiveness and increases carbon leakage risk as indicated by the rise in import share and the associated shift in demand. In column (2), the coefficient on the interaction term with the high-elasticity dummy is insignificant.[36] This suggests that, in IM markets, higher elasticity does not lead to substantial differences in response. Given that *C19* is conditionally classified as part of the high-elasticity group, this result appears plausible (see Section B.3). Furthermore, the results from the main PPML specifications in columns (2) to (4) indicate that IM sectors with high elasticity of substitution do not face greater carbon leakage risk compared to sectors with low elasticity.

**Table 7:** Impacts on the competitiveness of IM markets: high elasticity

| | OLS | PPML | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | |
| EUETS × EI | 0.108*** | 0.061*** | 0.050*** | -0.007** |
| | (0.030) | (0.019) | (0.018) | (0.003) |
| EUETS × EI × High elasticity | 0.067 | -0.028 | 0.041 | 0.066*** |
| | (0.043) | (0.034) | (0.033) | (0.002) |
| JointFTA | -0.092 | -0.010 | 0.024 | 0.000 |
| | (0.092) | (0.060) | (0.063) | (0.007) |
| JointCP | -0.103 | -0.023 | 0.002 | 0.001 |
| | (0.157) | (0.091) | (0.101) | (0.010) |
| JointWTO | 1.631*** | -0.634** | -0.597** | -0.016 |
| | (0.313) | (0.257) | (0.278) | (0.028) |
| *Fit statistics* | | | | |
| Observations | 99,346 | 99,346 | 99,346 | 99,346 |
| Adjusted $R^2$/Pseudo $R^2$ | 0.80462 | 0.97670 | 0.97573 | 0.99504 |

*Notes*: The coefficients in this table are obtained from regressions using equation 8, including the interaction term of $EUETS \times EI$ with the high-elasticity dummy. The specification incorporates home country-year, foreign country-year, IM sector-year, and country pair-IM sector fixed effects. Standard errors (in parentheses) are clustered at the country pair-IM sector level. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

[36] The contrasting signs of the OLS and PPML estimates can be attributed to differences in how the two methods handle the data. PPML accounts for the multiplicative nature of trade flows, accommodates zero-valued observations, and implicitly assigns greater weight to larger trade flows, making it more suitable for skewed trade data. By contrast, OLS assumes an additive linear relationship and may be biased under heteroskedasticity or skewed distributions. As the present study is concerned with trade variables, we place greater confidence in the PPML results.

The results of sectoral heterogeneity in FN markets are presented in Table 8. In column (2), none of the three explanatory variables exhibits a statistically significant effect on FN competitiveness in terms of import shares. This generally coincides with the results presented in Section 5.2, which also do not support the view that the EU ETS leads to a loss of competitiveness or carbon leakage through downstream production channels, even though the significance levels differ. While no main interaction terms show statistically significant effects on import shares, the patterns observed in import and total values reported in columns (3) and (4) provide tentative insights that market responses may differ across sectors according to their specific characteristics.

In the low-elasticity and non-protected benchmark group, the coefficient on import value exceeds that on total value and is positive and statistically significant, offering limited yet meaningful indication that the EU ETS may have reduced competitiveness in this group. Nonetheless, these effects are substantially attenuated for high-elasticity or protected sectors. The implied increase in import values is smaller for high-elasticity sectors than for low-elasticity ones, although the overall effect remains positive. By contrast, for protected sectors, the initially positive import value response observed for low-elasticity sectors is largely offset, yielding a negative coefficient. This pattern suggests that government-protected sectors are less likely to experience competitiveness losses following the EU ETS introduction than non-protected sectors.

In summary, the results do not provide statistically significant evidence that the EU ETS affects competitiveness or the risk of carbon leakage in FN sectors, as measured by import shares. While this precludes a definitive conclusion, the findings from changes in import and total values provide an indicative evidence that the impact of the EU ETS may vary across FN sectors depending on sectoral characteristics. Unlike IM sectors, FN sectors can adjust by shifting the sources of their intermediate inputs or modifying their markups, as discussed in Section 3. Accordingly, their responses to the EU ETS may tend to be more heterogeneous.

**Table 8:** The impacts on competitiveness of FN markets: high elasticity & protection

| | OLS | PPML | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | |
| EUETS × E | 0.061 | 0.452 | 1.010** | 0.462*** |
| | (0.471) | (0.502) | (0.475) | (0.025) |
| EUETS × E × High elasticity | -0.010 | -0.676 | -0.895* | -0.188*** |
| | (0.466) | (0.486) | (0.461) | (0.028) |
| EUETS × E × Protection | -0.066 | -0.524 | -1.023** | -0.336*** |
| | (0.455) | (0.484) | (0.456) | (0.023) |
| JointFTA | -0.053 | -0.130 | -0.105 | 0.001 |
| | (0.135) | (0.082) | (0.085) | (0.005) |
| JointCP | -0.056 | -0.101 | -0.220 | -0.013 |
| | (0.200) | (0.168) | (0.163) | (0.009) |
| JointWTO | 0.578** | 0.271 | 0.346 | 0.021 |
| | (0.247) | (0.223) | (0.233) | (0.017) |
| *Fit statistics* | | | | |
| Observations | 43,134 | 43,134 | 43,134 | 43,134 |
| Adjusted $R^2$/Pseudo $R^2$ | 0.84337 | 0.99469 | 0.99459 | 0.99934 |

*Notes*: The coefficients in this table are obtained from regressions using equation 9, including the interaction terms of $EUETS \times E$ and the three-category indicator variable: "Low elasticity," "High elasticity," and "Protection." The specification incorporates home country-year, foreign country-year, FN sector-year, and country pair-FN sector fixed effects. Standard errors (in parentheses) are clustered at the country pair-FN sector level. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

## 5.4 Carbon Leakage Risk

We now compare emission intensity across sectors between EU and non-EU countries to evaluate the magnitude of carbon leakage risk. Figure 3 illustrates the average emission intensity from 2005 to 2016,[37] separately for EU and non-EU countries. The EU sample includes all post-PSM home countries in the treatment group, while the non-EU sample comprises Australia, Brazil, Canada, Korea, Russia, the United States, and Switzerland, based on available data.

As Figure 3 shows, most sectors in EU countries tend to be less emission-intensive than their counterparts in non-EU countries. Although the relative difference between EU and

[37] 2016 is the final year available in the WIOD dataset.

non-EU countries is smaller in IM sectors (about 30%) than in FN sectors (about 42%),[38] the much higher absolute emission intensity in IM sectors—on average 30 times that of FN sectors—implies that the potential impact of carbon leakage is substantially greater in IM sectors. Therefore, IM sectors warrant greater policy attention.[39]

Deviating from the prevailing trend, sectors *C19* and *C21* exhibit higher emission intensities in the EU sample. For these sectors, EU emission intensities are roughly three times those of non-EU countries, indicating that potential demand shifts toward foreign goods would not increase leakage risk. Instead, if such shifts were to occur, they could even lead to reverse carbon leakage. Nevertheless, the baseline analysis already supports the conclusion that carbon leakage risks are not heightened: both the high-elasticity IM sector (*C19*) and the low-elasticity FN sector (including *C21*) show statistically insignificant changes in market shares, suggesting limited demand shifts between domestic and foreign goods.

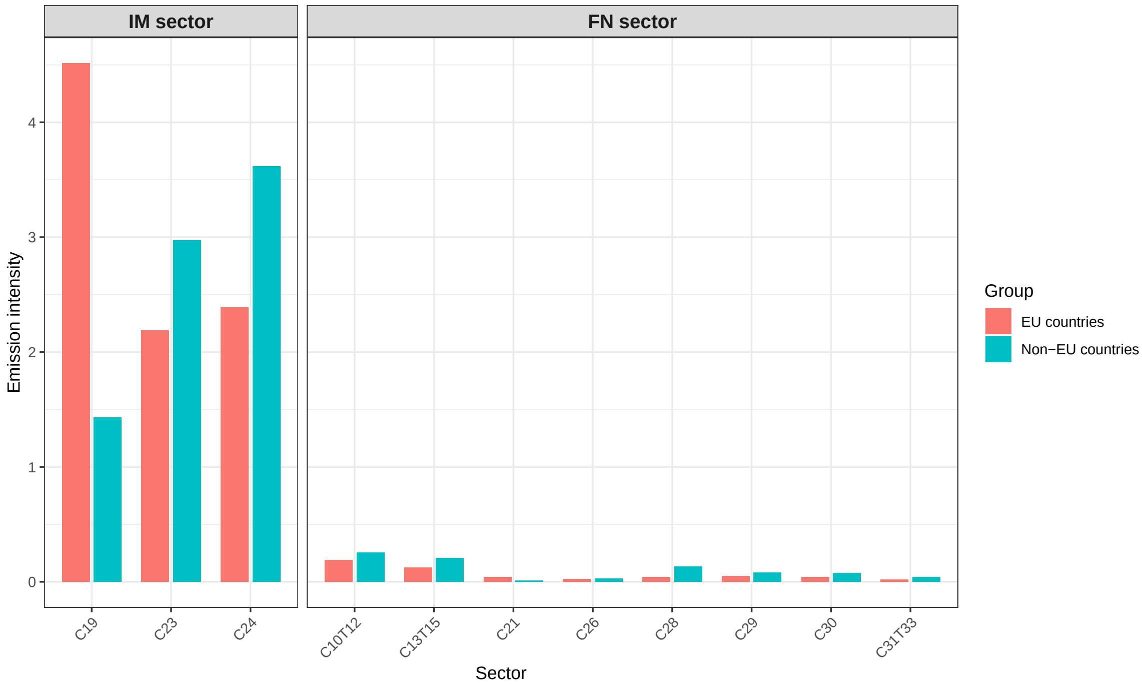


**Fig. 3.** Emission intensity across sectors

*Notes*: The figure illustrates the average emission intensity from 2005 to 2016 for EU home countries in the treatment group (red) and non-EU home countries in the control group (blue). The left and right panels show the emission intensities of the IM and FN sectors, respectively. The unit of intensity is $tCO_2eq$ per thousand USD of value added.

[38] These values are calculated after excluding sectors *C19* and *C21*—where emission intensity is higher in the EU—from the IM and FN sectors, respectively.

[39] As discussed earlier, FN sectors are not expected to experience elevated carbon leakage risk.

## 5.5 Robustness Checks

To confirm the robustness of our main results, we conduct a series of supplementary analyses, presented in Appendix C. First, we estimate the effects of the EU ETS using panel data over multi-year intervals. Piermartini and Yotov (2016) highlights the importance of examining results with data pooled across consecutive years, particularly because in fixed-effects estimation, the dependent and independent variables may not fully capture annual variations. Policy impacts can also lead to lags, resulting in imprecise yearly estimates. To address this, we employ 3- and 5-year intervals to analyze both the direct and indirect effects, with the results largely consistent with baseline findings, as shown in columns (2) and (6) in each panel in Table C1. The EU ETS appears to reduce the competitiveness of IM sectors in EU countries, thereby increasing carbon leakage risk, while FN markets are not adversely affected. Additionally, columns (2) and (6) in Panels A and B of Table C2 report that sectors with high substitution elasticities and protected sectors are less likely to experience further impacts of carbon pricing.

Second, we conduct a leave-one-out test to check whether the overall results are driven by any single influential country pair or sector. Equations 8 and 9 with interaction terms are re-estimated multiple times, each time excluding one sector or one country pair. Fig. C1 presents the results by sector, showing almost no deviation from the main findings. Notably, the coefficient of $EUETS \times EI$ remains significantly positive only when *C23* is dropped, whereas excluding other sectors leads to insignificant estimates. This implies that *C23* may downward-mask the impacts of the EU ETS, which is understandable given its relatively low elasticity (Table B3). Across more than 900 leave-one-out iterations by country pair, the coefficients remain largely stable in both magnitude and direction.[40] Finally, as shown in the rightmost panel of Fig. C1(b), excluding *C29* from the two protected sectors (*C13T15* and *C29*) results in a negative but statistically significant coefficient, indicating that *C29* provides a weaker protective effect than *C13T15*.

Third, Table C3 presents the results of applying a stricter criterion for high elasticity. We consider two alternative definitions. In the first, the sector with the lowest percentile rank among those initially classified as "high elasticity" (*C13T15*) is reclassified as "low elasticity". In the second, the two lowest-ranked sectors (*C13T15* and *C28*) are reclassified as "low elasticity".[41] Under the stricter criterion, *C13T15* is categorized as "low elasticity", necessitating a distinction between low and high elasticity within the protection category. As a result, the classification expands from three to four groups: "Low elasticity (baseline)", "High elasticity", "High elasticity and Protection", "Low elasticity and Protection". Columns

[40]The full results are available upon request.

[41]Since there is only a single high-elasticity sector in IM markets, the analysis is not conducted for IM sectors.

(2) and (6) in Table C3 show that the protection policy exhibits a strongly negative coefficient regardless of elasticity level. The effect is particularly pronounced and statistically significant for the low-elasticity sector (*C13T15*), consistent with the leave-one-out test. All other results align with the main findings.

Fourth, robustness is confirmed through a placebo test. We randomly select 10 countries from the set of non-ETS countries (48 countries) to form placebo treatment and control groups.[42] For each random assignment, we estimate our baseline specification and repeat this procedure 200 times. This exercise assesses whether our results could arise from arbitrary country assignments rather than from exposure to the EU ETS. Collectively, the placebo estimates shown in Fig. C2 suggest that our findings are unlikely to be driven by random assignment, indicating that the results remain reasonably robust despite potential imbalances between the placebo treatment and control groups.[43] Only the variable $EUETS \times EI$ (left panel of Figure C2(a)) shows that the baseline coefficient (red line) lies outside the 95% confidence interval (CI) of the coefficient distribution obtained from the 200 placebo simulations. This indicates that the estimated EU ETS effect in IM sectors is not likely to be driven by spurious factors and can reasonably be attributed to the EU ETS. By contrast, for all other variables, the baseline coefficients lie within the corresponding 95% CIs, consistent with the lack of statistically meaningful EU ETS effects on market shares when using these variables. Moreover, all the placebo CIs for these variables all include zero, showing that they do not exhibit statistically significant effects under random assignment.

To further assess robustness, we conduct three additional separate checks. The first replaces the 2004 emission intensity with the average over 2000-2004, while the second excludes the United States, one of the most influential countries in international trade, from the set of home countries to ensure that the results are not disproportionately influenced by its presence. Finally, we perform an analysis that expands the set of IM sectors to include *C17_18*, a sector with relatively low emission intensity but nevertheless targeted by the EU ETS. The overall conclusions, as shown in Tables C4 to C6, remain unchanged.

# 6 Conclusions

This study examines the effects of unilateral carbon pricing on international competitiveness and carbon leakage in both targeted IM sectors and non-targeted FN sectors. While previous

[42] Among the 48 non-ETS countries in the dataset, only 14 can plausibly be assigned to the placebo treatment group for IM markets due to limited emission intensity data.

[43] The constraints on emission intensity data complicate inference, as the 14 plausible placebo treatment countries for IM markets are disproportionately concentrated among large or influential economies (e.g., Canada, China, India, and Japan). This raises concerns that the placebo treatment and control groups may not be well-balanced in terms of observable characteristics.

research has largely focused on direct effects in targeted sectors, our study extends the analysis to non-targeted sectors, providing a more comprehensive understanding of the effects.

The key findings are as follows. First, unilateral carbon pricing in the home country slightly lowers its competitiveness in IM sectors, increasing the potential for carbon leakage. Second, the policy has no significant effect on FN sectors' competitiveness, highlighting that carbon leakage is unlikely in these sectors. Third, protected sectors in the home country may be more effective at reducing carbon leakage risks compared with unprotected sectors.

These findings have important implications for climate policy design in global supply networks. Policymakers should carefully consider potential competitiveness losses and carbon leakage risks in applying carbon pricing to highly import-dependent sectors. Concerns about indirect effects on non-targeted sectors may be overstated, which allows for a focus on targeted sectors. Carbon pricing should ideally be complemented by other measures. Although its overall impact on competitiveness is modest, emissions may still shift to other regions. Industry protection could help mitigate this risk, but may be in conflict with free trade objectives. Expanding CBAM globally in a non-protectionist manner could alleviate carbon leakage while preserving trade openness.

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# Appendix

## A Supplementary Material for the Theoretical Framework

In this subsection, we show the expectation regarding carbon leakage risk. Following the definition of Misch and Wingender (2024), carbon leakage—that is, the displacement of emissions to other countries caused by shifts in demand— in IM markets can be expressed as:

$$CL_{ll'} = -\frac{\Delta\text{carbon emissions}_{l'}}{\Delta\text{carbon emissions}_{l}} = -\frac{(1+\gamma_{l'})q_{l'}\bar{e}_{l'} - q_{l'}\bar{e}_{l'}}{(1-\gamma_l)q_l(1-\alpha_l)e_l - q_l e_l} = -\frac{\gamma_{l'}}{(\gamma_l\alpha_l - \alpha_l - \gamma_l)}\frac{q_{l'}\bar{e}_{l'}}{q_l e_l}, \tag{10}$$

where $e_l$, $\bar{e}_{l'} \geq 0$ denote the emission intensities of the domestic sector $l$ and the foreign sector $l'$, respectively. In this framework, the domestic sector is subject to carbon pricing, whereas the foreign sector is not. This implies that the embodied carbon emissions in domestic goods ($e_l$) are likely to be lower than those of the foreign sector ($\bar{e}_{l'}$); hence, we assume $e_l \leq \bar{e}_{l'}$.[44] The parameter $\alpha_l \in [0,1]$ represents the rate of emission reduction induced by carbon pricing, capturing factors such as technological improvements and changes in emission intensity. According to equation 10, the higher the value of $-\frac{\gamma_{l'}}{(\gamma_l\alpha_l-\alpha_l-\gamma_l)}$, the greater the risk of carbon leakage, implying that sectors with higher substitution elasticity are more exposed to carbon leakage.[45]

Regarding carbon leakage in FN markets, we similarly define:

$$CL_{kk'} = -\frac{\Delta\text{carbon emissions}_{k'}}{\Delta\text{carbon emissions}_{k}} = -\frac{(1+\gamma_{k'})q_{k'}\bar{e}_{k'} - q_{k'}\bar{e}_{k'}}{(1-\gamma_k)q_k(1-\alpha_k)e_k - q_k e_k} = -\frac{\gamma_{k'}}{(\gamma_k\alpha_k - \alpha_k - \gamma_k)}\frac{q_{k'}\bar{e}_{k'}}{q_k e_k}, \tag{11}$$

where we assume $e_k \leq \bar{e}_{k'}$. Equation 11 shows that the larger the magnitude of $-\frac{\gamma_{k'}}{(\gamma_k\alpha_k-\alpha_k-\gamma_k)}$, the greater carbon leakage risk. Thus, the domestic sectors $k$ that are more sensitive to substitution face a higher risk under carbon pricing.

[44] Although generally higher in countries with no carbon pricing, emissions may occasionally be lower in certain sectors. This issue is discussed in detail in Section 5.4.

[45] Since $\gamma_l, \alpha_l \in [0,1]$, it follows that $\gamma_l\alpha_l \leq \alpha_l + \gamma_l$, and then $\gamma_l\alpha_l - \alpha_l - \gamma_l \leq 0$.

# B Supplementary Explanation on Data

## B.1 Concordance Table

**Table B1:** Sectoral concordance of targeted sectors

| Division (ICIO table) | Activity (EC Directive) |
|---|---|
| C17_18 | Production of pulp from timber or other fibrous materials<br>Production of paper or cardboard with a production capacity exceeding 20 tonnes per day |
| C19 | Refining of mineral oil<br>Production of coke |
| C20 | Production of carbon black involving the carbonization of organic substances such as oils, tars, and cracker and distillation residues, where combustion units with a total rated thermal input exceeding 20 MW are operated<br>Production of nitric acid<br>Production of adipic acid<br>Production of glyoxal and glyoxylic acid<br>Production of ammonia<br>Production of bulk organic chemicals by cracking, reforming, partial or full oxidation or by similar processes, with a production capacity exceeding 100 tonnes per day<br>Production of hydrogen (H2) and synthesis gas by reforming or partial oxidation with a production capacity exceeding 25 tonnes per day<br>Production of soda ash (Na2CO3) and sodium bicarbonate (NaHCO3) |
| C23 | Production of cement clinker in rotary kilns with a production capacity exceeding 500 tonnes per day or in other furnaces with a production capacity exceeding 50 tonnes per day<br>Production of lime or calcination of dolomite or magnesite in rotary kilns or in other furnaces with a production capacity exceeding 50 tonnes per day<br>Manufacture of glass including glass fibre with a melting capacity exceeding 20 tonnes per day<br>Manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain, with a production capacity exceeding 75 tonnes per day<br>Manufacture of mineral wool insulation material using glass, rock or slag with a melting capacity exceeding 20 tonnes per day<br>Drying or calcination of gypsum or production of plaster boards and other gypsum products, where combustion units with a total rated thermal input exceeding 20 MW are operated |
| C24 | Metal ore (including sulphide ore) roasting or sintering, including pelletization<br>Production of pig iron or steel (primary or secondary fusion) including continuous casting, with a capacity exceeding 2,5 tonnes per hour<br>Production or processing of ferrous metals (including ferro-alloys) where combustion units with a total rated thermal input exceeding 20 MW are operated. Processing includes, inter alia, rolling mills, re-heaters, annealing furnaces, smitheries, foundries, coating and pickling<br>Production of primary aluminum<br>Production of secondary aluminum where combustion units with a total rated thermal input exceeding 20 MW are operated<br>Production or processing of non-ferrous metals, including production of alloys, refining, foundry casting, etc., where combustion units with a total rated thermal input (including fuels used as reducing agents) exceeding 20 MW are operated |

*Notes*: This table presents the concordance between the sectoral classifications in the ICIO table (ISIC Rev.4) and activities regulated under the EU ETS, as defined by Directive 2003/87/EC and Directive 2009/29/EC.

### B.2 $CO_2$ Emission Intensity

To assess whether the carbon-priced IM sectors classified by ISIC Rev.4 (Table B1) are indeed carbon-intensive, we calculate their average $CO_2$ emission intensity for the period 2000-2004. For each year, emission intensity is computed by dividing the $CO_2$ emissions of EU countries (sourced from the WIOD Environmental Accounts[46]) by the corresponding value added obtained from the ICIO table. As presented in Table B2, among these sectors covered by the EU ETS, only *C17_18* ranks low in emission intensity, while the others rank from first to fourth. Notably, the emission intensity of these top four sectors is more than tree times higher than that of the sectors ranked fifth and below.

**Table B2:** $CO_2$ emission intensity by sector

| Rank | Sector | EI | Rank | Sector | EI | Rank | Sector | EI |
|---|---|---|---|---|---|---|---|---|
| 1 | **C19** | 6.77 (4.41) | 7 | C16 | 0.25 (0.19) | 13 | C30 | 0.08 (0.06) |
| 2 | **C24** | 4.91 (3.84) | 8 | **C17_18** | 0.22 (0.18) | 14 | C28 | 0.08 (0.06) |
| 3 | **C23** | 3.24 (2.68) | 9 | C22 | 0.18 (0.13) | 15 | C21 | 0.06 (0.05) |
| 4 | **C20** | 1.29 (1.05) | 10 | C25 | 0.11 (0.08) | 16 | C26 | 0.05 (0.03) |
| 5 | C10T12 | 0.33 (0.25) | 11 | C29 | 0.10 (0.07) | 17 | C31T33 | 0.05 (0.04) |
| 6 | C13T15 | 0.26 (0.21) | 12 | C27 | 0.08 (0.06) | | | |

*Notes*: This table presents the ranking of sectors in descending order of their average $CO_2$ emission intensity (EI) over the period 2000-2004. The values in parentheses indicate the EI in 2004. The unit of EI is $tCO_2eq$ per thousand USD of value added. Sectors covered by the EU ETS are shown in bold.

We also employ emission intensity when estimating equation 8 to assess the direct effects. Specifically, we use each country's emission intensity in 2004, the year immediately preceding the implementation of the EU ETS, following Yamazaki (2017).[47]

### B.3 Elasticity of Substitution

Table B3 presents the sectoral elasticities reported in earlier studies. We reference three previous works—Imbs and Mejean (2017), Saito (2004), Welsch (2008)—because, unlike many studies that focus primarily on the United States, these analyses estimate elasticities using data from multiple EU countries. Specifically, Imbs and Mejean (2017) includes 13 EU ETS countries among 31, Saito (2004) covers 9 out of 14, and Welsch (2008) includes data from

[46] For details, see Corsatea et al. (2019).

[47] Yamazaki (2017) employs fixed GHG emissions based on the year prior to the policy shock.

four EU countries. Since direct comparison of elasticity estimates across the three studies is difficult, we adopt the following approach. For each study, we calculate the percentile rank of sectoral elasticities within that study's elasticity distribution. We then compute, for each sector in our dataset, the average of these percentile ranks across the three studies. Sectors whose average percentile ranks falls within the top 25% (0.75 or higher) are classified as having high elasticity. Based on this criterion, in the FN market, *C13T15* and *C28* through *C30* are classified as high elasticity, whereas, in the IM market, no sector meets this threshold (Table B3). However, there is a distinct gap between the elasticity of *C19* and the other IM sectors. Although *C19* does not meet the quantitative cutoff for highly elasticity, its elasticity is relatively higher than those of *C23* and *C24*. To account for potential heterogeneity, we therefore treat *C19* as "High elasticity" in our analysis.

**Table B3:** Elasticity of substitution in international trade

| | Elasticity of substitution | | | Percentile rank | Magnitude |
|---|---|---|---|---|---|
| | Imbs and Mejean (2017)[a] | Saito (2004) | Welsch (2008) | | |
| ***IM sector*** | | | | | |
| C19 | 7.90 | 1.16 | - | 0.72 | High[b] |
| C23 | 4.00 | 0.56 | - | 0.07 | Low |
| C24 | 6.20 | 0.71 | 0.53 | 0.30 | Low |
| ***FN sector*** | | | | | |
| C10T12 | 5.70 | 0.92 | 0.46 | 0.35 | Low |
| C13T15 | 11.03 | 1.39 | 0.85 | 0.79 | High |
| C21 | 5.9 | 1.16 | 0.97 | 0.52 | Low |
| C26 | 8.4 | - | 1.04 | 0.68 | Low |
| C28 | 9.00 | 1.33 | 1.63 | 0.86 | High |
| C29, C30 | 11.40 | - | 1.70 | 0.96 | High |
| C31T33 | 6.40 | - | - | 0.44 | Low |

*Notes*: Elasticities are presented in absolute values. Because the sectoral classification in the previous studies differ from ISIC Rev.4, we match the most closely related sectors across the datasets. The second column from the left reports the average of percentile ranks across the three studies.

[a] The average elasticity of related sectors, used in Imbs and Mejean (2017), for each corresponding sector.

[b] This indicates that *C19* exhibits higher elasticity relative to the other IM sectors but, under our original definition, is not formally classified as highly elastic.

# C Robustness Check Results

## C.1 Analyses with time intervals

**Table C1:** Impacts on the competitiveness of IM and FN markets

| | **A: 3-Year Intervals** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | IM markets | | | | FN markets | | | |
| | OLS | PPML | | | OLS | PPML | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | | | | | |
| EUETS × EI | 0.147*** | 0.048** | 0.063*** | 0.010** | | | | |
| | (0.397) | (0.344) | (0.299) | (0.011) | | | | |
| EUETS × E | | | | | 0.021 | -0.082*** | -0.036 | 0.125*** |
| | | | | | (0.034) | (0.025) | (0.027) | (0.006) |
| *Fit statistics* | | | | | | | | |
| Observations | 34,389 | 34,389 | 34,389 | 34,389 | 14,931 | 14,931 | 14,931 | 14,931 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.79455 | 0.97680 | 0.97586 | 0.99466 | 0.83206 | 0.99473 | 0.99467 | 0.99936 |

| | **B: 5-Year Intervals** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | IM markets | | | | FN markets | | | |
| | OLS | PPML | | | OLS | PPML | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | | | | | |
| EUETS × EI | 0.073** | 0.037** | 0.057*** | 0.015*** | | | | |
| | (0.037) | (0.018) | (0.017) | (0.004) | | | | |
| EUETS × E | | | | | -0.022 | -0.130*** | -0.082** | 0.136*** |
| | | | | | (0.044) | (0.033) | (0.033) | (0.008) |
| *Fit statistics* | | | | | | | | |
| Observations | 22,926 | 22,926 | 22,926 | 22,926 | 9,954 | 9,954 | 9,954 | 9,954 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.77308 | 0.97642 | 0.97553 | 0.99478 | 0.82199 | 0.99455 | 0.99444 | 0.99942 |

*Notes*: The coefficients reported in this table are estimated using equation 8 and 9. Panels A and B present results based on 3-year and 5-year intervals, respectively. The specification includes home country-year, foreign country-year, sector-year, and country pair-sector fixed effects. Standard errors, shown in parentheses, are clustered at the country pair-sector level. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

**Table C2:** The impacts on competitiveness of IM and FN markets: high elasticity & protection

**A: 3-Year Intervals**

| | IM markets | | | | FN markets | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | PPML | | | OLS | PPML | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | | | | | |
| EUETS × EI | 0.135*** | 0.071*** | 0.061*** | -0.006 | | | | |
| | (0.035) | (0.021) | (0.020) | (0.004) | | | | |
| EUETS × EI × High elasticity | 0.059 | -0.059 | 0.006 | 0.065*** | | | | |
| | (0.050) | (0.036) | (0.036) | (0.003) | | | | |
| EUETS × E | | | | | -0.266 | 0.512 | 1.131** | 0.553*** |
| | | | | | (0.506) | (0.559) | (0.543) | (0.025) |
| EUETS × E × High elasticity | | | | | 0.319 | -0.541 | -0.794 | -0.279*** |
| | | | | | (0.504) | (0.564) | (0.552) | (0.031) |
| EUETS × E × Protection | | | | | 0.274 | -0.576 | -1.132** | -0.419*** |
| | | | | | (0.491) | (0.539) | (0.524) | (0.023) |
| *Fit statistics* | | | | | | | | |
| Observations | 34,389 | 34,389 | 34,389 | 34,389 | 14,931 | 14,931 | 14,931 | 14,931 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.79457 | 0.97682 | 0.97586 | 0.99475 | 0.83205 | 0.99473 | 0.99469 | 0.99937 |

**B: 5-Year Intervals**

| | IM markets | | | | FN markets | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | PPML | | | OLS | PPML | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | | | | | |
| EUETS × EI | 0.047 | 0.032 | 0.036* | 0.006 | | | | |
| | (0.038) | (0.024) | (0.020) | (0.005) | | | | |
| EUETS × EI × High elasticity | 0.129** | 0.011 | 0.048 | 0.037*** | | | | |
| | (0.059) | (0.036) | (0.036) | (0.003) | | | | |
| EUETS × E | | | | | -0.321 | 0.324 | 0.994 | 0.532*** |
| | | | | | (0.589) | (0.637) | (0.608) | (0.029) |
| EUETS × E× High elasticity | | | | | 0.393 | -0.850 | -1.264* | -0.278*** |
| | | | | | (0.581) | (0.659) | (0.653) | (0.030) |
| EUETS × E × Protection | | | | | -0.020 | -0.109*** | -0.070** | 0.111*** |
| | | | | | (0.038) | (0.028) | (0.028) | (0.006) |
| *Fit statistics* | | | | | | | | |
| Observations | 22,926 | 22,926 | 22,926 | 22,926 | 9,954 | 9,954 | 9,954 | 9,954 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.77319 | 0.97642 | 0.97554 | 0.99481 | 0.82199 | 0.99455 | 0.99444 | 0.99942 |

*Notes*: The coefficients reported in this table are estimated using equation 8 and 9, incorporating the interaction terms with $EUETS \times EI$ and $EUETS \times E$. Panels A and B present the estimates based on 3-year and 5-year intervals, respectively. The specification includes home country-year, foreign country-year, sector-year, and country pair-sector fixed effects. Standard errors, shown in parentheses, are clustered at the country pair-sector level. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

## C.2 Leave-one-out test

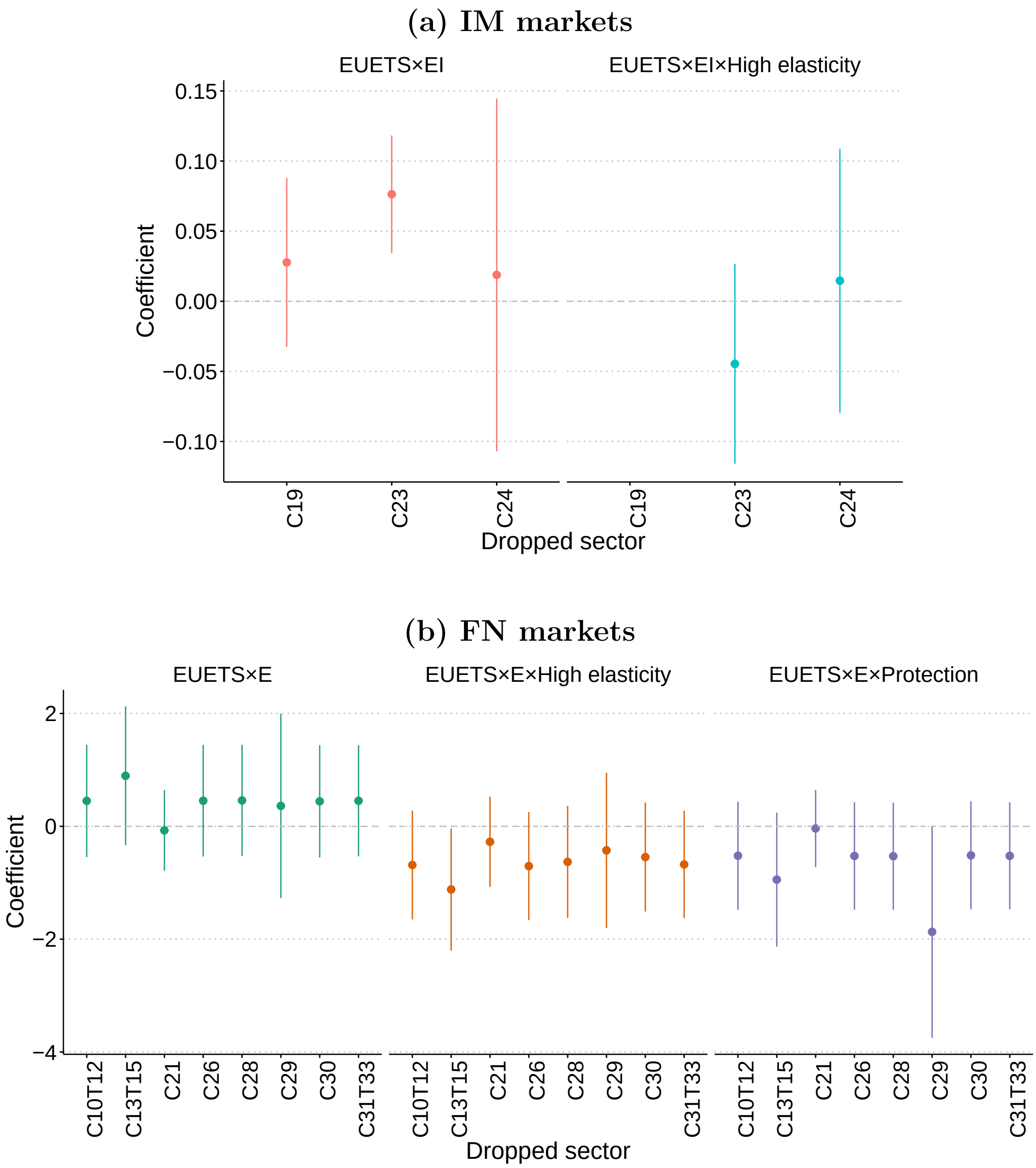


**Fig. C1.** Leave-one-out test

*Notes*: The figure presents the results of the leave-one-out test, where the equations 8 and 9 with interaction terms are re-estimated multiple times, each time excluding one sector from the sample. Panels (a) and (b) show the results for the IM and FN markets, respectively, with 95% confidence intervals. Results for *C19* are omitted in the right part of panel (a) because *C19* is the only sector classified as having high elasticity.

## C.3 Restricted Criteria on High Elasticity

**Table C3:** Impacts on the competitiveness of FN markets

| Reclassified sector | *C13T15* | | | | *C13T15* and *C28* | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | PPML | | | OLS | PPML | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | | | | | |
| EUETS × E | -0.014 | 0.256 | 0.880 | 0.534*** | -0.059 | 0.168 | 0.791 | 0.450*** |
| | (0.489) | (0.583) | (0.538) | (0.038) | (0.153) | (0.580) | (0.552) | (0.037) |
| EUETS × E × High elasticity | 0.051 | -0.515 | -0.792 | -0.246*** | 0.267 | -0.384 | -0.639 | -0.167*** |
| | (0.479) | (0.543) | (0.502) | (0.037) | (0.259) | (0.559) | (0.527) | (0.035) |
| EUETS × E | -1.215 | -1.762* | -1.862** | -0.143*** | -1.014 | -1.717* | -1.815** | -0.172*** |
| × Low elasticity and Protection | (0.973) | (0.909) | (0.913) | (0.054) | (0.968) | (0.895) | (0.901) | (0.060) |
| EUETS × E | 0.006 | -0.333 | -0.896* | -0.407*** | 0.052 | -0.248 | -0.810 | -0.326*** |
| × High elasticity and Protection | (0.472) | (0.560) | (0.517) | (0.037) | (0.150) | (0.557) | (0.530) | (0.036) |
| JointFTA | -0.051 | -0.126 | -0.102 | 0.001 | -0.049 | -0.126 | -0.102 | 0.001 |
| | (0.135) | (0.082) | (0.085) | (0.005) | (0.135) | (0.082) | (0.085) | (0.005) |
| JointCP | -0.052 | -0.099 | -0.219 | -0.013 | -0.052 | -0.099 | -0.219 | -0.013 |
| | (0.200) | (0.168) | (0.163) | (0.009) | (0.200) | (0.168) | (0.163) | (0.009) |
| JointWTO | 0.581** | 0.274 | 0.348 | 0.021 | 0.579** | 0.274 | 0.348 | 0.021 |
| | (0.247) | (0.223) | (0.233) | (0.017) | (0.247) | (0.223) | (0.233) | (0.017) |
| *Fit statistics* | | | | | | | | |
| Observations | 43,134 | 43,134 | 43,134 | 43,134 | 43,134 | 43,134 | 43,134 | 43,134 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.84339 | 0.99470 | 0.99459 | 0.99934 | 0.84342 | 0.99470 | 0.99459 | 0.99934 |

*Notes*: The coefficients reported in this table are estimated using equation 9, including the interaction terms with $EUETS \times E$ with more stricter criterion for high elasticity than in the baseline analysis. The specification includes home country-year, foreign country-year, sector-year, and country pair-sector fixed effects. Standard errors, shown in parentheses, are clustered at the country pair-IM sector level. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.

## C.4 Placebo Test

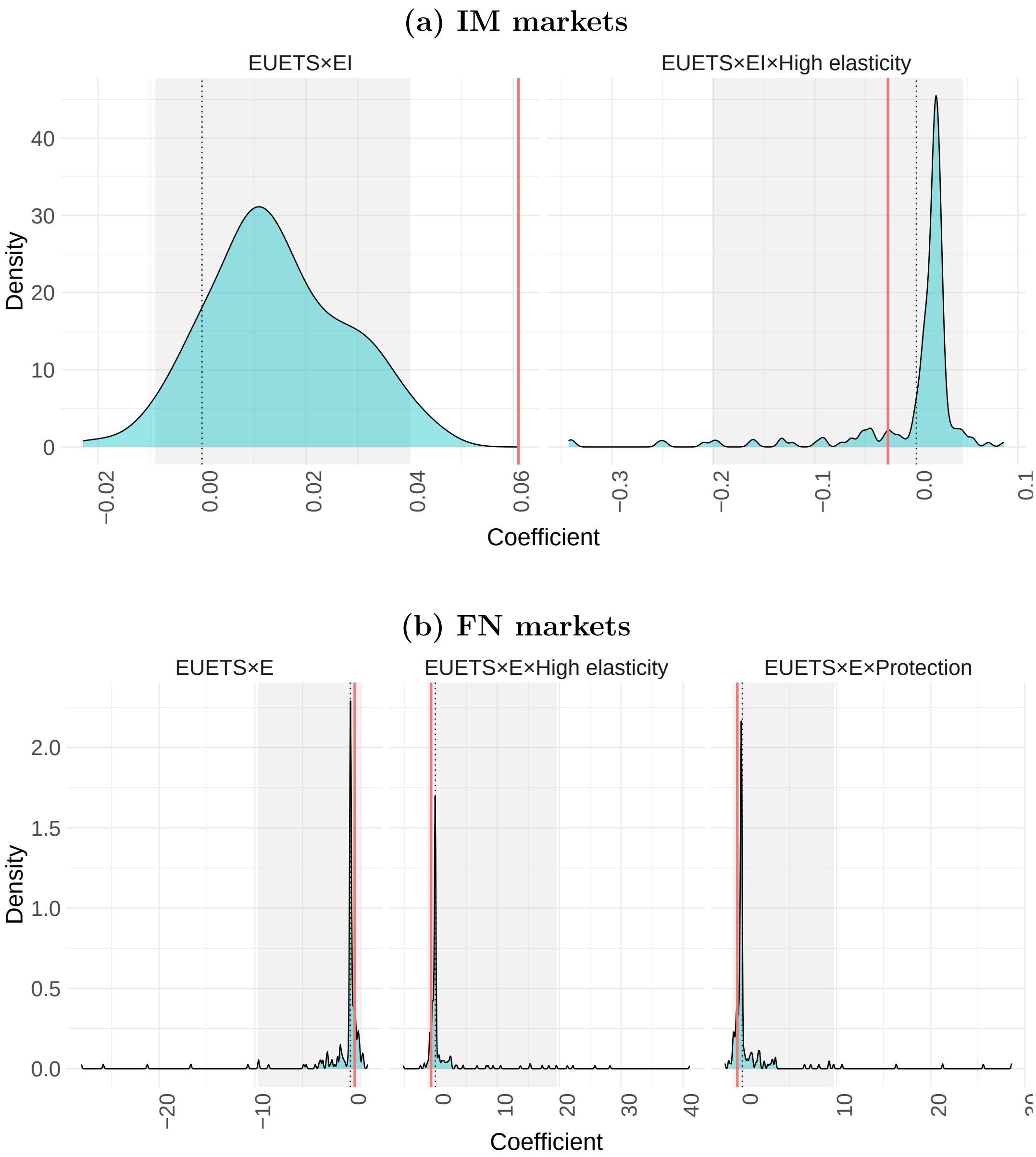


**Fig. C2.** Placebo test

*Notes*: The figure presents the results of the placebo test, where the equations 8 and 9 with interaction terms are re-estimated multiple times, each time resampling 10 countries for each treatment and control group. Panels (a) and (b) show the results for the IM and FN markets, respectively. The shaded area represents the 95% confidence intervals of the coefficients from the placebo estimations, while the red line and grey dotted lines indicate the baseline coefficients and zero, respectively.

## C.5 Other results

**Table C4:** Impacts on the competitiveness of IM and FN markets

**A: Average Emission Intensity (2000-2004)**

| | IM markets | | | | FN markets | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | PPML | | | OLS | PPML | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | | | | | |
| EUETS × EI | 0.084*** | 0.037*** | 0.039*** | 0.001 | | | | |
| | (0.019) | (0.011) | (0.010) | (0.002) | | | | |
| EUETS × E | | | | | -0.003 | -0.060*** | -0.032* | 0.086*** |
| | | | | | (0.019) | (0.015) | (0.017) | (0.005) |
| *Fit statistics* | | | | | | | | |
| Observations | 99,346 | 99,346 | 99,346 | 99,346 | 43,134 | 43,134 | 43,134 | 43,134 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.80465 | 0.97670 | 0.97571 | 0.99492 | 0.84338 | 0.99469 | 0.99458 | 0.99933 |

**B: Samples without the United States (Home Country)**

| | IM markets | | | | FN markets | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | PPML | | | OLS | PPML | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | | | | | |
| EUETS × EI | 0.122*** | 0.055*** | 0.070*** | 0.007** | | | | |
| | (0.029) | (0.020) | (0.014) | (0.004) | | | | |
| EUETS × E | | | | | -0.005 | -0.105*** | -0.088*** | 0.013*** |
| | | | | | (0.032) | (0.027) | (0.028) | (0.004) |
| *Fit statistics* | | | | | | | | |
| Observations | 97,136 | 97,136 | 97,136 | 97,136 | 41,444 | 41,444 | 41,444 | 41,444 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.80313 | 0.96916 | 0.96803 | 0.99207 | 0.84219 | 0.98489 | 0.98470 | 0.99876 |

*Notes*: The coefficients reported in this table are estimated using equation 8 and 9. Panels A and B present the estimates using average emission intensity for 2000-2004 and the sample excluding the United States, respectively. The specification includes home country-year, foreign country-year, sector-year, and country pair-sector fixed effects. Standard errors, shown in parentheses, are clustered at the country pair-IM sector level. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

**Table C5:** Impacts on the competitiveness of IM and FN markets: high elasticity & protection

| | IM markets | | | | FN markets | | | |
|---|---|---|---|---|---|---|---|---|
| **A: Average Emission Intensity (2000-2004)** | OLS | PPML | | | OLS | PPML | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | | | | | |
| EUETS × EI | 0.078*** | 0.039*** | 0.036*** | -0.003** | | | | |
| | (0.019) | (0.011) | (0.010) | (0.002) | | | | |
| EUETS × EI × High elasticity | 0.026 | -0.014 | 0.025 | 0.040*** | | | | |
| | (0.027) | (0.021) | (0.021) | (0.002) | | | | |
| EUETS × E | | | | | 0.072 | 0.545 | 1.067** | 0.407*** |
| | | | | | (0.359) | (0.517) | (0.504) | (0.030) |
| EUETS × E × High elasticity | | | | | -0.044 | -0.706 | -0.982** | -0.209*** |
| | | | | | (0.355) | (0.491) | (0.475) | (0.030) |
| EUETS × E × Protection | | | | | -0.074 | -0.589 | -1.071** | -0.315*** |
| | | | | | (0.348) | (0.503) | (0.490) | (0.029) |
| *Fit statistics* | | | | | | | | |
| Observations | 99,346 | 99,346 | 99,346 | 99,346 | 43,134 | 43,134 | 43,134 | 43,134 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.80466 | 0.97670 | 0.97571 | 0.99502 | 0.84337 | 0.99469 | 0.99459 | 0.99933 |

| | IM markets | | | | FN markets | | | |
|---|---|---|---|---|---|---|---|---|
| **B: Samples without the United States (Home Country)** | OLS | PPML | | | OLS | PPML | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | | | | | |
| EUETS × EI | 0.109*** | 0.068*** | 0.057*** | -0.008*** | | | | |
| | (0.059) | (0.036) | (0.036) | (0.003) | | | | |
| EUETS × EI × High elasticity | 0.067 | -0.035 | 0.033 | 0.067*** | | | | |
| | (0.043) | (0.035) | (0.034) | (0.002) | | | | |
| EUETS × E | | | | | 0.086 | 0.434 | 1.035** | 0.417*** |
| | | | | | (0.470) | (0.504) | (0.477) | (0.018) |
| EUETS × E× High elasticity | | | | | -0.031 | -0.570 | -0.879* | -0.249*** |
| | | | | | (0.464) | (0.529) | (0.507) | (0.028) |
| EUETS × E × Protection | | | | | -0.089 | -0.524 | -1.091** | -0.395*** |
| | | | | | (0.454) | (0.488) | (0.461) | (0.017) |
| *Fit statistics* | | | | | | | | |
| Observations | 97,136 | 97,136 | 97,136 | 97,136 | 41,444 | 41,444 | 41,444 | 41,444 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.80315 | 0.96917 | 0.96803 | 0.99228 | 0.84219 | 0.98491 | 0.98476 | 0.99880 |

*Notes*: The coefficients reported in this table are estimated using equation 8 and 9, including the interaction terms with $EUETS \times EI$ and $EUETS \times E$. Panels A and B present the estimates using average emission intensity for 2000-2004 and the sample excluding the United States, respectively. The specification includes home country-year, foreign country-year, sector-year, and country pair-sector fixed effects. Standard errors, shown in parentheses, are clustered at the country pair-IM sector level. ***, **, and * indicate statistical significance at 1%, 5%, and 10%, respectively.

**Table C6:** Impacts on the competitiveness of IM and FN markets: including *C17_18*

**A: Baseline**

| | IM markets | | | | FN markets | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | PPML | | | OLS | PPML | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | | | | | |
| EUETS × EI | 0.141*** | 0.096*** | 0.099*** | -0.008*** | | | | |
| | (0.021) | (0.017) | (0.017) | (0.002) | | | | |
| EUETS × E | | | | | -0.007 | -0.095*** | -0.047 | 0.118*** |
| | | | | | (0.032) | (0.027) | (0.029) | (0.006) |
| *Fit statistics* | | | | | | | | |
| Observations | 157,378 | 157,378 | 157,378 | 157,378 Observations | 43,134 | 43,134 | 43,134 | 43,134 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.82174 | 0.97713 | 0.97637 | 0.99592 | 0.84338 | 0.99469 | 0.99458 | 0.99933 |

**B: Heterogeneity**

| | IM markets | | | | FN markets | | | |
|---|---|---|---|---|---|---|---|---|
| | OLS | PPML | | | OLS | PPML | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| Dependent Variables: | Ln(Import share) | Import share | Import value | Total value | Ln(Import share) | Import share | Import value | Total value |
| *Variables* | | | | | | | | |
| EUETS × EI | 0.132*** | 0.104*** | 0.092*** | -0.019*** | | | | |
| | (0.022) | (0.017) | (0.020) | (0.002) | | | | |
| EUETS × EI × High elasticity | 0.043 | -0.039 | 0.029 | 0.072*** | | | | |
| | (0.043) | (0.035) | (0.032) | (0.003) | | | | |
| EUETS × E | | | | | -0.126 | 0.055 | 0.224 | 0.154*** |
| | | | | | (0.238) | (0.228) | (0.239) | (0.022) |
| EUETS × E× High elasticity | | | | | 0.147 | -0.312 | -0.182 | 0.094*** |
| | | | | | (0.246) | (0.287) | (0.293) | (0.024) |
| EUETS × E × Protection | | | | | 0.111 | -0.137 | -0.248 | -0.033 |
| | | | | | (0.223) | (0.203) | (0.215) | (0.021) |
| *Fit statistics* | | | | | | | | |
| Observations | 157,378 | 157,378 | 157,378 | 157,378 | 43,134 | 43,134 | 43,134 | 43,134 |
| Adjusted $R^2$ /Pseudo $R^2$ | 0.82175 | 0.97714 | 0.97638 | 0.99601 | 0.84338 | 0.99469 | 0.99458 | 0.99933 |

*Notes*: The coefficients reported in Panel A are estimated using equations 8 and 9, while those in Panel B are estimated using the same equations incorporating interaction terms with $EUETS \times EI$ and $EUETS \times E$. The dataset is extended to include sector *C17_18* as an IM sector. The specification includes home country-year, foreign country-year, sector-year, and country pair-sector fixed effects. Standard errors, shown in parentheses, are clustered at the country pair-sector level. ***, **, and * denote statistical significance at 1%, 5%, and 10%, respectively.