Firms' Supply Chain Adaptation to Carbon Taxes*

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November 2024

*The views expressed herein are those of the authors and not necessarily those of the FRB of New York or the Federal Reserve System.

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$\rightarrow$ Carbon leakage

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→ Carbon leakage

- Solution: Border adjustment tax ("carbon tariff")

This paper's setting: EU policy

The European Union has been at the forefront of climate policy:

- 2005-present: Emissions Trading System (ETS) + free permits for firms exposed to international competition
  - Complements individual countries' carbon taxes
  - Impacts carbon pricing across all EU countries
  - * Potential for leakage via importing intermediates from non-EU countries
- 2025-forward: ETS + Carbon Border Adjustment Mechanism (CBAM)
  - * Targeted at stopping leakage

Some questions that implementation of policies raise

- Does a cap-and-trade system like the EU-ETS create significant carbon leakage?
- What is a CBAM's potential impact on both emissions and economic efficiency?
- Crucially depends on **firms' adaptation** to carbon policies
- Especially relevant for decisions that involve a forward-looking dimension (Investment, **Sourcing decisions**)

This paper

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1. Provide novel evidence on **leakage** by exploiting French trade data
   - Build a novel classification of clean (unregulated) and dirty (regulated) inputs based on the actual coverage of European policies
   - Exploit granular import data to dig into firms' sourcing of clean vs. dirty goods from ETS and non- ETS member countries, over time

   → Over the 2010s, French firms increasingly source dirty inputs from non-EU markets (compared to clean inputs sourced from non-EU markets as well as dirty inputs sourced from ETS countries)

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1. Provide novel evidence on **leakage** by exploiting French trade data
2. Extend Antràs, Fort and Tintelnot (2017) model of firm sourcing decisions to two sectors (clean and dirty) and heterogeneous carbon price policies
   - Model allows us to capture both **extensive** and intensive margins of imports
   - Estimate the model using pre-ETS firm-level data

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3. Run counterfactuals that quantify the impact of:
   - **The ETS on leakage**: A €100/ton CO_2 EU tax

   → Reduces the emission-content of inputs sourced by French firms by −1.84M tons relative to a no-tax equilibrium

   → Reproduces 80% of firm-level carbon leakage observed in the data

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3. Run counterfactuals that quantify the impact of:
   - **The ETS on leakage**: A €100/ton of CO_2 EU-wide tax
   - **The CBAM on new sourcing decisions**: Extending the €100/ton CO_2 tax to non-ETS countries:

   → Increases the drop in the emission-content of inputs to −6.94M tons

   → Reverses leakage

Literature

- **Trade impact of carbon policies:** Dechezleprêtre and Sato (2017), Aldy and Pizer (2015), Sato and Dechezleprêtre (2015), Naegele and Zaklan (2019)

→ Investigate the impact of ETS

- **ETS evidence:** Firm-level: Joltreau and Sommerfeld (2019), Borghesi et al. (2020), Dechezleprêtre, Gennaioli, Martin, Muûls and Stoerk (2022), Barrows, Calel, Jégard and Ollivier (2024), Colmer, Martin, Muûls and Wagner (2023), Känzig, Marenz and Olbert (2024)

→ Focus on manufacturing firms' sourcing of intermediate inputs

- **Trade and environment quantitative approach:** Shapiro (2016, 2021), Copeland, Shapiro and Taylor (2022), Bellora and Fontagné (2023)

→ Focus on firms' *adaptation* to climate policies

Institutional context and data

EU ETS market

- A cap and trade system for GHG emissions, where firms buy or receive emissions allowances that they can then trade. At year-end each firm surrenders enough allowances to fully cover its emissions
- Introduced in 2005 but really effective since phase 3 (2012-2013) and stringency has increased over time Carbon price
- Geographic coverage: EU + Iceland, Liechtenstein and Norway (also linked to Swiss ETS market)
- Sectoral coverage: Metal products, Coke & refined petroleum, Paper products, Mineral products, Chemical products, (Aviation) Details

Carbon Border Adjustment Mechanism

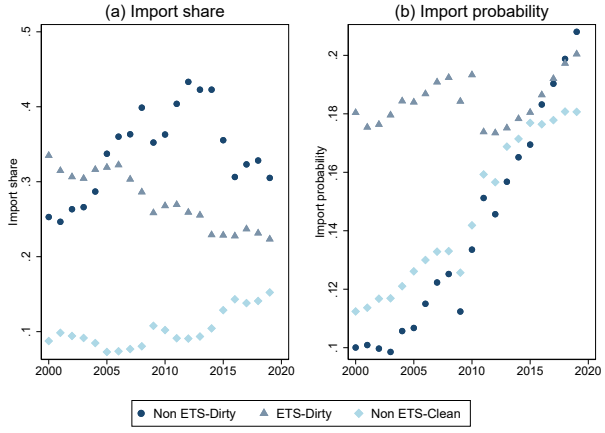
- Extension of the cap and trade system to EU importers. At year-end importers declare the emissions embedded in imports, deduct any existing payment of a carbon price and surrender the corresponding number of certificates
- From 2026 with a transition phase between 2023 and 2025, aligned with the phase-out of the allocation of free allowancves under the ETS
- Geographic coverage: All non-ETS countries with some specific support to LDCs
- Sectoral coverage: Comparable (but not identical) to ETS Details

Data

- Product-level
  - EU Transaction log + Regulation (EU) 2023/956 of the European Parliament
  - Sectoral coverage of EU policies to define a set of dirty (i.e. regulated) products
  - 1,464 nc8 products, 31% of the value of imports in the corresponding HS chapters
- Firm-level
  - Import flows over 2000-2019, by product and country of origin (discontinuity in 2011 for intra-EU imports)
  - Balance-sheet data for 2004: Sales, input purchases and sector
  - Restricted to 44 dirty-intensive manufacturing sectors and firms' core inputs
- Sector-country level
  - Input-Output Tables, 138 sectors
  - Gravity variables (CEPII)
  - Pollution intensities (WIOD)

Motivating stylized facts

Aggregate trade patterns



Notes: This figure presents aggregate import statistics based on the firm$\times$ product import dataset that classifies products as either clean or dirty. Panel (a) presents import shares and panel (b) presents the probability of sourcing from a given sourcing country (extensive margin). Each panel plots the treated group, 'non-ETS Dirty', vs. both control groups: (i) 'non-ETS Clean' or (ii) 'ETS-Dirty'.

Evidence of carbon leakage

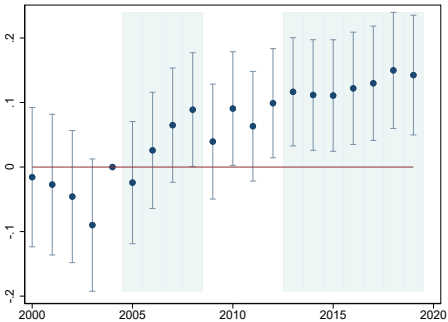
- Reduced-form evidence using a simple descriptive set-up

$$y_{fpit} = \exp\left[\sum_{\tau=-4}^{15} \beta_\tau \mathbb{1}\left(i \notin ETS\right) \mathbb{1}\left(p \in Dirty\right) \mathbb{1}\left(t = \tau\right) + \mathbf{X}'_{fpit}\boldsymbol{\theta} + \varepsilon_{fpit}\right]$$

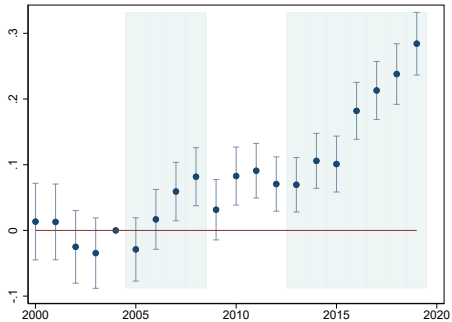
- y_{fpit} the share of imports of product p from country i or a dummy for positive import flow
- Interested in how β_τ evolves over time
- Control groups:
  - Clean products sourced from non-ETS
  - Dirty products sourced from ETS
- Robustness: Set of fixed effects, statistical model, heterogeneous treatment effects

Evidence of carbon leakage

(a) Import Share



(b) Import Probability



Notes: "Treatment" group: Imports of dirty inputs from non-ETS. " Control": Clean inputs from non-ETS countries. Control for product×country and year fixed effects. Standard errors are clustered in the product×country×year dimension.

Fixed Effects | LPM controlling for heterogeneous coefficients | Control group | ETS vs non-ETS firms

Theoretical framework

Theoretical Framework

- A quantitative multi-country sourcing model + a methodology to solve firm's problem with interdependencies, following Antràs, Fort and Tintelnot (2017)
- Additional ingredients to capture heterogeneous **environmental regulations**:
  - Clean / Dirty inputs
  - Country- and sector-specific carbon taxes

$\Rightarrow$ A framework to think about the trade consequences of environmental policies

$\Rightarrow$ Captures both intensive and extensive margins of firms sourcing decisions

Households

- Households in country i value the consumption of differentiated varieties (ω) according to a CES aggregator:

$$C_i = \left[\int_{\omega \in \Omega} q_i(\omega)^{\frac{\sigma-1}{\sigma}} \, d\omega \right]^{\frac{\sigma}{\sigma-1}}, \quad \sigma > 1$$

- Market demand:

$$B_i = \frac{1}{\sigma} \left(\frac{\sigma}{\sigma - 1} \right)^{1-\sigma} E_i P_i^{\sigma-1}$$

E_i (exogenous) nominal expenditures on manufacturing goods,

$P_i = \left[\int_{\omega \in \Omega} p_i(\omega)^{1-\sigma} \, d\omega \right]^{\frac{1}{1-\sigma}}$ the ideal price index

Final goods production

- Firms produce (non-tradable) final consumption goods with bundles of (tradable) clean (C) and dirty (D) inputs, which can be produced domestically or imported
- Nested CES structure

$$y_i(\varphi) = \varphi \left[y_i^D(\varphi)^{\frac{\eta-1}{\eta}} + y_i^C(\varphi)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

with

$$y_i^D(\varphi) = \left[\int_{\nu \in \mathcal{A}^D} y_i^D(\varphi, \nu)^{\frac{\rho-1}{\rho}} d\nu \right]^{\frac{\rho}{\rho-1}}, \quad y_i^C(\varphi) = \left[\int_{\nu \in \mathcal{A}^C} y_i^C(\varphi, \nu)^{\frac{\rho-1}{\rho}} d\nu \right]^{\frac{\rho}{\rho-1}}$$

Sourcing intermediates

- Intermediates are produced under CRS technology à la Eaton and Kortum (2002):

$$Pr\left(a_j^t(\nu) \leq a\right) = exp\left(-T_j^t a^{\theta^t}\right), \quad with \quad T_j^t > 0$$

- A type-specific fixed cost for offshoring $f_{ij}^t(\varphi) \rightarrow \mathcal{I}^t(\varphi) \subset J^t$ the firm's *Global Sourcing Strategy (GSS)*

- A variable trade cost:

$$\tau_{ij}^t = \underbrace{\tilde{\tau}_{ij}^t}_{\text{Iceberg trade cost}} \times \underbrace{tax_{ij}^t}_{\text{Bilateral carbon tax}}$$

$\Rightarrow$ Cost of sourcing function of trade cost, productivity, and wage:

$$c^t\left(\varphi, \nu; \mathcal{I}^t(\varphi)\right) = \min_{j \in \mathcal{I}^t(\varphi)} \left\{\tau_{ij}^t a_j^t(\nu) w_j\right\}$$

Solution of the sourcing problem (i)

- Conditional on sourcing, share of inputs sourced from country j:

$$\chi_{ij}^t(\varphi; \mathcal{I}_i^t(\varphi)) = \begin{cases} \frac{T_j^t \left(\tau_{ij}^t w_j\right)^{-\theta^t}}{\Theta_i^t(\omega; \mathcal{I}_i^t(\varphi))} & \text{if} \quad j \in \mathcal{I}^t(\varphi) \\ 0 & \text{if} \quad j \notin \mathcal{I}^t(\varphi) \end{cases}$$

with

$$\Theta_i^t(\varphi; \mathcal{I}^t(\varphi)) \equiv \sum_{k \in \mathcal{I}^t(\varphi)} T_k^t \left(\tau_k^t w_k\right)^{-\theta^t}$$

$\Rightarrow$ More stringent / asymmetric environmental regulation increases bilateral iceberg costs thus reducing the share of inputs from the regulating country in any firm's input bundle (Intensive margin adjustment)

Solution of the sourcing problem (ii)

$$\pi_i(\varphi; \mathcal{I}^D(\varphi), \mathcal{I}^C(\varphi)) = \left(\frac{c(\varphi; \mathcal{I}^D(\varphi), \mathcal{I}^C(\varphi))}{\varphi} \right)^{1-\sigma} B_i - w_i \sum_{j \in \mathcal{I}^D(\varphi)} f_{ij}^D(\varphi) - w_i \sum_{j \in \mathcal{I}^C(\varphi)} f_{ij}^C(\varphi)$$

with

$$c(\varphi; \mathcal{I}^D(\varphi), \mathcal{I}^C(\varphi)) = \left[\left(c^D(\varphi; \mathcal{I}^D(\varphi)) \right)^{1-\eta} + \left(c^C(\varphi; \mathcal{I}^C(\varphi)) \right)^{1-\eta} \right]^{\frac{1}{1-\eta}}$$

$$c^t(\varphi; \mathcal{I}^t(\varphi)) = \left(a^t \right)^{\frac{1}{1-\rho}} \left(\gamma^t \Theta^t(\varphi; \mathcal{I}^t(\varphi)) \right)^{-1/\theta^t}$$

$\Rightarrow$ A large combinatorial optimization problem which can be solved using algorithm from Jia (2008), extended by Arkolakis, Eckert and Shi (2023)

- Trade off: reduction in variable costs / fixed costs
- More stringent / asymmetric environmental regulation reduces the benefit, thus the firm's incentive to source from the country (Extensive margin adjustment)

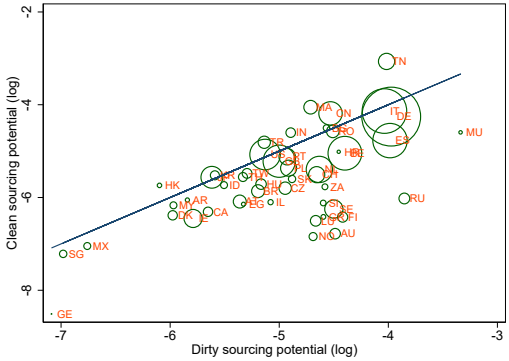
Structural estimation

Structural estimation

1. Use (pre-ETS) French import data to estimate *sourcing potential* by type – $T_j^t \left(\tilde{\tau}_{ij}^t w_j\right)^{-\theta^t}$
2. Elasticities and productivity parameters taken from literature
3. Given model structure, apply Simulated Method of Moments (SMM) to firm-level data to estimate relative share of intermediates ($\mathcal{A}^C$ and $\mathcal{A}^D$), aggregate demand (B_i, i=France) and fixed costs ($\{f_{ij}^C(\varphi)\}_j$ and $\{f_{ij}^D(\varphi)\}_j$)

1. Estimation of sourcing potential

$$\log \chi^t_{fij} - \log \chi^t_{fii} = \alpha^t_{ij} + \varepsilon^t_{fij}, \quad \alpha^t_{ij} = \log T^t_j \left(\tilde{\tau}^t_{ij} w_j\right)^{-\theta^t} - \log T^t_i \left(\tilde{\tau}^t_{ii} w_i\right)^{-\theta^t}$$



Notes: This figure plots the exponential of α^t_{ij} for $t = C, D$. The size of the bubbles is proportional to the value of overall imports. The blue line is the 45 degree line. A country below the line has a comparative advantage over France in dirty inputs.

2. Elasticities and productivity parameters

Parm.	Value	Description	Source
κ	4.25	Shape parm. firm prod. (Pareto)	Melitz and Redding (2015)
θ^t	1.789	Shape parm. of intermediate inputs efficiency (Fréchet)	Antràs et al. (2017)
η	3	Elas. of sub. btw C and D inputs	Papageorgiou et al. (2017)
σ	6.9	Elas. of sub. for CES cons.	Firm data on sales/inputs

3. Simulated Method of Moments

- Parametrize the distribution of fixed costs:

$$f_{ij}^t(\varphi) = \bar{f}_{ij}^t \times \exp\left(x^t\right),\ x^t \sim \mathcal{N}(0, \sqrt{\delta^t})$$

with

$$\log \bar{f}_{ij}^t = \log \beta_0^t + \beta_{short}^t D_{ij} \log dist_{ij} + \beta_{long}^t (1 - D_{ij}) \log dist_{ij} + contig_{ij} \log \beta_{cont}^t - \beta_{corr}^t corr_j + EU_{ij} \log \beta_{EU}^t - \beta_{TAB}^t TAB_j \left[-\beta_{Climate}^t Climate_j \text{ if } t = D\right]$$

with $D_{ij} \equiv 1[dist_{ij} < 5,000\text{km}]$, $corr_j$ a measure of the control of corruption, TAB_j WB trading across borders score, $Climate_j$ Yale's Environmental Protection Index

Targeted moments

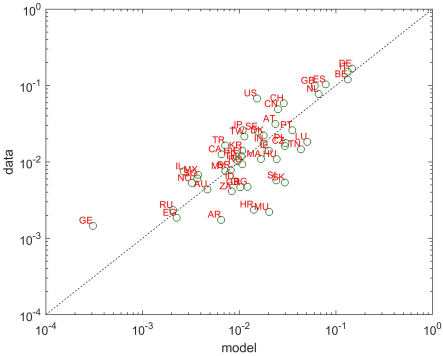
Parameter	Moments matched
	Fixed cost of sourcing each type-t: f_{ij}^t
β^t	Share of importers of t goods as a fraction of all firms Share of importers of t goods from each country
δ^t	# firms importing t goods from most popular country over # of firms that import t goods Share of importers of t goods among firms below the sales median
$\mathcal{A}^D$	Share of dirty inputs aggregated across firms
B_i	Share of firms with sales below data median value

Notes: β^t explain avg. source-country fixed costs; δ^t generates randomness in fixed costs across firms; $\mathcal{A}^D$ is the mass of dirty goods sourced; B is market demand.

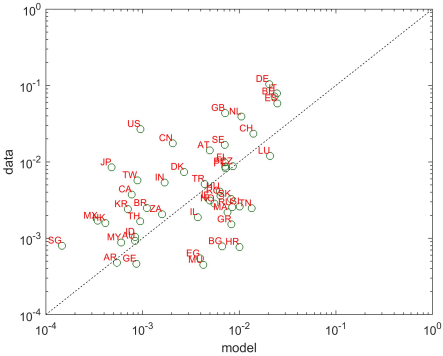
Model fit

Panel I. Share of importers by source country

(a) Clean



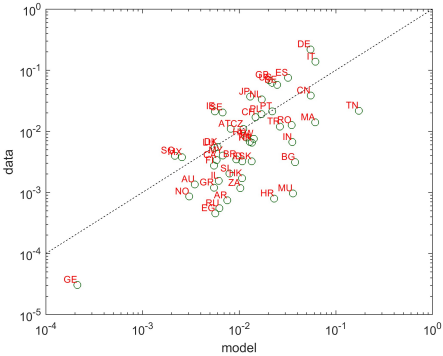
(b) Dirty



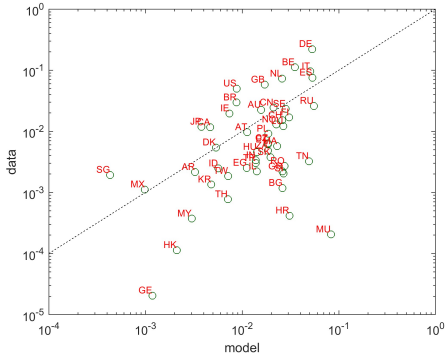
Model fit (ii)

Panel II. Share of imports by source country

(a) Clean



(b) Dirty

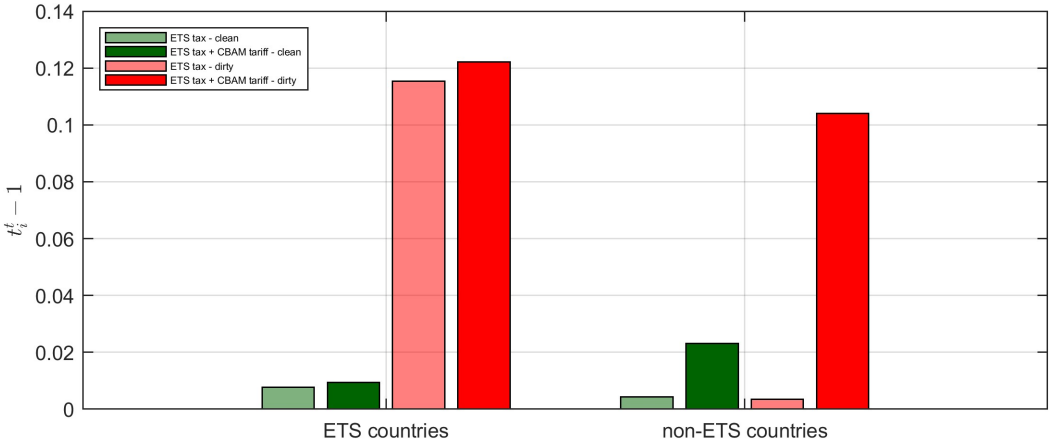


Counterfactuals

Carbon taxes and carbon tariffs

- Run two policy experiments using the estimated model
  - **ETS scenario**: A carbon tax of €100 per ton of CO_2 affecting all ETS sectors in ETS countries
  - **ETS+CBAM scenario**: Same + a carbon tariff of €100 per ton of CO_2 affecting all CBAM products imported from non-ETS countries
- Calibrate tax rates using WIOD data on CO_2 intensities by sector$\times$country (sector-based approach of embodied carbon emissions)
- Use IO tables to compute the overall incidence of these taxes along the value chain
- No tax revenues / Tax revenues rebated to consumers

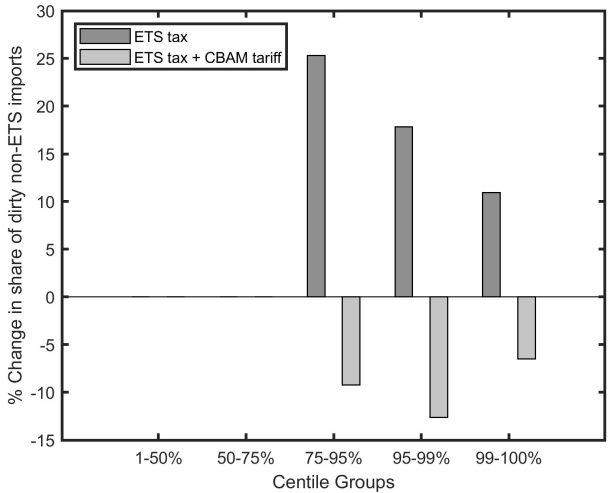
Carbon taxes and carbon tariffs



Carbon leakage under ETS: Data vs Model

	Data (1)	ETS (2)	ETS + CBAM (3)
	Panel (a) Import Share		
Dirty product × Non-ETS × $\mathbb{1}$ (*tax* = €100 or Post)	0.129***	0.106***	-0.046***
	(0.019)	(0.002)	(0.002)
Pseudo R^2	0.162	0.118	0.119
Observations	7,560,435	402,579	398,892
	Panel (b) Import Probability		
Dirty product × Non-ETS × $\mathbb{1}$ (*tax* = €100 or Post)	0.126***	0.025***	-0.016***
	(0.010)	(0.001)	(0.001)
Pseudo R^2	0.044	0.002	0.000
Observations	7,560,435	402,579	398,892
# (Simulated) Firms	27,240	36,000	
Control group	Non-ETS Clean products		
Fixed effects	pc,t	pc,t	

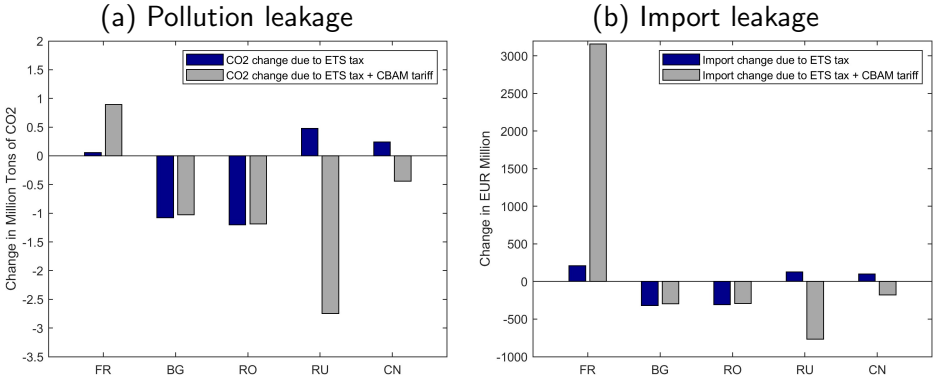
Carbon leakage along the Productivity Distribution



Overall impact of carbon policies

Variable	ETS	ETS + CBAM
Panel (a) Δ Million tons emissions embedded in inputs		
Total	-1.84	-6.94
... *from clean inputs only*	0.02	-0.39
... *from dirty inputs only*	-2.13	-6.55
... *from FR inputs only*	0.06	0.89
... *from ETS (ex. FR) inputs only*	-5.65	-3.45
... *from non-ETS inputs only*	3.48	-4.39
Panel (b) Δ Million EUR in inputs purchases		
Total	0	0
... *from clean inputs only*	189.14	1845.37
... *from dirty inputs only*	-189.14	-1845.37
... *from FR inputs only*	211.41	3160.36
... *from ETS (ex. FR) inputs only*	-1575.62	-1338.99
... *from non-ETS inputs only*	1364.21	-1821.37
Panel (c) Δ Welfare		
% ΔP_i	0.051	0.542
% ΔV_i without tax rebate, SCC €200	-.0047	-.0501
% ΔV_i with full tax rebate, SCC €200	+.3103	+.4931
% ΔV_i without tax rebate, SCC €1500	-.0022	-.0246
% ΔV_i with tax rebate, SCC €1500	+.3128	+.5187

The geography of leakage



Notes: This figure plots the change in pollution in millions of tons (panel (a)) and in imports in millions of euros (panel (b)) under ETS and ETS+CBAM for the 5 most affected countries

Conclusion

- We quantify the impact of carbon policies on leakage through firms' carbon embodied consumption of intermediates
- Empirically, we observe a sizeable reallocation of inputs covered by carbon policies away from regulated countries
- Our estimated model calibrated with a €100/ton CO_2 tax replicates the observed leakage qualitatively but underestimate it quantitatively
- Augmenting the carbon tax with a carbon tariff more than compensate leakage

Appendix

Carbon Price over ETS period

Back

ETS sectoral coverage and ETS-regulated products

Back

ETS sector		HS products	
Code	Description	Code	Description
1	Combustion install (thermal input > 20MW)	27.16	Electrical energy
2	Mineral oil refineries	27.09-27-15,68.07	Petroleum oils, gases, jelly, coke, bituminen, asphalt (articles thereof)
3	Coke ovens	27.01-27.06	Coal, Lignite, Peat, Coke, Coal Gas, Mineral Tars
4	Metal ore (including sulphide ore) roasting or sintering Install	26 ex. 26.18-26.21	Metal ores and concentrates
5	Install for the prod of pig iron or steel	72 ex 72.04	Iron and steel (ex waste)
6	Install for the prod of cement clinker or lime	25.21-25.23	Lime and cement
7	Install for the manuf of glass	70.01-70.06	Glass and glassware
8	Install for the manuf of ceramic products	69	Ceramic products
9	Industrial plants for the prod of pulp, paper and board	47-48 ex 47.07	Pulp of wood, Paper and paperboard (except waste)
10	Aircraft operator activities		
20	Combustion of fuels	27.16	Electrical energy
21	Refining of mineral oil	27.09-27.15	Petroleum oils, gases, jelly, coke, bituminen and asphalt
22	Prod of coke	27.04, 27.08, 27.13	Coke of coal, lignite, petroleum
23	Metal ore roasting or sintering	26 ex. 26.18-26.21	Metal ores and concentrates
24	Prod of pig iron or steel	72 ex. 72.04	Iron and Steel (ex waste)
25	Prod or processing of ferrous metals	73	Articles of iron or steel
26	Prod of primary aluminium	76	Aluminium and articles thereof
27	Prod of secondary aluminium	76	Aluminium and articles thereof
28	Prod or processing of non-ferrous metals	74-75,78-81	Non-ferrous metals and articles thereof
29	Prod of cement clinker	25.23	Cement
30	Prod of lime, or calcination of dolomite/magnesite	25.21-25.22, 25.18-25.19	Lime, dolomite, magnesite
31	Manuf of glass	70.01-70.06	Glass and glassware
32	Manuf of ceramics	69	Ceramic products
33	Manuf of mineral wool	68.06	Slag wool, rock wool and similar mineral wools
34	Prod or processing of gypsum or plasterboard	68.09	Articles of plaster
35	Prod of pulp	47 ex 47.07	Pulp of wood (except waste)
36	Prod of paper or cardboard	48	Paper and paperboard
37	Prod of carbon black	28.03	Carbon blacks and other forms of carbon nes
38	Prod of nitric acid	28.08	Nitric and sulphonitric acids.
39	Prod of adipic acid	29.1712	Adipic acid
40	Prod of glyoxal and glyoxylic acid	29.12, 29.18	Aldehydes, Carboxylic acids
41	Prod of ammonia	28.14	Ammonia, anhydrous or in aqueous solution
42	Prod of bulk chemicals	28-29	Organbic and inorganic chemicals
43	Prod of hydrogen and synthesis gas	28.04	Hydrogen, rare gases and other non-metals
44	Prod of soda ash and sodium bicarbonate	28.3630	Sodium hydrogencarbonate (sodium bicarbonate)
45	Capture of greenhouse gases under Directive 2009/31/EC		
46	Transport of greenhouse gases under Directive 2009/31/EC		
47	Storage of greenhouse gases under Directive 2009/31/EC		
99	Other activity opted-in pursuant to Article 24 of Directive 2003/87/EC		

Notes: This table shows the mapping between the coverage of ETS and HS products. The list of ETS sectors is taken from the EUTL.

CBAM product coverage

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Category	Code	Description
Cement	25.07	Other kaolinic clays
	25.2310	Cement clinkers
	25.2321	White Portland cement, whether or not artificially coloured
	25.2329	Other Portland cement
	25.2330	Aluminous cement
	25.2390	Other hydraulic cements
Electricity	2716	Electrical energy
Fertilisers	28.08	Nitric acid; sulphonitric acids
	28.14	Ammonia
	28.3421	Nitrates of potassium
	31.02	Mineral or chemical fertilisers, nitrogenous
	31.05	Mineral or chemical fertilisers, other
	ex.	Except
	31.0560	Mineral or chemical fertilisers containing phosphorus and potassium
Aluminium	76.01	Unwrought aluminium
	76.03	Aluminium powders and flakes
	76.04	Aluminium bars, rods and profiles
	76.05	Aluminium wire
	76.06	Aluminium plates, sheets and strip, of a thickness exceeding 0,2 mm
	76.07	Aluminium foil not exceeding 0,2 mm
	76.08	Aluminium tubes and pipes
	76.09	Aluminium tube or pipe fittings
	76.10	Aluminium structures and parts of structures; aluminium plates, rods, profiles, tubes and the like
	76.11	Aluminium reservoirs, tanks, vats and similar containers, of a capacity exceeding 300 litres
	76.12	Aluminium casks, drums, cans, boxes and similar containers, of a capacity not exceeding 300 litres
	76.13	Aluminium containers for compressed or liquefied gas
	76.14	Stranded wire, cables, plaited bands and the like, of aluminium
	76.16	Other articles of aluminium
Chemicals	28.0410	Hydrogen

Category	Code	Description
Iron and steel	72	Iron and steel
	ex.	Except
	72.0220	Ferro-silicon
	72.0250	Ferro-silico-chromium
	72.0270	Ferro-molybdenum
	72.0280	Ferro-tungsten and ferro-silico-tungsten
	72.0291	Ferro-titanium and ferro-silico-titanium
	72.0292	Ferro-vanadium
	72.0293	Ferro-niobium
	72.029910	Ferro-phosphorus
	72.029930	Ferro-silico-magnesium
	72.029980	Other
	72.04	Ferrous waste and scrap; remelting scrap ingots and steel
Iron and steel	26.0112	Agglomerated iron ores and concentrates, other than roasted iron pyrites
	73.01	Sheet piling of iron or steel
	73.02	Railway or tramway track construction material of iron or steel
	73.03	Tubes, pipes and hollow profiles, of cast iron
	73.04	Tubes, pipes and hollow profiles, seamless, of iron (other than cast iron) or steel
	73.05	Other tubes and pipes, the external diameter of which exceeds 406,4 mm, of iron or steel
	73.06	Other tubes, pipes and hollow profiles of iron or steel
	73.07	Tube or pipe fittings of iron or steel
	73.08	Structures and parts of structures of iron or steel
	73.09	Reservoirs, tanks, vats and similar containers of iron or steel, of a capacity exceeding 300 l
	73.10	Tanks, casks, drums, cans, boxes and similar containers of iron or steel, of a capacity not exceeding 300 l
	73.11	Containers for compressed or liquefied gas, of iron or steel
	73.18	Screws, bolts, nuts, and similar articles, of iron or steel
	73.26	Other articles of iron or steel

Notes: This table reproduces the list of HS products listed in Regulation (EU) 2023/956 of the European Parliament and of the Council of 10 May 2023 establishing a carbon border adjustment mechanism.

Robustness to fixed effects

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	(1)	(2)	(3)	(4)	(5)	(6)
	Panel (a) Import Share					
Dirty product × Non-ETS						
× ETS Phase 1	0.056**	0.085***	0.159***	0.050	0.083**	0.083***
	(0.025)	(0.024)	(0.024)	(0.037)	(0.035)	(0.024)
× ETS Phase 2	0.109***	0.169***	0.276***	0.066**	0.119***	0.174***
	(0.021)	(0.021)	(0.021)	(0.032)	(0.030)	(0.021)
× ETS Phase 3	0.161***	0.268***	0.359***	0.067**	0.133***	0.277***
	(0.021)	(0.021)	(0.020)	(0.031)	(0.029)	(0.021)
Pseudo R^2	.162	.384	.388	.390	.390	.384
	Panel (b) Import Probability					
Dirty product × Non-ETS						
× ETS Phase 1	0.024*	0.018	0.043***	0.031*	0.030*	0.017
	(0.013)	(0.013)	(0.012)	(0.018)	(0.018)	(0.013)
× ETS Phase 2	0.079***	0.078***	0.097***	0.082***	0.076***	0.091***
	(0.011)	(0.011)	(0.010)	(0.015)	(0.015)	(0.011)
× ETS Phase 3	0.181***	0.183***	0.141***	0.074***	0.072***	0.205***
	(0.011)	(0.011)	(0.010)	(0.015)	(0.015)	(0.011)
Pseudo R^2	.044	.158	.166	.161	.169	.158
Observations	7,553,888					
# Firms	27,240					
Control group	Non-ETS Clean products					
Fixed effects	pc,t	fpc,t	fpc,ct	fpc,st	fpc,ct,st	fpc,ETSt

Robustness to heterogeneous coefficients

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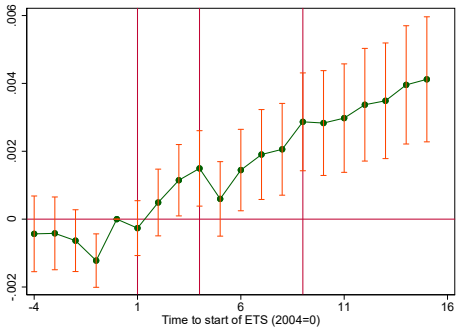
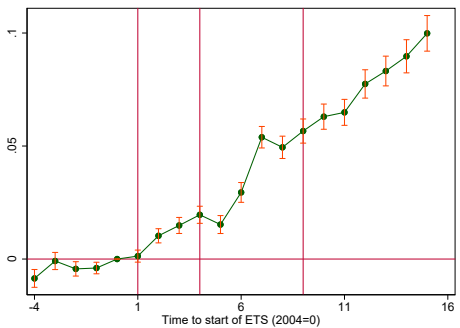
(a) Import share



(b) Import probability



Notes: This figure shows the point estimates recovered from the estimation of a log-linear version of our estimated equation, using the estimator in de Chaisemartin and D'Haultfœuille (2020). The underlying equation controls for product×country and year fixed effects.

Robustness to control group

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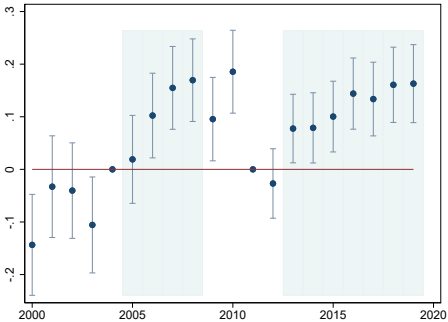
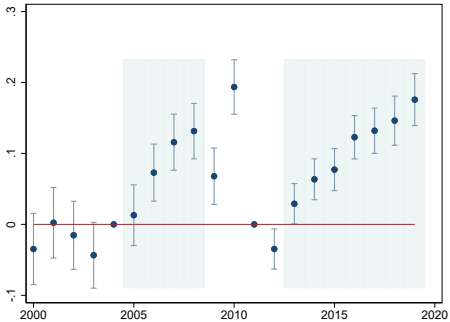
(a) Import share



(b) Import probability



Notes: This figure shows the point estimates recovered from the baseline equation using imports of dirty inputs sourced from ETS countries as control. The equation controls for product×country and year fixed effects, as well as a dummy that is equal to 1 from 2011 for intra-European flows.

ETS regulated versus non-ETS regulated firms

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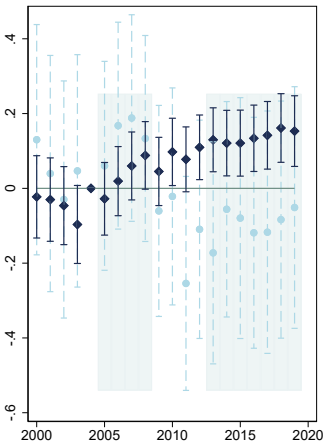
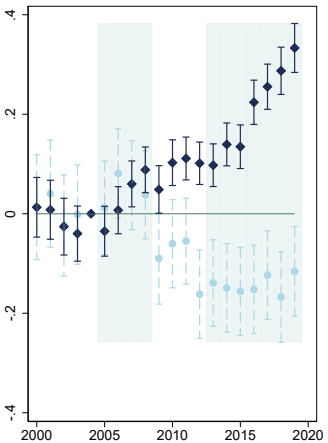
(a) Import share



(b) Import probability



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