Carbon taxation, leakage and investment
EEA-ESEM

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Motivation

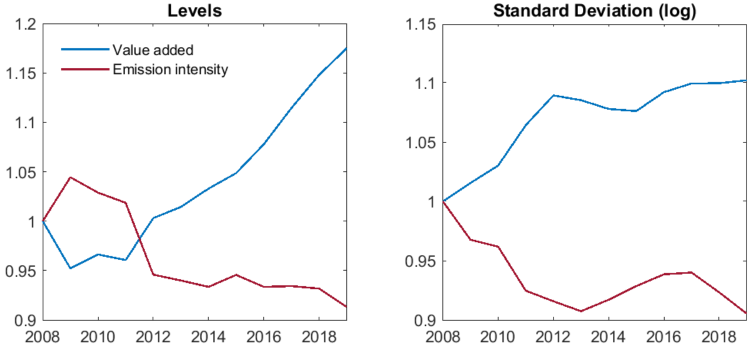


Figure: Aggregate Evolution of firms in EU ETS

Note: The left panel shows how aggregate value added and emission intensity have changed since 2008. The right panel displays the evolution of dispersion, measured by the standard deviation of the logarithm of both value added and emission intensity. Both in terms of a 2-year moving average

This paper

1. Search for structural reductions in Emission intensity in the data
   - EU ETS data from 2005 to 2019
   - Associated with capital growth
   - Large, polluting firms invest more
   - Sensitive to carbon price increases
     - ★ Emission-intense firms invest more when price is high

2. Dynamic model of firm dynamics that incorporates this mechanism and looks at transition from 2008 to 2017 for EU:
   - ETS has decreased total emission output
   - Substantial welfare effects
   - Size dispersion increases, clean technology decreases

3. Other counterfactual exercises:
   - CBAM increases domestic investment

Literature

- Trade and environmental policy (Forslid et al., 2018; Shapiro and Walker, 2018)
  - Findings: (i) firm dynamics model of abatement (ii) more productive firms are cleaner
  1. Abatement costs are sunk cost - variable cost
  2. Heterogeneity in abatement/investment decision
  3. Carbon leakage

- Ex-post empirical literature ETS (De Jonghe et al., 2020; Dechezleprêtre and Sato, 2017; Martin et al., 2016)
  - Findings: (i) government-induced, (ii) emission-intense firms are harder hit, (iii) more (green) innovation, (iv) capital deepening, ...
  1. long-term - short term
  2. What's the mechanism?

- Directed (green) technical change (Acemoglu et al., 2016; Hassler et al., 2021)
  1. Investment - Innovation
  2. Firm perspective

Overview

Emission trading system (ETS)

The European Union Emission trading system

The EU ETS is a cap-and-trade system in the European Union that caps industry emissions. It allocates emission certificates to firms which these may use to omit emissions or trade on a secondary market.

- Variable price of carbon ζ
  - more stringent if aggregate demand are high
  - Encourages firms to reduce emissions
- Fixed free allocation of certificates κ
  - $\leq$ 2012 Based on initial conditions
  - $>$ 2012 Based on bench-marking
  - To avoid 'carbon leakage'

Firms perspective

Price-taking firms with clean technology s have present value:

$$\nu(s;\zeta,\kappa) = \pi(s;\zeta,\kappa) + \beta E_{\zeta,\kappa}[\nu'(s;\zeta,\kappa)] \tag{1}$$

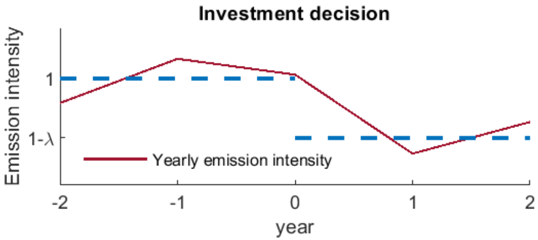
where $dv(s)/ds > 0$ and $d^2v(s)/d^2s < 0$

They can react in two ways:

1. Transfer of a previously polluting installation. Either by closing off, or relocation abroad, falling under *carbon leakage*. This would reduce both value added, but emission output even more.
   - **Relocate** ξ if $\nu^f(s) - \nu(s) > k_\xi$
2. Invest in greener technologies, such as wind turbines, a greener vehicle fleet, or purchasing a greener installation. This would reduce emissions relative to the value produced.
   - **Invest** ω if $\nu(s+\chi) - \nu(s) > k_\omega$

Structural reduction in Emissions

- Data: MF firms ORBIS + EU Transaction Log (EUTL)
- Start from idea that investments/divestments are lumpy and dynamic in nature
- Emission intensity $\tilde{s}_{i,t} = E_{i,t}/V_{i,t}$
  - Lumpiness: $\Delta\tilde{s}_{i,t} > 20\%$ at year t
  - Dynamic: $\Delta\bar{s}_i > 20\%$ for 3 years



- Benefit: (i) No assumption on type of reduction (ii) whether or not reduction pays off, (iii) in line with structural model, and (iv) lmited data requirements

Evolution Structural reductions

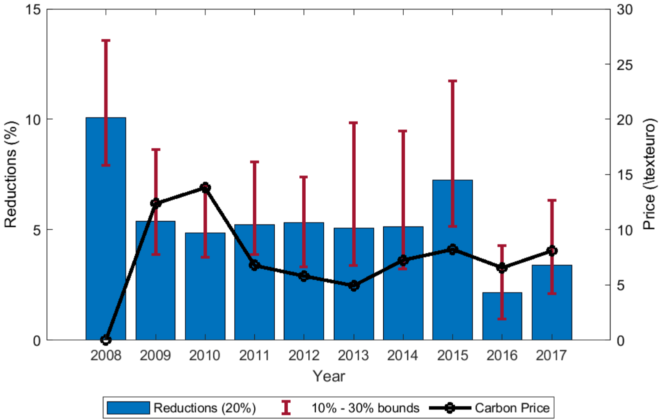


Figure: Yearly rate of structural reductions

Empirical Results

- Indicator of capital investment: ✓
  - Event study approach
  - Associated with increase capital growth
  - Not with growth employment or material cost (i.e. other input)
  - No return to the mean post
  - Robust to alternative functional forms + TWFE + oil price

- Mechanism present in the data: ✓
  1. Ex-ante large, more polluting firms invest more
     - No statistical significance freely allocated certificates matter
  2. Investment elastic to carbon price for highly polluting firms
  3. Minor evidence that multinational subsidiaries that exit more likely to receive more emission certificates

  - Robust to alternative functional forms + sub-samples + oil price + non-market policies + ...

Evolution over time

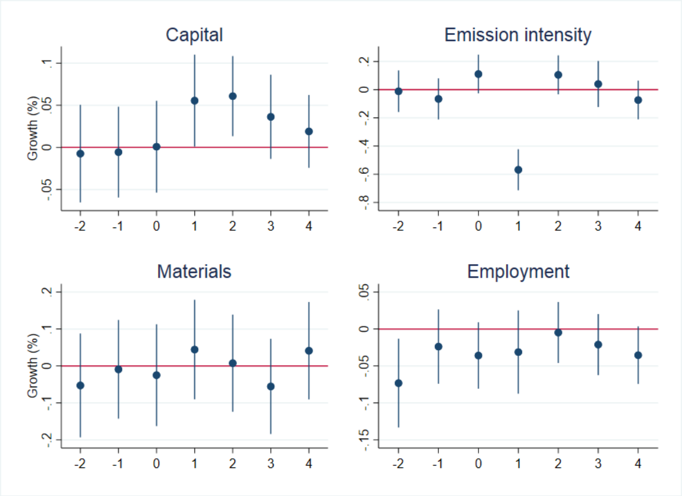


Figure: Implication Emission Reduction

Structural Model

Overview of the Model:

- Heterogeneous firms endowed with productivity z_i and clean technology s_i

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  - Monopolistic competition: $p_i = \mu * W c_i / z_i$
  - Emission output: $e_i = q_i / s_i$

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- Active in 2 countries; Home country sets policies ζ_t and κ_t
  - Variable trade cost τ
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  - Balanced budget home country: $\int \zeta = \int \kappa$
- Every time t, (home) Firms have 2 discrete choices
  - Invest and receive updated clean technology ($s' = s\lambda$ with $\lambda > 0$)
  - Relocate abroad to evade taxation completely

Clean transition

Focus on transition from 2007 - 2017

- Carbon price ζ_t set exogenously
- Continuous technological progress: $z_{i,t} = \gamma z_{i,t-1}$
- Discrete decisions - Investment ω_t, Relocation ξ_t - are time-dependent
  - **Deviation BGP**

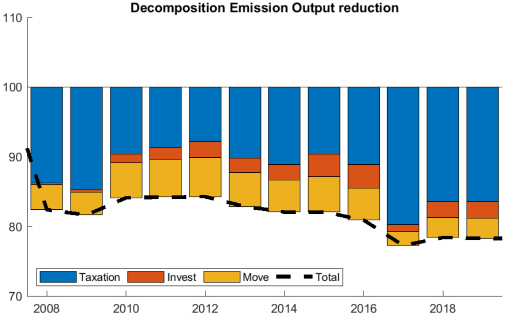
Calibrated to EU ETS

- In phase I of EU ETS (2005 - 2007), the market was incomplete, yielding a carbon price $\zeta \approx 0$ resulting in $c_i \equiv (1 + \zeta/s_i) \approx 1$
  - $VA(z, s) = VA(z)$
  - Use this condition to obtain joint distribution of (z, s)
- Matching occurrences of discrete decisions during transition to match costs: k_ω and k_ξ

Disclaimer: Calibration not finished yet!

Results - Aggregates

$$\Delta E_t^h = \underbrace{\Delta E_t^h|_{P^*,\omega,\xi=0}}_{\text{direct margin}} + \underbrace{\Delta E_t^h|_{P^*,\omega=0}}_{\text{Relocation}} + \underbrace{\Delta E_t^h|_{P^*,\xi=0}}_{\text{Investment}} \quad (2)$$



$$\partial E^h/\partial \zeta < 0 \quad \& \quad \partial E^h/\partial \xi < 0 \quad \& \quad \partial E^h/\partial \omega < 0$$

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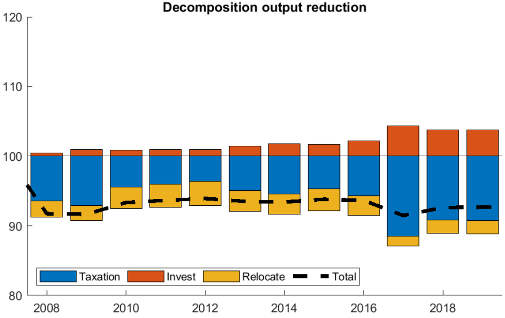
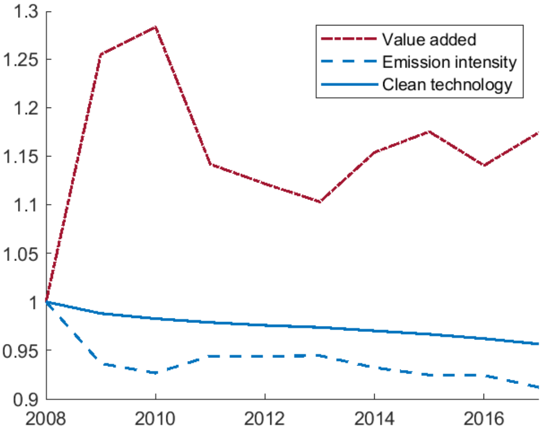


$$\partial Q^h/\partial \zeta < 0 \quad \& \quad \partial Q^h/\partial \xi < 0 \quad \& \quad \partial Q^h/\partial \omega > 0$$

Results - Firm Inequality



Results - Implications Trade

Table: Relative change due to trade policies

	Baseline	*CBAM*		*Trade cost* $(2 * \tau)$	
		Levels	(%)	Levels	(%)
Investment share (dom)	5.42	6.17	(113)	3.53	(65)
Investment share (for)	0	1.87		0	(0)
Domestic output	94.4	98.3	(104)	96.9	(102)
Domestic emissions	66.0	73.4	(111)	86.6	(131)
Domestic firms	99.3	100	(101)	99.5	(100)
Import ratio	24.2	21.3	(88)	4.5	(19)
Δ Import ratio	112.0	98.9	(88)	106.2	(94)

Situation in 2018 relative to 2008 for different models. Model (1), CBAM, includes a *Carbon Border Adjustment Mechanism* - a pollution taxation for foreign firms akin to domestic firms. Model (2), Trade cost, looks at the effect of the effect of interconnectedness on investment decisions. The percentages are relative to baseline model

Conclusion

- EU ETS program works
  - If prices increase, firms invest more
  - Increases green investment
  - Reduces aggregate domestic emissions
- Unequal evolution of carbon emission reduction
  - Large, polluting firms capitalize best $\rightarrow$ Increase inequality
- Substantial aggregate effects
  - Mainly driven by direct effect taxation
  - Trade important channel in reduction
    - Higher impact trade cost
    - CBAM reduces carbon leakage $\rightarrow$ increases investment

D. Acemoglu, U. Akcigit, D. Hanley, and W. Kerr. Transition to Clean Technology. *Journal of Political Economy*, 124(1):52–104, Feb. 2016. ISSN 0022-3808. doi: 10.1086/684511. URL https://www.journals.uchicago.edu/doi/full/10.1086/684511. Publisher: The University of Chicago Press.

O. De Jonghe, K. Mulier, and G. Schepens. Going Green by Putting a Price on Pollution: Firm-level Evidence from the EU. *SSRN Electronic Journal*, Working Paper N° 390, 2020. ISSN 1556-5068. doi: 10.2139/ssrn.3725061. URL https://www.ssrn.com/abstract=3725061.

A. Dechezleprêtre and M. Sato. The Impacts of Environmental Regulations on Competitiveness. *Review of Environmental Economics and Policy*, 11 (2):183–206, July 2017. ISSN 1750-6816. doi: 10.1093/reep/rex013. URL https://www.journals.uchicago.edu/doi/10.1093/reep/rex013. Publisher: The University of Chicago Press.

R. Forslid, T. Okubo, and K. H. Ulltveit-Moe. Why are firms that export cleaner? International trade, abatement and environmental emissions. *Journal of Environmental Economics and Management*, 91:166–183, Sept. 2018. ISSN 0095-0696. doi: 10.1016/j.jeem.2018.07.006. URL https://www.sciencedirect.com/science/article/pii/S0095069617303340.

J. Hassler, P. Krusell, and C. Olovsson. Directed Technical Change as a Response to Natural Resource Scarcity. *Journal of Political Economy*, 129(11):3039–3072, Nov. 2021. ISSN 0022-3808. doi: 10.1086/715849. URL https://www.journals.uchicago.edu/doi/full/10.1086/715849. Publisher: The University of Chicago Press.

R. Martin, M. Muûls, and U. J. Wagner. The Impact of the European Union Emissions Trading Scheme on Regulated Firms: What Is the Evidence after Ten Years? *Review of Environmental Economics and Policy*, 10(1):129–148, Jan. 2016. ISSN 1750-6816. doi: 10.1093/reep/rev016. URL https://www.journals.uchicago.edu/doi/10.1093/reep/rev016. Publisher: The University of Chicago Press.

J. S. Shapiro and R. Walker. Why Is Pollution from US Manufacturing Declining? The Roles of Environmental Regulation, Productivity, and Trade. *American Economic Review*, 108(12):3814–3854, Dec. 2018.

ISSN 0002-8282. doi: 10.1257/aer.20151272. URL
https://pubs.aeaweb.org/doi/10.1257/aer.20151272.

Ex-ante characteristics

Cross-sectional regression:

$$I^t = \beta lnV_{i,0} + \eta ln\tilde{s}_{i,0} + X'\alpha + \delta_{s,c} + \epsilon_{i,0} \quad (4)$$

$I^t \in \{0,1\}$ indicates if firm invest in $t \in \{2008-2012, 2013-2017\}$. $V_{i,0}$ and $\tilde{s}_{i,0}$ initial levels of value added and emission intensity.

	(1) $I^{<2012}$	(2) $I^{>2012}$
ln_Emission_intensity	0.049***	0.046***
	(0.009)	(0.010)
ln_va	0.038***	0.054***
	(0.010)	(0.011)
ln_allocated	-0.014	0.002
	(0.013)	(0.015)
Adjusted R-squared	0.065	0.098
Observations	1950	2037
Country-Sector F.E	✓	✓
Clustered S.E.	C-S	C-S

Table: Firm characteristics

Investment price

Regression framework:

$$\omega_{i,t} = \beta \ln(\tilde{s}_{i,t}) + \phi \ln(\tilde{s}_{i,t}) \ln(\zeta_t) + \iota_{c,t} + \tau_{s,t} + \delta_i + \epsilon_{i,t} \quad (5)$$

$\omega_{i,t} \in \{0, 1\}$ indicates whether firm i invested in year t. ζ_t and $\tilde{s}_{i,t}$ denote carbon price and emission intensity at time t.

	$\omega_{i,t}$	$\omega_{i,t}$	$\omega_{i,t}$
ln_price	0.002***	0.002*	0.002***
	(0.001)	(0.001)	(0.001)
ln_oil_price			-0.003
			(0.622)
Non_market_EPS		0.000	
		(0.962)	
Adjusted R-squared	0.109	0.110	0.109
Observations	22,230	22,230	22,230
Country-Year F.E	✓	✓	✓
Sector-Year F.E	✓	✓	✓
Firm F.E	✓	✓	✓
Clustered S.E.	Firm	Firm	Firm

Results: Price elasticity of investment $\epsilon_{\omega,\zeta} \equiv \partial\omega_{i,t}/\partial ln(\zeta_t) = 0.002 \ln(\tilde{s}_{i,t})$