Is broader trading welfare improving for tradable performance standards?

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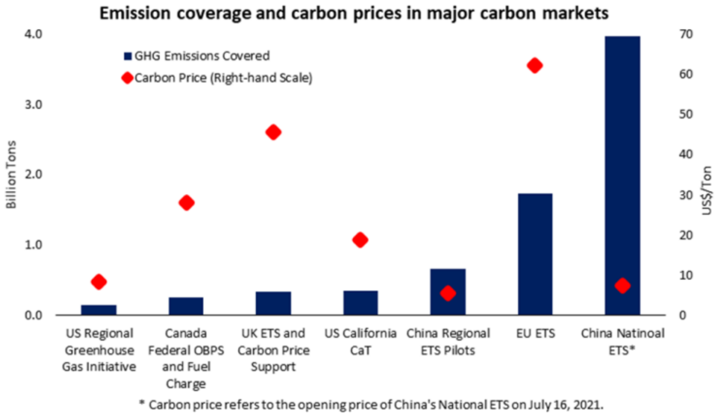
China's carbon mechanism matters



(source: Raiser et al., World Bank (2021))

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$\Rightarrow$ The total number of allowances, and therefore total emissions, are *endogenous to firms' production decisions.*

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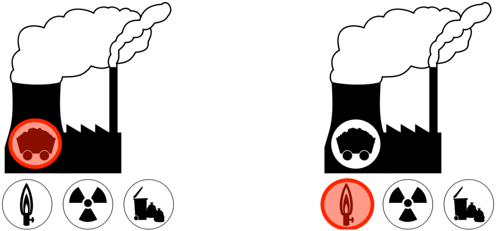

$$\hat{\beta}_{coal} > \hat{\beta}_{gas}$$

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- For a given set of intensity benchmarks and an economy composed of several sectors *all covered by carbon pricing* we ask:
  1. a theoretical question: under which circumstances does broader allowance trading increase welfare?
  2. an empirical question: can broader trading in the context of the Chinese TPS decrease welfare under credible policy parameters?

Preview of main results

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- For credible policy parameters, broader trading is found likely to *increase* total emissions.
- We find that broader trading increases welfare if, and only if, the SCC below $\sim$\$91/ton CO_2.

Chinese carbon mechanism

- Progress so far:
  - **2009 and 2015:** China announced carbon emission targets during the United Nations Climate Change Conferences of the Parties.
  - **2010s:** several pilot programs for carbon trading mechanisms were implemented at the provincial and municipal levels (using both C&T and TPS designs).
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  - **Phase 1 (2021-23):** covers only the electricity sector, where different intensity benchmarks are applied to distinct sub-sectors (e.g. coal-fired, gas-fired, etc.)
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⇒ Many policy decisions remain to be made, including intensity benchmarks and sectoral coverage.

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- In particular, when demand is inelastic, the output subsidy simply represents a transfer since aggregate production does not increase: a TPS may then be able to implement the first-best outcome.

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- In particular, when demand is inelastic, the output subsidy simply represents a transfer since aggregate production does not increase: a TPS may then be able to implement the first-best outcome.
- Yet, implementing firm-specific benchmarks creates inefficiencies even in this setting.

Why can broader trading increase emissions?

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- There are only two (non-strategic) firms in each sector:
  1. One "clean" firm that:
     - does not emit carbon dioxide.
     - is assigned an intensity benchmark $\hat{\beta}_1$.
  2. One "dirty" firm that:
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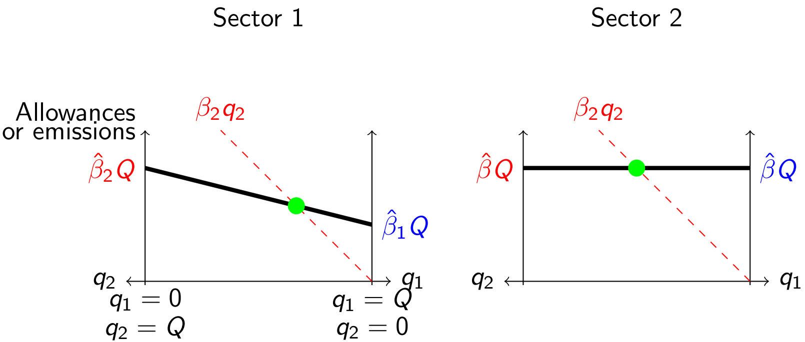
- We therefore have, for each sector:
  - **Emissions** $= \beta_2 q_2$
  - **Total allowances** $= \hat{\beta}_1 q_1 + \hat{\beta}_2 q_2$

Intra-sectoral allowance trading



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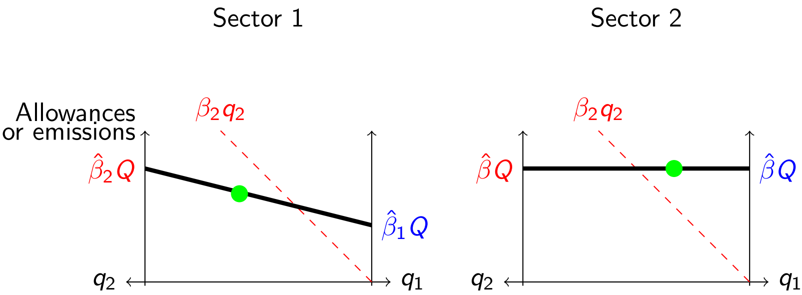
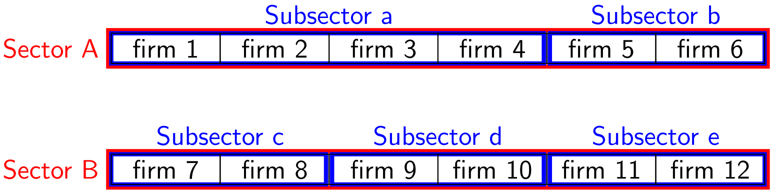


$\Rightarrow$ Total emissions increase!

Structure of the economy

- Sector (indexed by i) $\equiv$ set of firms that compete to sell a homogeneous commodity.
- Sub-sector (indexed by $s \in i$) $\equiv$ subset of firms in sector i.
- Firms (indexed by $j \in s$) $\equiv$ we denote with n_s the number of firms belonging to sub-sector s and $N_i \equiv \sum_{s \in i} n_s$.



Sectors, subsectors and firms.

Supply-side

- Firms' carbon intensities are heterogeneous so that the emissions of firm j are:

$$e_j(q, a) \equiv (\beta_j - a)q$$

where β_j is its initial carbon intensity, a are abatement efforts and q is output.

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- Private supply cost functions are assumed identical for all firms within a sector:

$$c_i(q,a) \equiv \frac{1}{2}\left[N_i q^2 + \frac{q}{\mu_i} a^2\right] \tag{1}$$

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- Firms are assumed to behave as price-takers.

Demand-side and welfare metric

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- so that:

$$\Delta SW = -\Delta PC - \Delta EC = -\Delta SC \tag{2}$$

$\Rightarrow$ In the analytical model, we use (minus) changes in social costs to measure changes in social welfare.

TPS and scenarios of interest

- Under the Chinese TPS:
  - allowances are allocated based on a sub-sector-specific intensity benchmark $\hat{\beta}_s$.
  - firm j producing a quantity q and investing in a level a of abatement (per unit of output) gets a net allowance:
  $$(\hat{\beta} - (\beta_j - a))q = (\hat{\beta} - \beta_j + a)q$$
  - in equilibrium, each firm holds a net quantity of allowances equal to zero.

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  - in equilibrium, each firm holds a net quantity of allowances equal to zero.
- For an exogenously-given vector of intensity benchmarks $\hat{\beta}_s$, we compare two scenarios:
  - **Intra-sectoral (i.e. "narrow") allowance trading:** firms can only trade allowances with firms belonging to their sector.
  - **Inter-sectoral (i.e. "broad") allowance trading:** firms can trade allowances with any TPS-covered firm in the economy.

Production costs

Proposition (Broader trading decreases total private costs)

We have:

$$PC_{inter} \leq PC_{intra}$$

In words, enabling broader trading (weakly) decreases total private production (or equivalently compliance) costs.

Formula

Emissions

Proposition (Ambiguous impact of broader trading on emissions)

Moving from intra-sectoral trading to inter-sectoral trading has an ambiguous impact on emissions. Under a simplifying assumption, economy-wide emissions decrease ($\Delta E < 0$) if, and only if:

$$\mathrm{Cov}_i\left(\langle\bar{\beta} - \hat{\beta}\rangle Q, \sigma^2 + \mu Q - \tilde{\sigma}_{\bar{\beta}\hat{\beta}}\right) < 0$$

where $\sigma_i^2 \equiv \frac{1}{N_i}\sum_{s\in i}\sum_{j\in s}(\beta_j - \bar{\beta}_i)^2$ and $\tilde{\sigma}_{\bar{\beta}\hat{\beta},i} \equiv \langle\bar{\beta}\hat{\beta}\rangle_i - \langle\bar{\beta}\rangle_i\langle\hat{\beta}\rangle_i$

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$\Rightarrow$ Broader trading decreases economy-wide emissions iff the sectors with greater required emission reduction are also the sectors that are more difficult to reduce emissions.

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Welfare

The change in social cost following a policy intervention is:

$$\Delta SC = \Delta PC + (\Delta E)t^* \tag{3}$$

where t^* is the social cost of carbon.

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Proposition (Broader trading and welfare)

Moving from intra-sectoral to inter-sectoral allowance trading:

- *is welfare-improving if emissions decrease.*
- *has an ambiguous impact on welfare if emissions increase. More specifically, there exists a threshold value $\hat{t}$ such that welfare increases if, and only if:*

$$t^* < \hat{t}$$

Discussion of subsector benchmarks

Numerical model

- Based on the model by Goulder et al. (2022).
- Multi-sector general equilibrium
- Multi-period (2020-2035)
- Heterogeneity within sectors
- Institutional features
    - Existing taxes and subsidies
    - Electricity market regulations
    - Supporting policies for renewable electricity
    - State-owned enterprises

Main result

Table: Private costs and emission reductions under inter-sectoral and intra-sectoral trading

	Private cost (billion 2020$)		Emission reduction (million ton)	
year	Inter-sectoral	Intra-sectoral	Inter-sectoral	Intra-sectoral
2020	0.70	0.70	120	120
2021	0.82	0.82	137	137
2022	0.92	0.92	152	152
2023	1.46	2.03	278	304
2024	2.88	3.78	438	468
2025	4.79	6.21	608	640
2026	6.62	9.59	814	858
2027	9.73	13.95	1038	1085
2028	13.50	19.38	1272	1318
2029	17.95	26.04	1516	1561
2030	23.03	34.01	1767	1809
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- Allowing demand to be elastic is found to reinforce our results. Intuitively, "output subsidies" then also induce distortions at the "extensive margin" of total sectoral demand.
- Implementing uniform benchmarks makes broader trading more likely to be welfare improving.
- Extensions of the analytical framework: imperfect competition, within-sector heterogeneity in abatement costs, benchmark setting and political acceptability.

Recap

Analytical results: broader trading...

- ...decreases total private production costs.
- ...has an ambiguous impact on total emissions.

Empirical results:

- For credible policy parameters, broader trading is found to *increase* total emissions.
- We assess the threshold SCC to be about \$91/ton, meaning this concern can be relevant for realistic SCCs.

Thank you!

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Production costs

Define $\hat{\beta}_s \equiv (1-\alpha_s)\bar{\beta}_s$ and $\Omega_i^2 \equiv \langle(\alpha\bar{\beta})^2\rangle_i - \langle\alpha\bar{\beta}\rangle_i^2$.

Proposition (Broader trading decreases total private costs)

Total private supply costs under respectively intra-sectoral and inter-sectoral trading are equal to:

$$\begin{cases} PC_{intra} = \frac{1}{2}\sum_i Q_i^2 + \frac{1}{2}\sum_i \frac{\left(\langle\alpha\bar{\beta}\rangle_i Q_i\right)^2}{\langle\sigma^2\rangle_i + \mu_i Q_i + \Omega_i^2} \\ PC_{inter} = \frac{1}{2}\sum_i Q_i^2 + \frac{1}{2}\frac{\left(\sum_i\langle\alpha\bar{\beta}\rangle_i Q_i\right)^2}{\sum_i\left(\langle\sigma^2\rangle_i + \mu_i Q_i + \Omega_i^2\right)} \end{cases}$$

We therefore have:

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In words, enabling broader trading (weakly) decreases total private production costs.

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Emissions

Proposition (Ambiguous impact of broader trading on emissions)

Total emissions are equal to:

$$\begin{cases} E_{intra} = \sum_i \bar{\beta}_i Q_i - \sum_i \left[\left(\sigma_i^2 + \mu_i Q_i - \tilde{\sigma}_{\bar{\beta}\hat{\beta},i} \right) \frac{\langle \alpha \bar{\beta} \rangle_i Q_i}{\langle \sigma^2 \rangle_i + \mu_i Q_i + \Omega_i^2} \right] \\ E_{inter} = \sum_i \bar{\beta}_i Q_i - \left(\sum_i \left(\sigma_i^2 + \mu_i Q_i - \tilde{\sigma}_{\bar{\beta}\hat{\beta},i} \right) \right) \left(\frac{\sum_i \langle \alpha \bar{\beta} \rangle_i Q_i}{\sum_i \left(\langle \sigma^2 \rangle_i + \mu_i Q_i + \Omega_i^2 \right)} \right) \end{cases}$$

Under the simplifying assumption that:

$$\forall i,\ i',\ \langle \sigma^2 \rangle_i + \mu_i Q_i + \Omega_i^2 = \langle \sigma^2 \rangle_{i'} + \mu_{i'} Q_{i'} + \Omega_{i'}^2$$

then, moving from intra-sectoral trading to inter-sectoral decreases emissions if, and only if:

$$\mathrm{Cov}_i \left(\langle \alpha \bar{\beta} \rangle Q, \sigma^2 + \mu Q - \tilde{\sigma}_{\bar{\beta}\hat{\beta}} \right) < 0$$

Back

Importance of heterogeneous sub-sector benchmarks

- Under our assumption of inelastic sectoral demand, total emissions are identical under both scenarios when benchmarks are uniform within each sector.

- In summary:

Case	Production costs	Emissions	Social Welfare
Heterogeneous within-sector benchmarks	$PC_{inter} \leq PC_{intra}$	$E_{inter} \lesseqgtr E_{intra}$	$E_{inter} > E_{intra}$ is likely for political acceptability reasons $\Rightarrow$ Welfare ranking depends on the social cost of carbon
Uniform within-sector benchmarks	$PC_{inter} \leq PC_{intra}$	$E_{inter} = E_{intra}$	Intersectoral trading is unambiguously welfare improving

- In particular, optimally-chosen uniform benchmarks implements the first-best allocation under both intra- and inter-sectoral trading.

  $\Rightarrow$ Critical importance of political economy consideration.

Back

Decarbonisation of EU-ETS firms: myth or reality?

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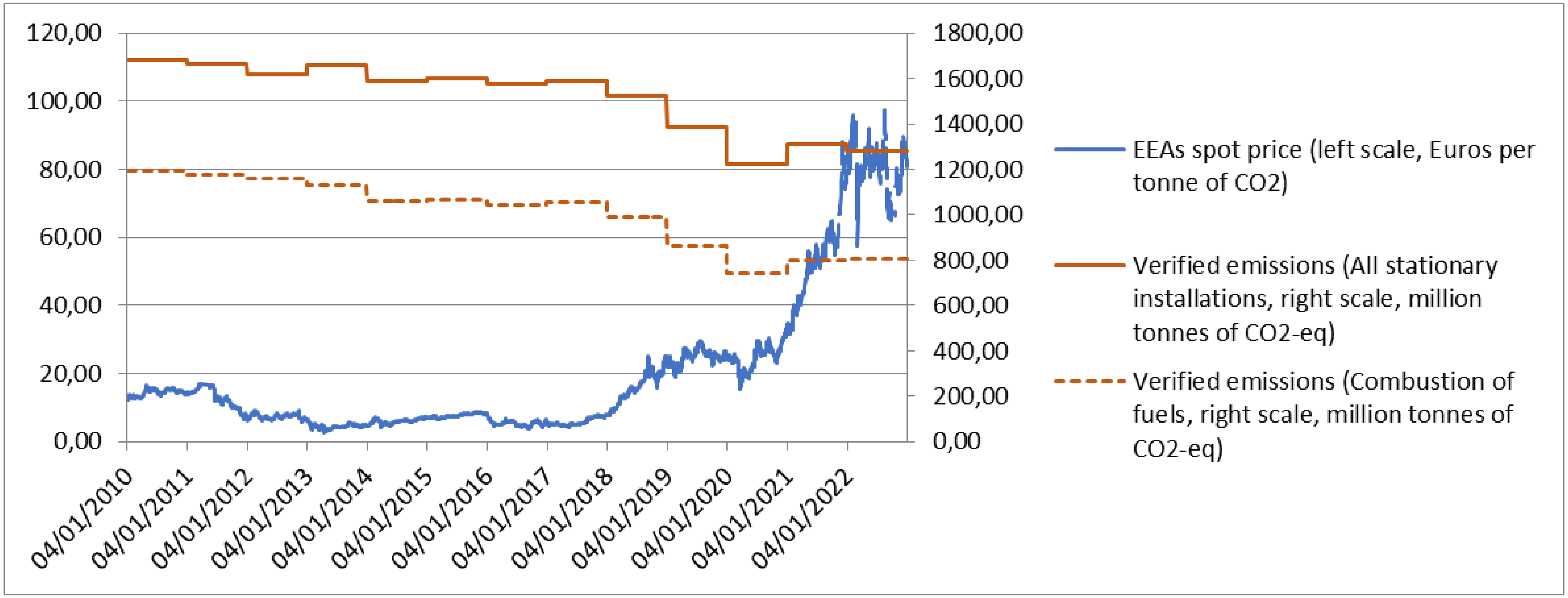
Paper's Motivation

Paper's motivation

- As regards the EU-ETS, The fit for 55 EU program launched in July 2021 has one of the following specific objectives
  - *"Ensuring continued effective protection for the sectors exposed to a significant risk of carbon leakage while **incentivising the uptake of low-carbon technologies**."*
    - After 18 years of existence, it is still considered that the EU-ETS should be more incentivising for low-carbon investments!
    - **What kind of policy reform should be enforced?**
  - Echoes the recent controversy that emerged as regards the **"quality" of emissions reductions induced by carbon pricing**
    - Lilliestam, J., Patt, A. & Bersalli, G. (2021). "The effect of carbon pricing on technological change for full energy decarbonization: A review of empirical ex post evidence". *Wiley Interdisciplinary Reviews: Climate Change*, 12(1).
    - van den Bergh, J. & Savin, I. (2021). "Impact of carbon pricing on low-carbon innovation and deep decarbonisation: controversies and path forward". *Environmental and Resource Economics*, 80(4), 705–715

Paper's motivation

- By essence, an ETS caps emissions
- But does it mean that regulated firms use more climate friendly technologies?



Paper's motivation

- Can be better understood by pointing two difficulties
  - How to define and assess the **counterfactual emissions** (what emissions should have been observed in absence of the regulation?)
    - Addressed as soon as during the first pilot phase with econometric methods based on aggregate data
      - Ellerman, D. A. & Buchner, B. K. (2008). "Over-allocation or abatement? A preliminary analysis of the EU ETS based on the 2005-06 emissions data". *Environmental and Resource Economics*, 41, 267–287
      - Anderson, B. & Maria, C. D. (2011). "Abatement and Allocation in the Pilot Phase of the EU ETS". *Environmental and Resource Economics*, 48, 83–103
    - And more recently with micro data and diff-in-diff methods
      - Dechezlepretre, A., Nachtigall, D. & Venmans, F. (2023). "The joint impact of the European Union emissions trading system on carbon emissions and economic performance". Journal of Environmental Economics and Management, 118, 102758
  - **How to distinguish between 1) short term and reversible reductions 2) long term irreversible emissions**

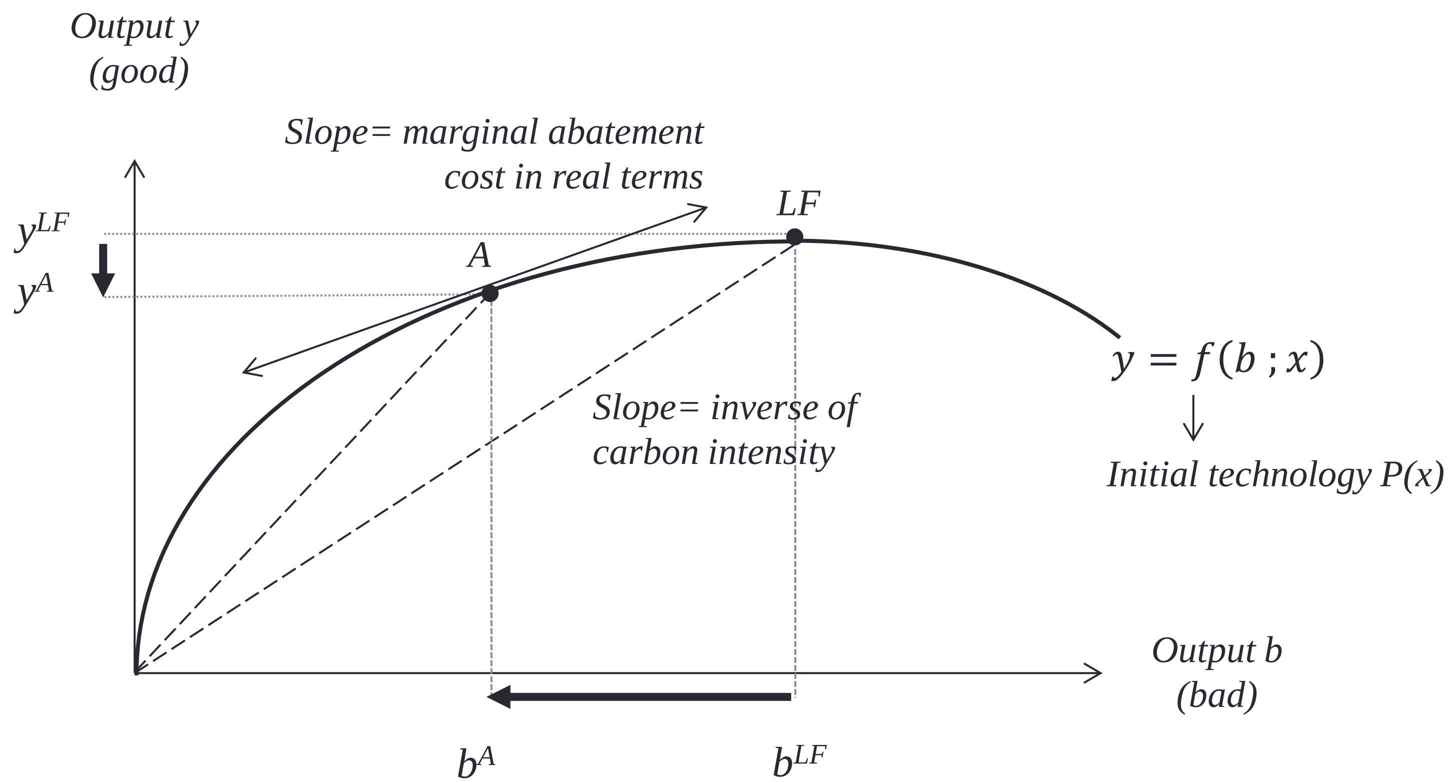
Paper's motivation

- Therefore, this paper proposes a methodology based on frontier analysis (Shepard, 1970)
  - More specifically **multioutput directional distance function with one desirable output and one undesirable output (GhG emissions)**
    - Chung, Y. H., Färe, R. & Grosskopf, S. (1997). "Productivity and undesirable outputs: a directional distance function approach". *Journal of Environmental Management*, 51(3), pp. 229–240.
  - Key advantages:
    - no *a priori* assumptions on the behaviour of firms (market power for instance…)
    - no *a priori* assumptions on the type/direction of technical change
  - => Characteristics of the technology under "laissez faire" can be retrieved from observations made under a regulation regime

Conceptual framework

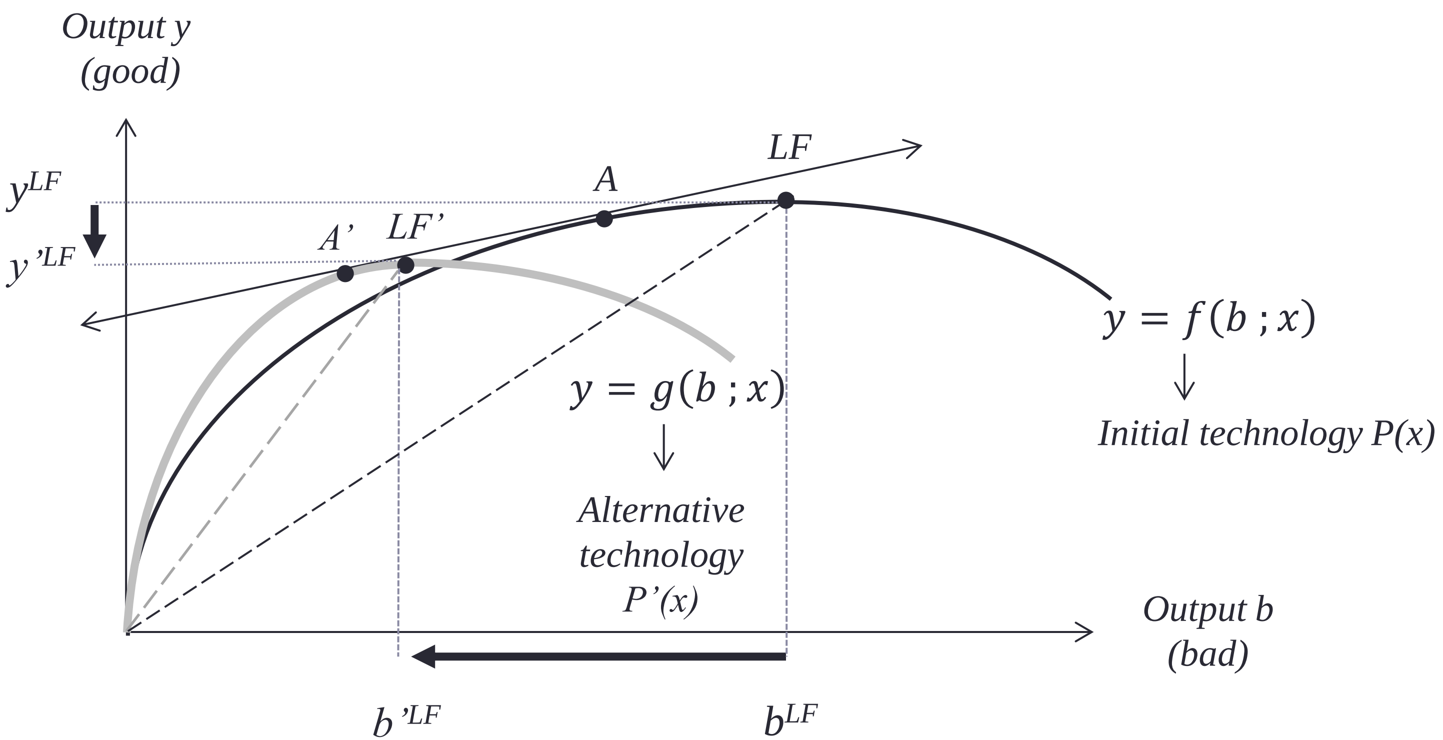
Conceptual framework

- Short term abatements result from a slide along the frontier induced, for instance, by carbon pricing.
  - Helps identifying the situation that would prevail under "laissez faire", the corresponding baseline emissions b^{LF} and carbon intensity ci^{LF}, and comparing it with the observed situation



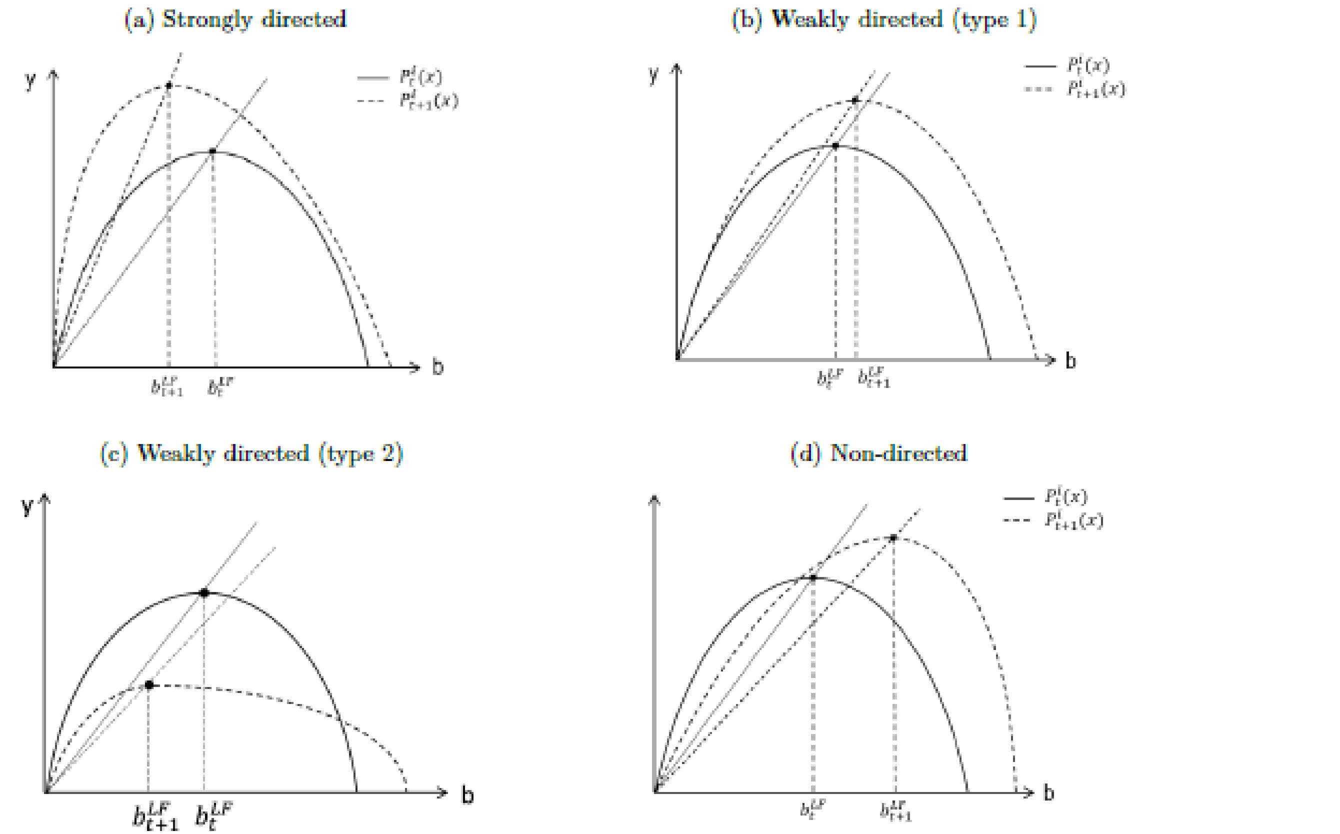
Conceptual framework

- Long term abatements result from a switch from the initial technology to the new one
  - The switch more specifically occurs when the explicit or implicit price of emissions excess the slope of *(A ,A')*
  - In this illustrative example, it results on a reduction of both baseline emissions an carbon intensity under "laissez faire"



Conceptual framework

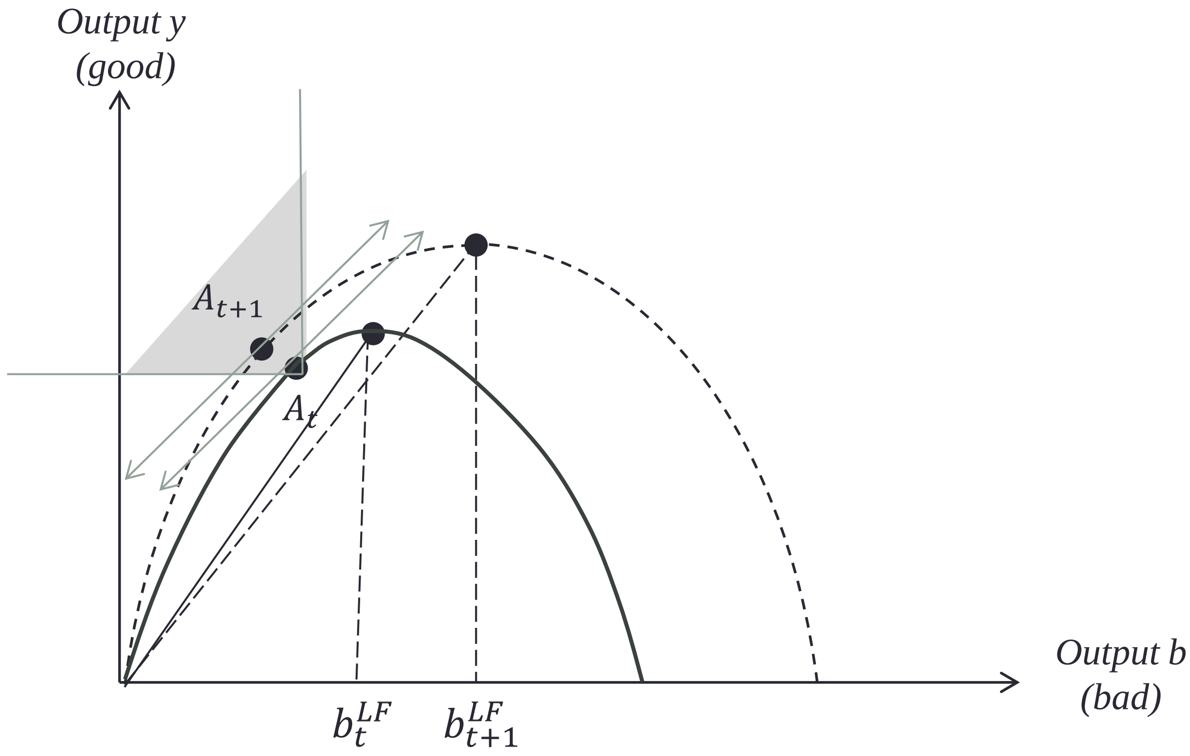
- Based on the dynamics of baseline emissions and carbon intensity under "laissez faire", a typology of four types of TC emerges



Note: $P_t^i(x)$ and $P_{t+1}^i(x)$ denote the technological frontier of plant i at t (solid curve) and $t+1$ (dashed curve), respectively. b_t^{LF} and b_{t+1}^{LF} denote *laisserfaire* baseline emissions at t and $t+1$.

Conceptual framework

- Looking at the dynamics of observed emissions and observed carbon intensity (Kaya's identity) may be misleading
  - They can decrease whereas technical change is non directed (i.e. baseline emissions and carbon intensity under "laissez faire" increase)



Empirical approach

Empirical approach

- The empirical approach relies on a quadratic distance function between observations and the frontier, the parameters of which are determined so as to minimise the total distance subject to the following constraints
  - Observations are located on or under the technological frontier
  - The distance to the frontier decreases (resp. increases) with respect to a marginal increase in the desirable (resp. undesirable) output
  - The distance to the frontier increases with respect to a marginal increase in input use
  - A positive amount of inputs is required to obtain a positive amount of outputs
- The technological frontier is then obtained as the set of inputs and outputs such that the distance to the frontier is zero
- Each date is treated independently
  - As illustrated in slide 9, it may be optimal to switch to a new production possibility set that does not encompass those of the previous dates

Empirical approach

- Two data sets have been matched at the firm level
  - The European Union Transaction Log
    - Records stationary installations covered by the EU-ETS and their verified emissions
    - We more specifically used the EUTL data processed as a relational database by Jan Abrell
      - https://www.euets.info
  - Bureau van Dijk - ORBIS
    - To retrieve data on sales, cost of employees, cost of energy and materials, tangible assets
  - The period studied ranges from 2012 to 2021 (Full Phase III of the EU-ETS)
    - Only firms with all information available for the whole period have been kept => the sample used is time invariant
    - Only sectors with sufficiently numerous firms to implement the parametric data envelopment analysis have been kept

Empirical approach

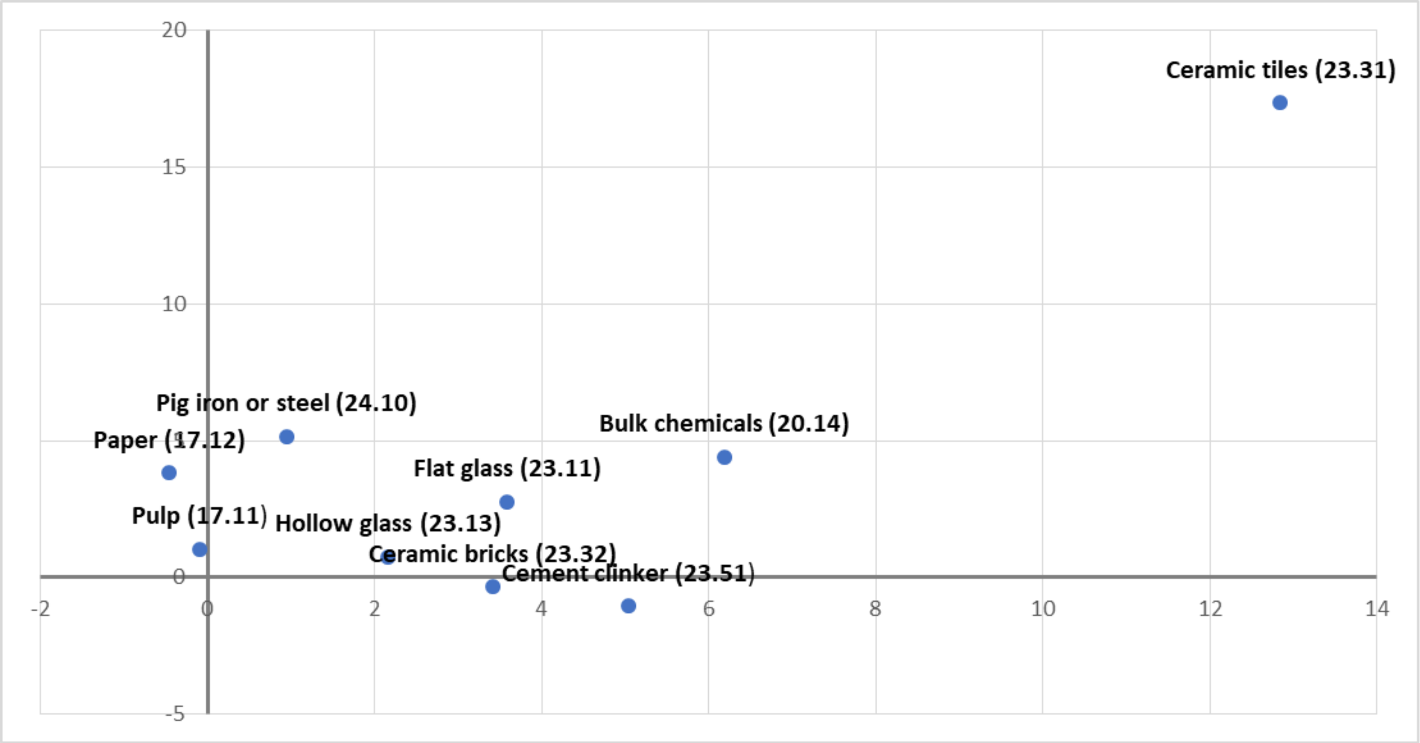
Industry (Nace 2)	#Obs	CO_2 int. in 2012	CO_2 int. in 2021	Emissions (10^3 t)	Production (10^6)	Capital (10^6)	Energy (10^6)	Labor (10^6)
Pig Iron or steel (24.10)	44	0.218 (0.121)	0.240 (0.242)	88 (85)	447 (407)	132 (146)	279 (271)	49 (51)
Cement clinker (23.51)	23	7.961 (2.240)	8.282 (2.030)	1529 (1098)	197 (162)	164 (173)	59.5 (44.2)	33.1 (31.2)
Flat glass (23.11)	11	1.193 (0.368)	1.344 (0.456)	127 (63)	117 (66)	68.6 (55.1)	60.2 (46.1)	16.3 (9.86)
Hollow glass (23.13)	30	0.736 (0.355)	0.799 (0.280)	110 (149)	134 (156)	58.15 (59.11)	41.63 (43.46)	27.27 (33.14)
Ceramic tiles (23.31)	9	0.507 (0.373)	0.836 (0.559)	61.60 (40.68)	194 (275)	138 (280)	100 (157)	22.76 (33.53)
Ceramics bricks (23.32)	32	1.433 (1.260)	1.205 (0.958)	47.93 (69.82)	43.86 (59.80)	25.21 (32.51)	14.22 (20.72)	9.60 (16.25)
Pulp (17.11)	19	0.188 (0.195)	0.211 (0.222)	27.17 (31.12)	171 (167)	126 (174)	82.71 (81.62)	17.75 (17.89)
Paper (17.12)	69	0.285 (0.235)	0.278 (0.239)	48.20 (77.47)	388 (1477)	184 (809)	187 (692)	52.97 (227.5)
Bulk chemicals (20.14)	12	0.598 (0.716)	0.745 (0.730)	571 (509)	1415 (1362)	250 (192)	873 (894)	106 (122)

Note: Indicated values are means over years and plants. Production and inputs are expressed in k€. Emissions are expressed in tCO_2. The column #Obs indicates the number of production sites per cross-section. Medians are reported in brackets.

Results

Results

- From 2012 to 2021:
  - most sectors exhibit non directed technological change
  - some have benefited from type 1 or type 2 weakly directed technological change
  - none has been subject to strongly directed technological change



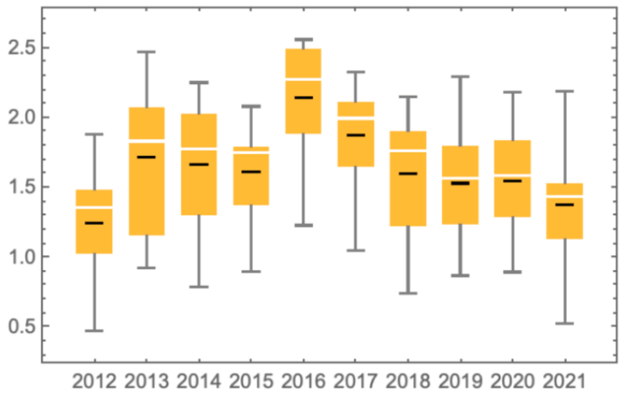
% change of baseline emissions (2012-2021)

% change of carbon intensity (2012-2021)

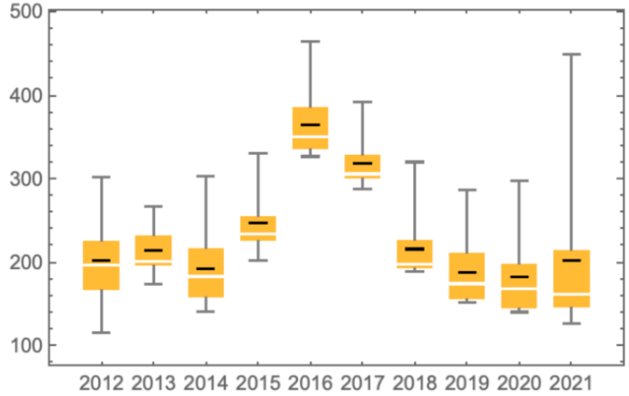
Results

- The flat glass (NACE 23.11) sector exhibits a non directed TC, but the dynamics has changed to strongly directed in the mid period

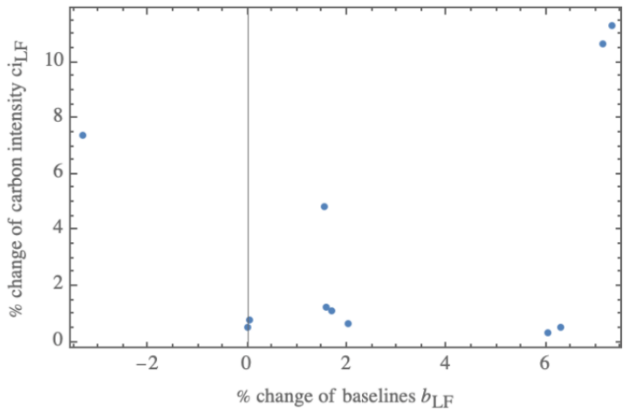
(a) Box and whisker chart for technology-intrinsic carbon intensity



(b) Box and whisker chart for baseline emissions



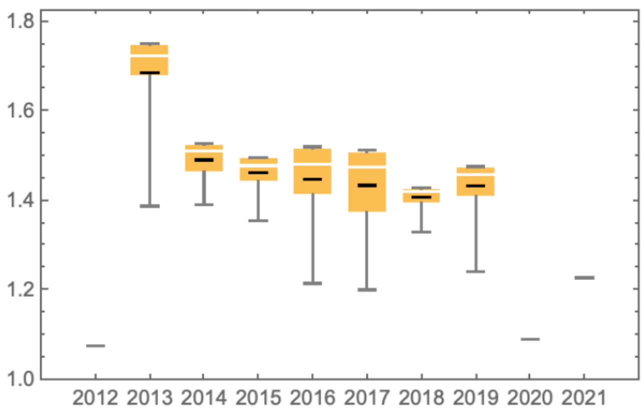
(c) Average location of firms



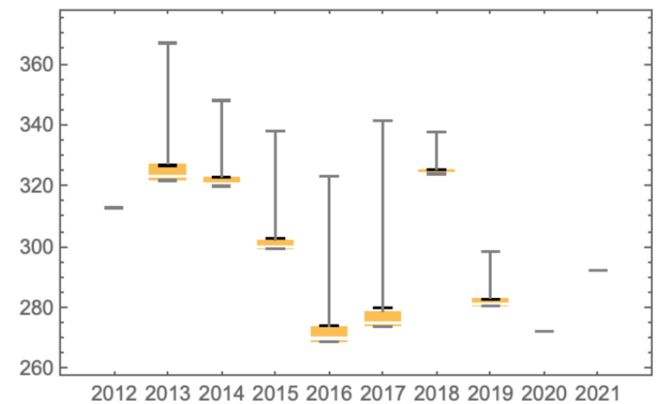
Results

- The Ceramic Bricks (NACE 23.32) sector exhibits a Type 2 weakly directed technological change, unless year 2012 is disregarded

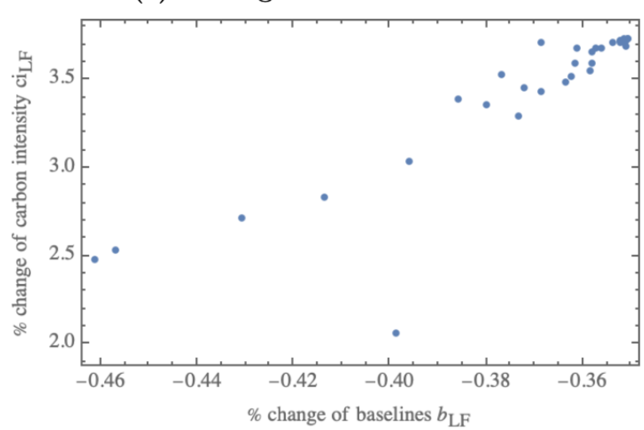
(a) Box and whisker chart for technology-intrinsic carbon intensity



(b) Box and whisker chart for baseline emissions



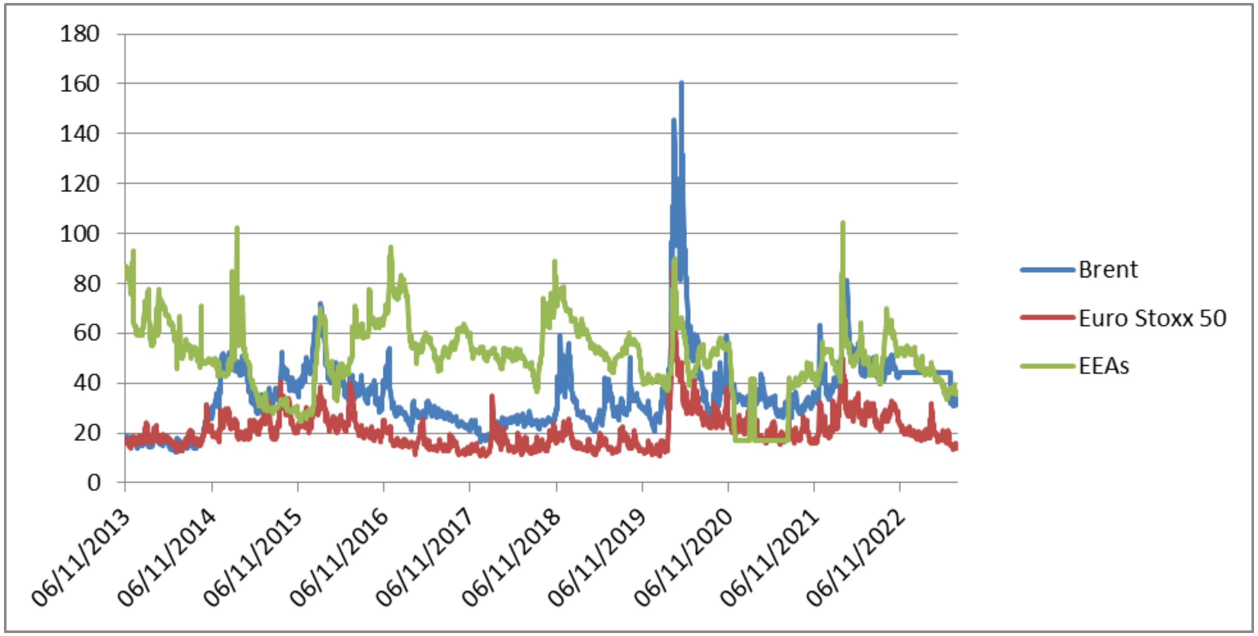
(c) Average location of firms



Policy implications

Policy implications

- Why so few low-carbon investments, even at the end of the period studied when the price of EUAs increased sharply?
  - A matter of fact is that the implied volatility of EUAs is significantly higher than that of other assets



Implied volatility (source: Refintiv)

Policy implications

- => Decision makers consider that there is too high risk and uncertainty surrounding the return on low carbon investments
  - Uncertainty as regards the time consistency of EU-ETS regulation
    - See for instance the proposal made by some members of the European Parliament in July 2022 to finance the REpower EU plan by auctioning quotas that had been placed in the MSR
      - if it had been accepted, the proposal would have induced an increase in the intertemporal supply of EUAs and therefore a decrease in their price.
    - The problem may worsen with the increase of revenues from EUAs auctions and CBAM
  - More generally policy makers may have different objectives, the weight of which change due to swing voters during elections
    - The current European Commission is strongly committed to the Fit for 55 plan, but what about the next one?
    - Some EU member states are already advocating in favour of a less stringent climate policy
    - Short term political gains may prevail on long term climate challenges

Policy implications

- The problem is reminiscent of the one encountered by monetary policy
  - Central bank independence has been put forward as a solution to the problem of time inconsistency in monetary policy
    - See the seminal article by Kydland and Prescott (1977)
  - It may also be a solution to the problem of volatility
    - See the recent work by Gariga & Rogriguez (2023) on inflation volatility
- => Having an independent regulator in charge of the EU-ETS instead of the EC directly ruling it may reduce risk and uncertainty
  - Independence is multifaceted (Dincer & Eichengreen, 2014) but some key characteristics have been highlighted
    - Longer term for head of the regulated agency compared to the term of policy makers
      - Limits the influence of swing voters during electoral periods (Waller & Walsh, 1996)…
    - But still appointed by policy makers to ensure accountability
      - Official mandate to make the price signal effective

Thank you for your attention!

Potsdam Institute for
Climate Impact Research

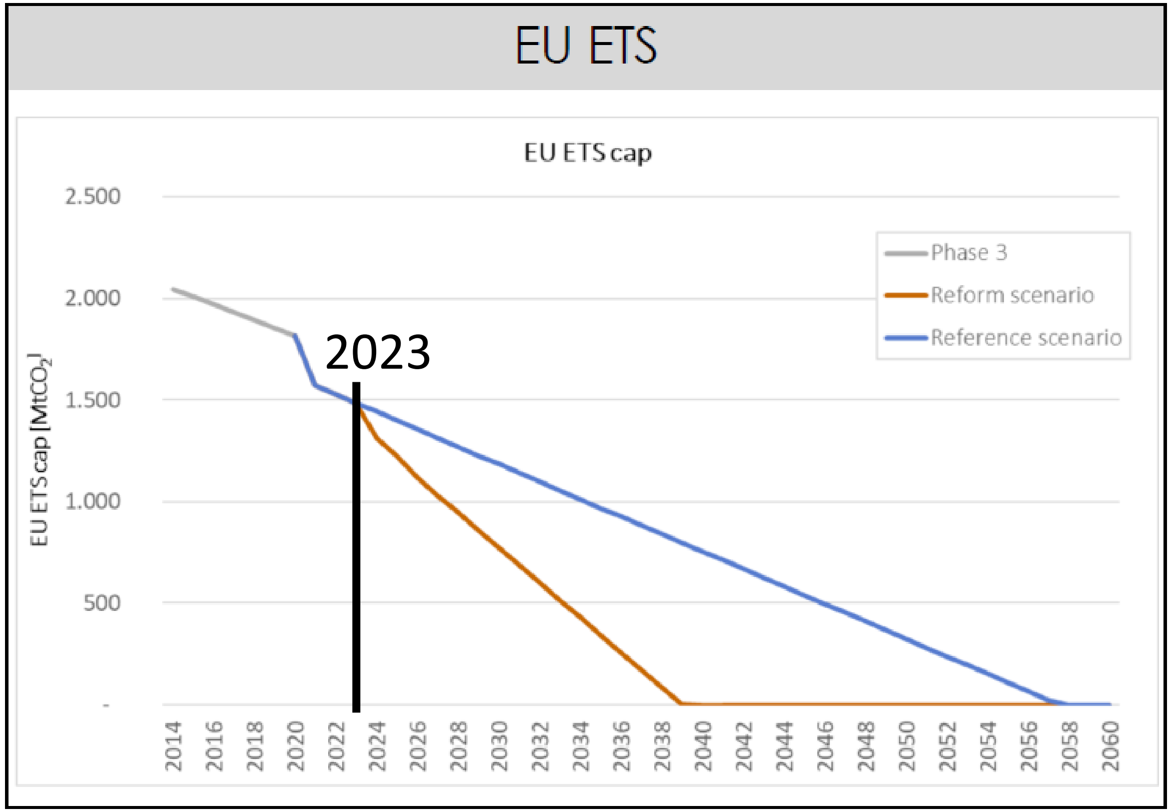
P I K

The Emerging Endgame: The EU ETS on the Road Towards Climate Neutrality

M. Pahle, C. Günther, S. Osorio, S. Quemin & R. Pietzcker

CEC Annual Conference 2023

Cap reaching zero is around the corner now



2039 (reform)

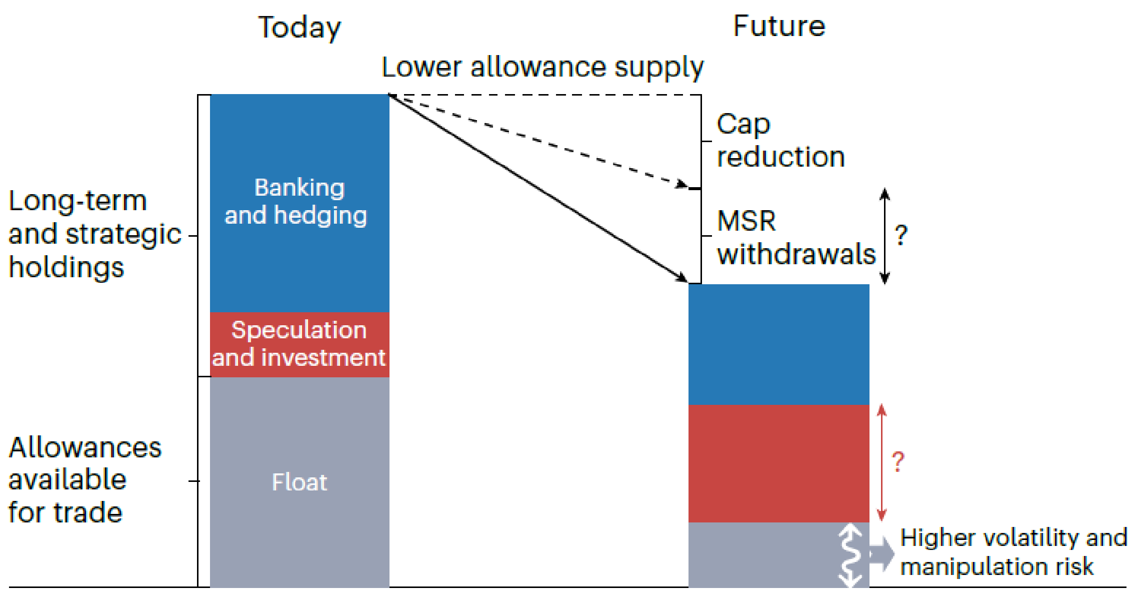
2057 (pre-reform)

Main research questions

- ETS **“endgame”** in the next decade, overlaps with current **investment horizons**

→ 1. How will the market(s) react to the reform?

→ 2. Implications for ETS functioning when cap approaches zero?



Source: Quemin & Pahle (2022)

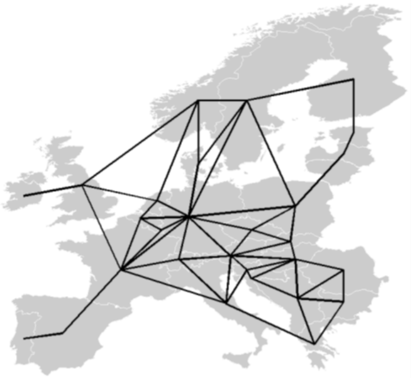
Literature on “future” of ETS

- **Forward looking research** (theoretical analysis, numerical modelling) can be grouped into **two categories**:
- **Ceteris paribus** analysis of **market**, e.g. extrapolation of current adjusted design:
  - Energy mix and carbon prices, e.g. Pietzcker et al. (2021)
  - MSR, e.g. Perino et al. (2022), Osorio et al. (2021)
- Analysis of **specific policy aspects**:
  - CDR, Franks et al. (2022), Kalkuhl et a. (in prep.)
  - Behavior of non-compliance traders, e.g. Quemin & Pahle (2022)
  - Linking & international, e.g. Verde & Borghesi (2022), Doda et al. (2019)
- Very little research specifically on **“endgame”**:
  - carbon removal reserve to manage prices (Rickels et al. 2022)
  - vanishing cost heterogeneity (Newell & Stavins 2003)
  - increasing price corners (Goodkind & Coggins 2015)

Methods

- Part I: **Ceteris paribus analysis** using the LIMES-EU model
- Part II: **Qualitative exploration** (*thinking through*) of factors that may determine the "endgame", and if it exists at all

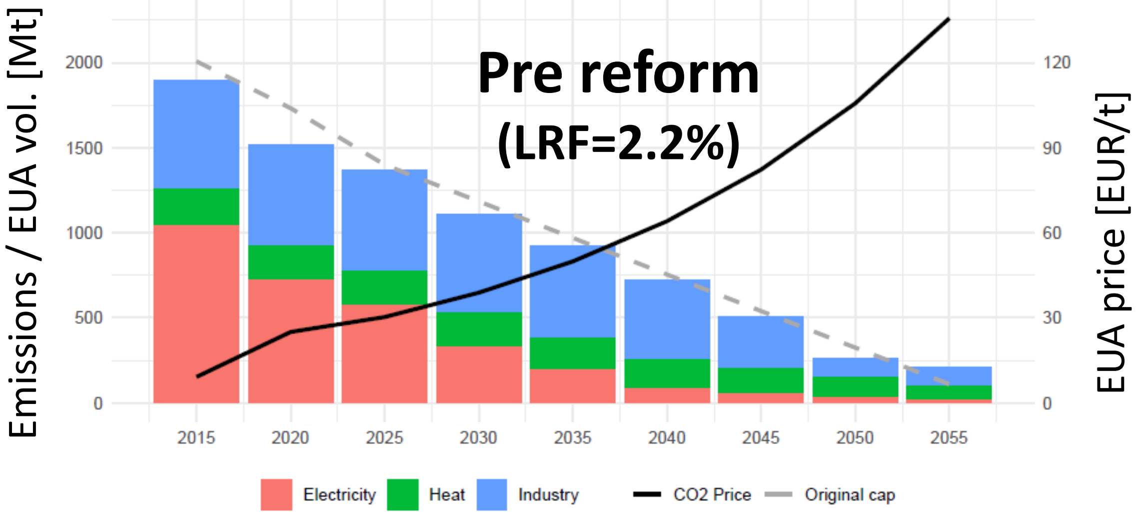
LIMES-EU in a nutshell

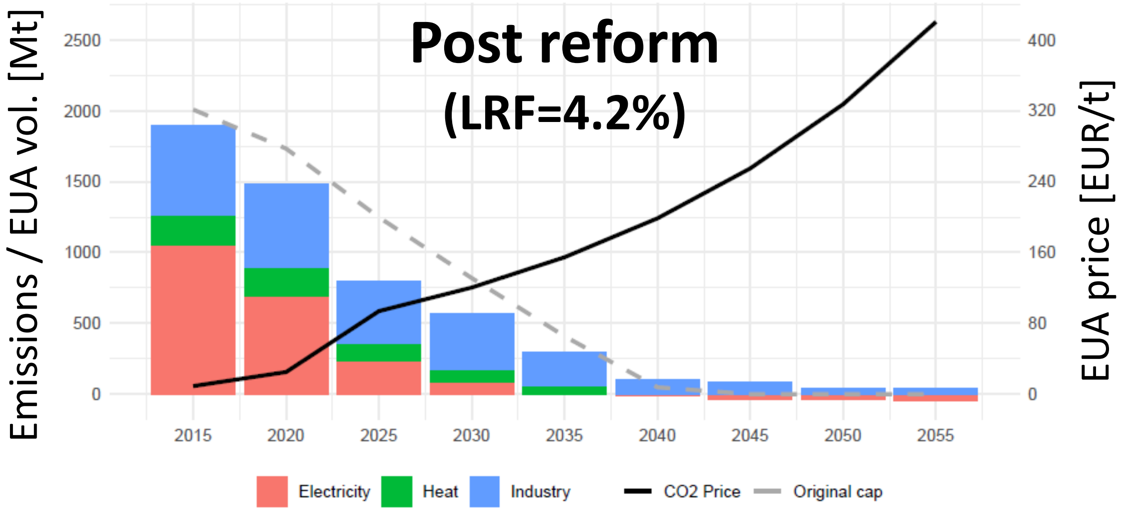


- Linear optimization model
- Temporal resolution:
  - From 2010 to 2070 in 5-year steps
  - 6-10 representative days per year
  - 8 time slices per day
  - Perfect foresight
- Geographical scope: Europe (29 model regions)
  - EU (w/o MT and CY) + CH + NO + aggregated Balkan
- 33 generation and storage technologies
- EU ETS energy-intensive industry: MACC
- Policy focus: EU ETS and MSR

PART I: MODEL-BASED ANALYSIS OF MARKET DYNAMICS

Market dynamics pre & post reform

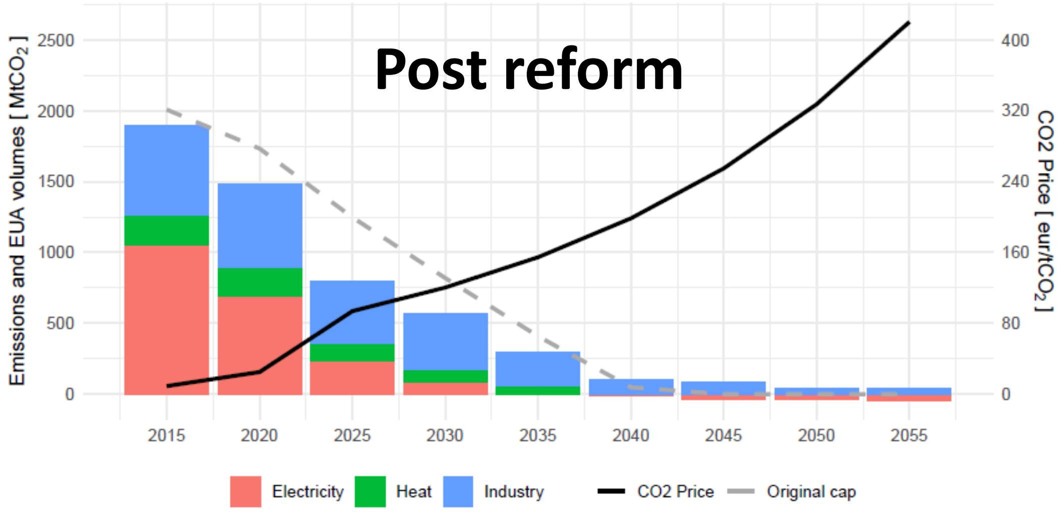


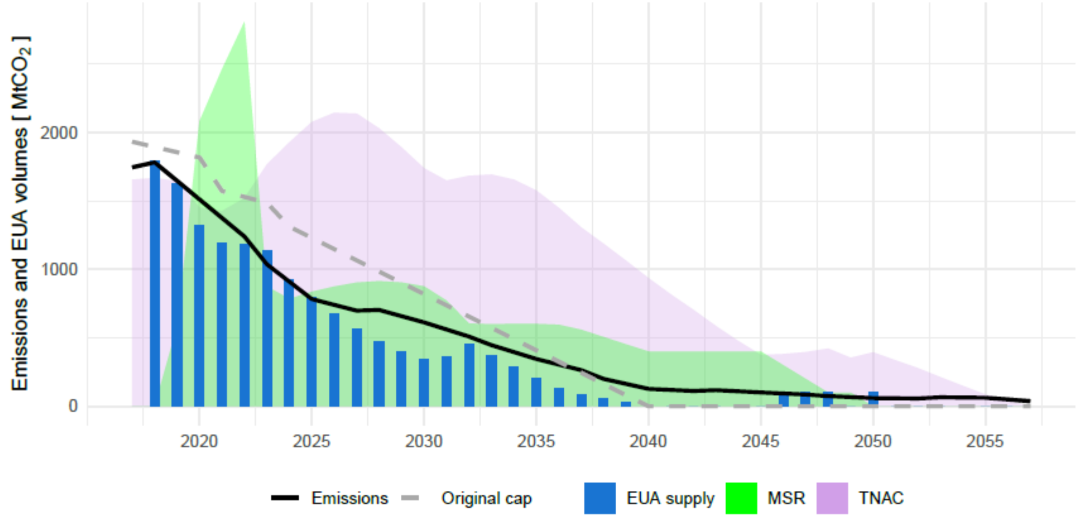


2030 ETS price: **40 €/t**

2030 ETS price: **140 €/t**

The devil is in the details





- ETS increasingly price set by “residual” emissions: **industry MAC** and **electricity CCS**
- **TNAC (bank) to rise again**, peaking ~2025
  - ➝ Anticipation of much costlier abatement in later decades
  - ➝ Highly dependent on discount rate
- High MSR intake, supply as small **as 500 Mt by 2030** already

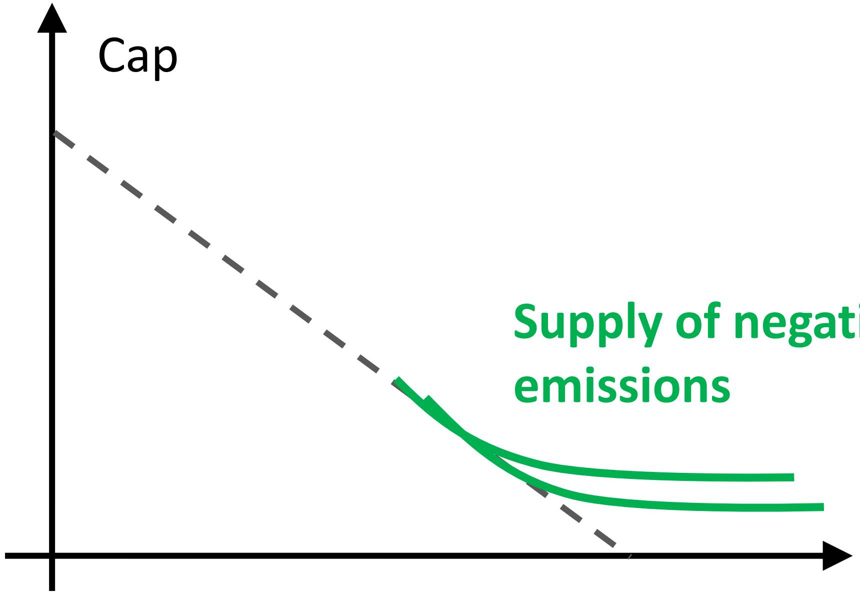
P I K

PART II: EXPLORATION BEYOND CURRENT REFORM

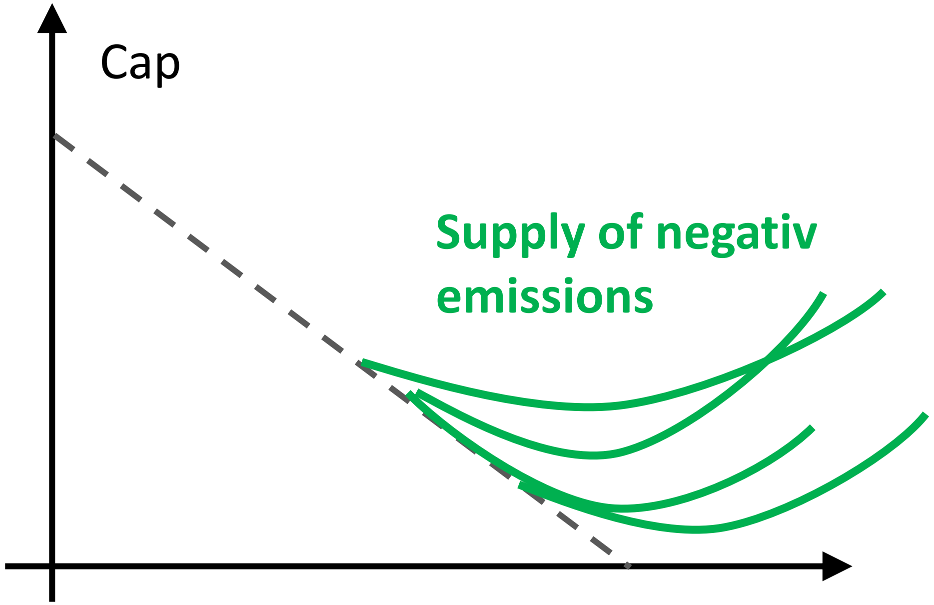
Will the market function?

- Elicitation of colleagues' views:
  - Agreement: Major change is from (single) public to (multiple) private sellers
  - Disagreement: ETS suitable mainly for **transition towards** net zero vs. also suitable **for net-zero management**
- Management → **stable equilibrium & non idiosyncratic market**?
  - Volume:
    - How large will be the demand for/supply of negative emissions, or offsets?
    - How permanent will CDR be? Will there be multiple products?
  - Scope: Will the market grow through physical or financial linking?
  - Failures: Will there be market power and/or low liquidity issues?

Two hypotheses about transition of supply from positive to negative: asymptotic vs. contract-and-expand



Orderly transition into net-zero equilibrium



Transition to net-zero equilibrium **mirrors tightening of the cap**

→ **Actual "endgame" challenge ambiguity** about transition to net zero?

→ ETS fitness for climate neutrality will hinge on it

CR certification in progress, but huge uncertainty

Figure 35 Net carbon removals from LULUCF direct and indirect (filtered scenarios, EU)

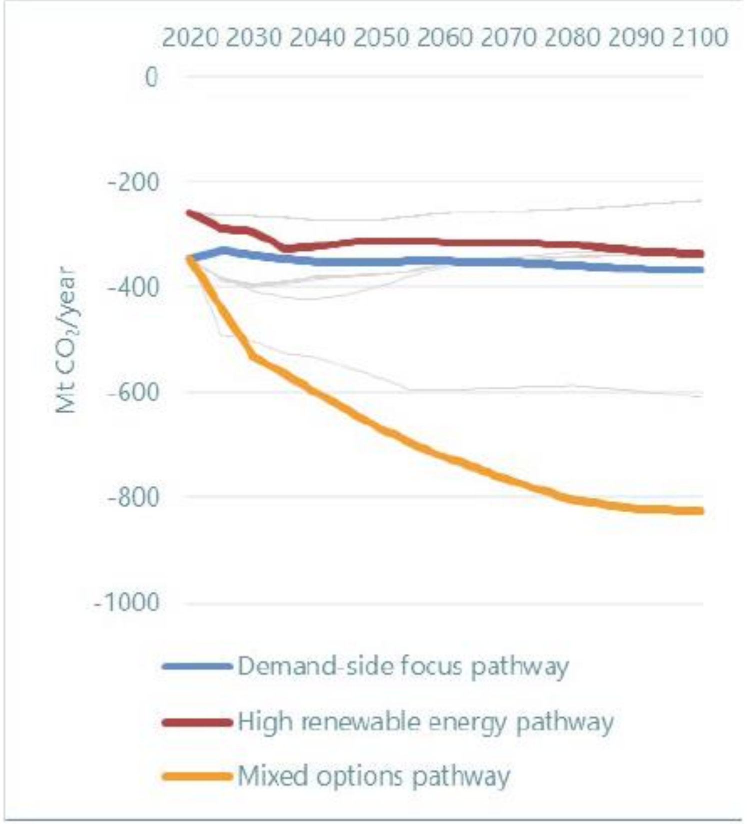
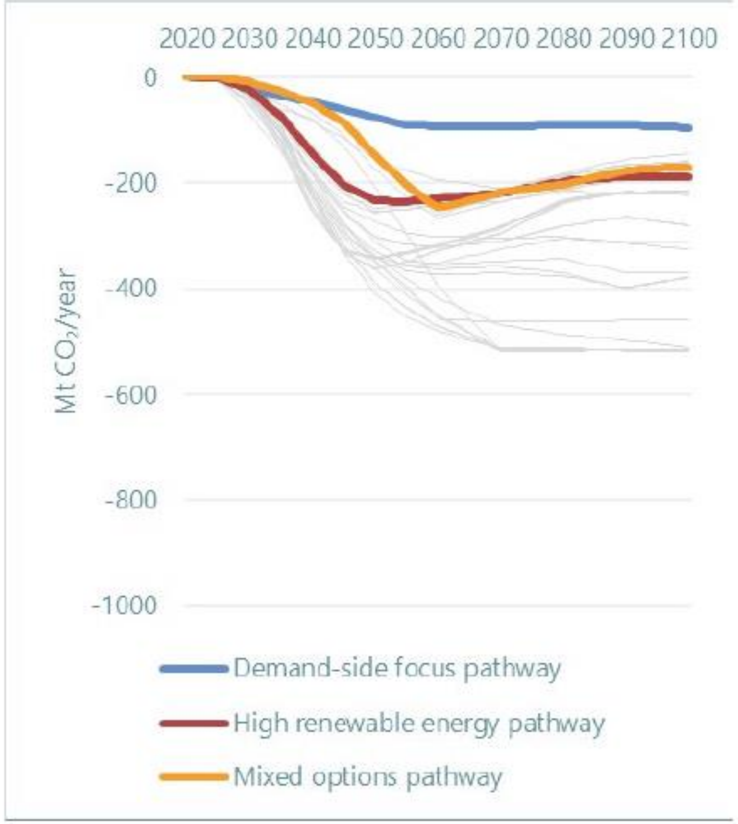


Figure 36 Carbon removals from BECCS and DACCS (filtered scenarios, EU)



Source: EU Scientific Advisory Board on CC (2023)

Conclusions

- Pending ETS reform will substantially tighten supply by around 2030 already → ETS approaching **“endgame”**?
- “Endgame” characterized by **transition from positive to negative supply equilibrium**, could take substantially different forms
- **Ambiguity about transition** likely a major factor to determine ETS function in the **post-2030 period**
- Need to **urgently resolve** ambiguity to **ensure credibility**
- Very little research yet, high time to **address this question** → this (collection of) work about **which specific questions to ask**

Fossil investment under climate policy: empirical evidence

Wassim Le Lann

Climate Economics Chair Annual Conference

September 2023

Plan

Context: fossil resource

- Paris Agreement targets requires stopping new fossil resource extraction projects (Bouckaert et al., 2021; Shukla et al., 2022).
- Economically viable fossil fuel reserves exceed by far our remaining carbon budget (McGlade and Ekins, 2015; Welsby et al., 2021)
- Investment plans of the fossil energy industry remain incompatible with preferred climate mitigation pathways (Kuhne et al., 2022)

Context: climate governance

Current climate governance:

- Governments try to mitigate climate change mostly by adopting demand-side climate policies destined to reduce economies' reliance on fossil energy.
- Considerable heterogeneity in countries' efforts to address climate change.
- Large literature debating the effect of these features of climate policy-making on fossil resource extraction (green paradox, leakage...)

Research question

Research question:

- What are the effects of these climate policy-making features (demand-side, unilateral...) on the new investments of the oil gas sector in fossil ressource extraction ?

→ This paper aims to empirically investigate this question using investment data.

Sample

Capital expenditures and financial information on 207 oil and gas extractive companies:

- From 2009 to 2021
- Located in 30 countries
- 7721 firm-quarter observations
- representing one quarter of proven oil and gas reserves in 2020.

Measuring climate policy effort

Use of Grantham Institute's *Climate Change Laws of the World* dataset.

Two measures of policy-making effort to fight climate change:

- National level: number of climate policies passed in a window of four quarters in the firm's country of headquarters.
- Global level: number of climate policies passed in a window of four quarters worldwide (detrended).

→ Three versions of each proxy: all climate policies, mitigation policies only, energy sector targeted policies.

OG investment & climate policies: national level

Standard panel investment regression (e.g., Julio and Yook, 2012; Gulen and Ion, 2016; Ilyas et al., 2021) augmented by a measure of national climate policy effort:

$$INV_{i,j,t} = \alpha_i + \gamma_t + \beta_1 NCE_{j,t-1} + \beta_2 Q_{i,t-1} + \beta_3 CF_{i,t-1} + \beta_4 SG_{i,t-1} + \beta_5 Size_{i,t-1} + \beta_6 Lev_{i,t-1} + \beta_7 \%\Delta GDP_{j,t-1} + \varepsilon_{i,t},$$

Measure of corporate investment → capital expenditures scaled by lagged total assets.

OG investment & climate policies: national level

	All climate policies	Mitigation policies	Energy sector policies
Tobin's q	0.0114***	0.0114***	0.0113***
	(0.0016)	(0.0016)	(0.0016)
Cash flow	0.0413**	0.0413**	0.0407**
	(0.018)	(0.018)	(0.018)
Sales growth	0.00296***	0.00299***	0.00297***
	(0.00083)	(0.00082)	(0.00082)
GDP growth	0.0112	0.00859	0.00797
	(0.028)	(0.028)	(0.028)
Firm size	−0.00299**	−0.00301**	−0.00301**
	(0.0014)	(0.0014)	(0.0014)
Leverage	−0.0315***	−0.0313***	−0.0312***
	(0.0047)	(0.0046)	(0.0046)
National climate effort	−0.000522**	−0.000769**	−0.00111***
	(0.00025)	(0.00030)	(0.00035)
Observations	7721	7721	7721
R^2	0.438	0.438	0.439
Firm FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Clustered by firm	Yes	Yes	Yes
Clustered by time	Yes	Yes	Yes

Note: Robust standard errors, clustered by firm and time, are reported in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

Robustness

Decrease in investment rates range from -1.6% to -3.5% relative to the sample average following the passing of one additional climate policy in the previous four quarters.

Results are robust to:

- partitioning of the sample (large vs small companies, EP vs integrated companies)
- changes in the initial sample (exclusion of Covid-19 period, exclusion of most represented countries in the sample).
- use of alternative measure of corporate investment (capital expenditures scaled by PPE, forward PPE growth).

Channel: climate transition risk ?

How can climate policy-making in a firm's country of headquarters be associated with a decrease in OG investment given that many of these companies are MNE ?

Pro-climate government might increase companies exposure to adverse governmental or court decisions ($\uparrow$ climate transition risk):

- Keystone XL pipeline project
- French Duty of Care Act (Aczel, 2021)

Channel: climate transition risk ?

Climate transition risk $\rightarrow$ increase in the risk of stranded assets associated with irreversible investments $\rightarrow$ decrease investments in fossil capital. Highlighted by recent theoretical contributions (Bauer et al., 2018; Baldwin et al., 2020; Fried et al., 2022).

To test this channel:

- Construct a measure of investors concerns on climate change using transcripts from earning call conferences and Sautner et al. (2020) climate change dictionary.
- Regress this measure on NCE and controls using PPML regressions.

Effect of NCE on investors concerns

		All climate policies	Mitigation policies	Energy sector policies
Log questions length	1.426***	1.384***	1.406***	1.390***
	(0.22)	(0.20)	(0.20)	(0.20)
Tobin's q	0.0981	0.0163	0.0612	0.0970
	(0.44)	(0.44)	(0.44)	(0.43)
Cash flow	−8.958***	−8.951***	−8.989***	−8.483***
	(2.45)	(2.39)	(2.51)	(2.50)
Sales growth	−0.252**	−0.241*	−0.268**	−0.251**
	(0.13)	(0.13)	(0.12)	(0.12)
GDP growth	3.815	3.274	3.421	3.126
	(4.89)	(5.21)	(5.23)	(5.22)
Leverage	0.156	0.165	0.132	0.102
	(1.27)	(1.21)	(1.21)	(1.21)
Firm size	0.164	0.127	0.151	0.193
	(0.27)	(0.26)	(0.26)	(0.26)
National climate effort		0.0580**	0.0694**	0.137***
		(0.027)	(0.032)	(0.046)
Observations	2142	2142	2142	2142
Pseudo R^2	0.387	0.389	0.389	0.391
Firm FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Clustered by firm	Yes	Yes	Yes	Yes
Clustered by time	Yes	Yes	Yes	Yes

Note: Robust standard errors, clustered by firm and time, are reported in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

OG investment & climate policies: global level

To study the effect of climate policies at the global level: investment model augmented by a measure of global climate policy effort (relaxing time fixed effects) :

$$
\begin{aligned}
INV_{i,j,t} = {} & \alpha_i + \gamma M_{t-1} + \beta_1 GCE_{t-1} + \beta_2 NCE_{j,t-1} \\
& + \beta_3 Q_{i,t-1} + \beta_4 CF_{i,t-1} + \beta_5 SG_{i,t-1} + \beta_6 Size_{i,t-1} \\
& + \beta_7 Lev_{i,t-1} + \beta_8 \%\Delta GDP_{j,t-1} + \varepsilon_{i,t},
\end{aligned}
$$

M_{t-1}: vector of macroeconomic controls (oil price uncertainty, global economic policy uncertainty)

OG investment & climate policies: global level

	All climate policies	Mitigation policies	Energy sector policies
Oil price uncertainty	−0.00328***	−0.00337***	−0.00339***
	(0.00077)	(0.00075)	(0.00077)
GEPU	−0.00425*	−0.00420*	−0.00405*
	(0.0023)	(0.0023)	(0.0023)
Tobin's q	0.0132***	0.0130***	0.0132***
	(0.0016)	(0.0016)	(0.0016)
Cash flow	0.0616***	0.0584***	0.0596***
	(0.018)	(0.018)	(0.018)
Sales growth	0.00311***	0.00307***	0.00305***
	(0.00095)	(0.00095)	(0.00096)
GDP growth	−0.0750***	−0.0813***	−0.0781***
	(0.019)	(0.024)	(0.020)
Firm size	−0.00292**	−0.00291**	−0.00291**
	(0.0013)	(0.0013)	(0.0013)
Leverage	−0.0385***	−0.0380***	−0.0382***
	(0.0052)	(0.0050)	(0.0051)
National climate effort	−0.000723**	−0.00103**	-0.00131***
	(0.00030)	(0.00038)	(0.00047)
Global climate effort	0.0000484	0.0000901**	0.0000583
	(0.000031)	(0.000036)	(0.000049)
Observations	7721	7721	7721
R^2	0.413	0.415	0.413
Firm FE	Yes	Yes	Yes
Time FE	No	No	No
Clustered by firm	Yes	Yes	Yes
Clustered by time	Yes	Yes	Yes

Note: Robust standard errors, clustered by firm and time, are reported in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% level, respectively.

OG investment: interaction between national and global climate policies

Definition of low NCE:

- A country is classified as having a low NCE (national climate policy effort) if it did not pass a single climate policy in the previous h years. Otherwise it is classified as having a high NCE.

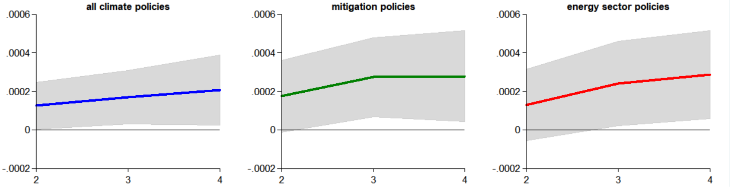
OG investment: interaction between national and global climate policies

Interactions terms between GCE and the climate policy effort of the firm's country of headquarters:

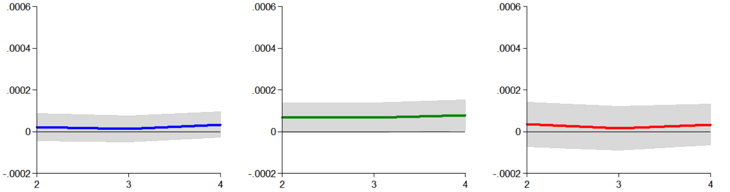
$$\begin{aligned} INV_{i,j,t} = {} & \alpha_i + \gamma M_{t-1} + \beta_1^{+} GCE_{t-1} \times \mathbb{1}^{+}_{j,t-1} \\ & + \beta_1^{-} GCE_{t-1} \times \mathbb{1}^{-}_{j,t-1} + \beta_2 NCE_{j,t-1} + \beta_3 Q_{i,t-1} \\ & + \beta_4 CF_{i,t-1} + \beta_5 SG_{i,t-1} + \beta_6 Size_{i,t-1} \\ & + \beta_7 Lev_{i,t-1} + \beta_8 \%\Delta GDP_{j,t-1} + \varepsilon_{i,t}, \end{aligned}$$

- $\mathbb{1}^{+}_{j,t-1}$ takes the value one if the firm's country of headquarters has high NCE and zero otherwise.
- $\mathbb{1}^{-}_{j,t-1}$ takes the value one if the firm's country of headquarters has weak NCE and zero otherwise.

(a) Weak national climate policy effort



(b) High national climate policy effort



OG investment: interaction between national and global climate policies

- For firms located in countries having weak NCE, increase in OG investment rates ranges from 0.5% to 0.8% for an additional climate policy in excess of the global trend.
- Little evidence of such an effect for companies located in countries having a high NCE.

Fossil investment leakage towards firms less exposed to the risk of stranded assets ?

Conclusion

- Overall, irreversible investment channel dominates green paradox effects.
- Green paradox effects might be found in micro datasets, at the project level.
- Global coordination is required to effectively mitigate climate change.