Cap and Trade with Imperfect Hedging

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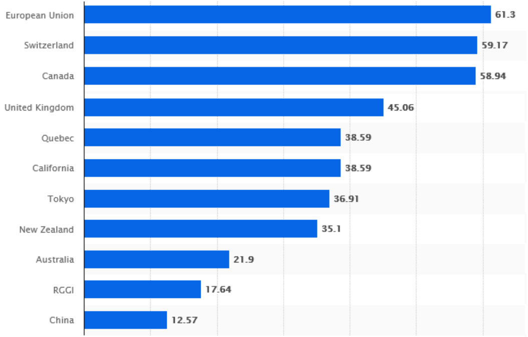
Cap and Trade

- Emissions externalities + No other friction $\Rightarrow$ Cap and trade achieves first best
  - Cap: Firms can't emit more than total number of permits issued by regulator
  - Trade: Firms can trade permits
- Cap-and-trade systems cover 19% of emissions in 2025
- Price of emission permits (\$/ton of CO2, April 2024)



Cap and Trade $\Rightarrow$ Risk

- Emissions caps should reflect the social cost of carbon
- Uncertainty about the social cost of carbon due uncertainty about model parameters, model structure, and preferences
  - *"The range of estimates is large (...) In the past 10 years, estimates of the Social Cost of Carbon have increased from \$9 per ton CO2 to \$40 for a high discount rate and from \$122 per ton CO2 to \$525 for a low discount rate."* (Tol, 2023)

$\Rightarrow$ Uncertainty about future price of permits ("transition risk")

Cap and Trade $\Rightarrow$ Risk $\Rightarrow$ Hedging

- Emitters can hedge permit price volatility by buying storable permits or derivatives

- However, financial frictions may hinder hedging

    - *"The hedging component (i.e., removing carbon price uncertainty) could also be fulfilled by sufficient ex ante purchases of ETS allowances as the later are 'bankable' (i.e., unused allowances can be saved for later use). Frontloading purchases of ETS allowances would, however, require up-front financing and may hit the financing constraints of companies."* (Draghi report, 2024)

Questions

- Positive: How do financial frictions hinder hedging of transition risk?

- Normative: How do financial frictions affect optimal climate policy?

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- Literature
  - Exposure to/pricing of transition risk (Bolton & Kacperczyk 2021, Sautner et al. 2023, etc.)

    Our paper: How frictions affects hedging and pricing of transition risk
  - How credit rationing affect green investments and optimal policy (Rola-Janicka Doettling 2023, Heider Inderst 2022, Oehmke Opp 2025)

    Our paper: How frictions affect hedging and optimal policy

Road Map

1. Stylized facts about risk and hedging in the EU Exchange Trading System

2. Model: Positive + Normative

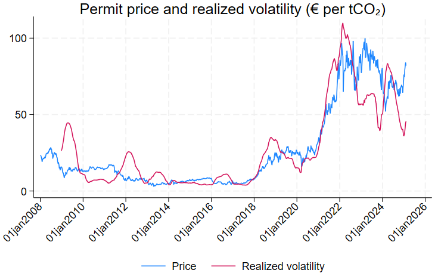
1. Stylized Facts

EU ETS

- Started in 2008 (after experimental phase 2005-2007)
- Firms must surrender permits to cover their yearly GHG emissions
- $\approx$ 50% of permits auctioned, 50% freely allocated
- Secondary trading: spot (one-day ahead futures), futures (most liquid is next December), and options
- Market participants: emitters and financial firms

Fact 1: Risk

- **Permit price is volatile**



  - Price fluctuations reflect policy uncertainty due to climate and political uncertainty

- **Emitters' price risk exposures are large**

  - Average cost of compliance for European emitters ≈ 40% of pre-tax profits

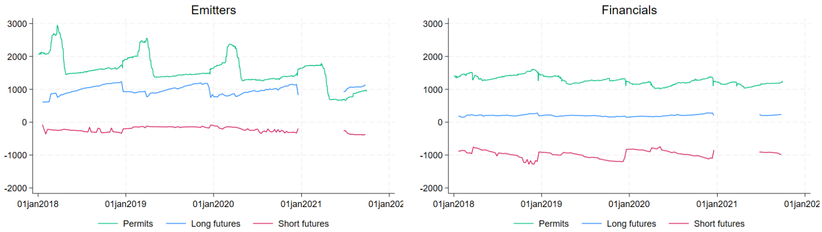
Fact 2: Hedging

- **Emitters hedge permit price risk**

  (i) Store permits

  (ii) Buy futures contracts on permits (from financial institutions)

Holdings of permits and futures (million tCO_2)



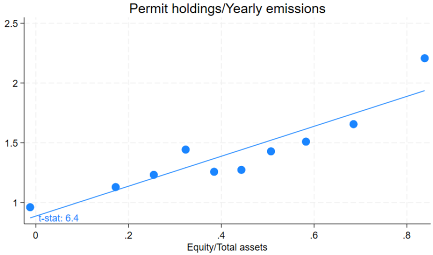
Fact 3: Imperfect Hedging

- **Less capitalized emitters:**

  (i) have lower storage of permits

  (ii) delay purchases of permits within the annual compliance cycle

  (iii) hedge relatively more using futures than permits



- Interpretation: Permit holdings require upfront financing $\Rightarrow$ costly for firms with binding financial constraints

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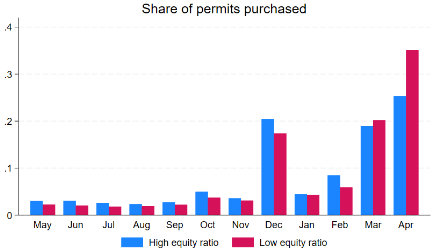

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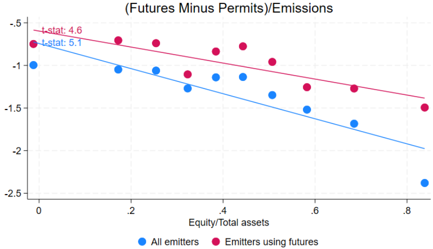

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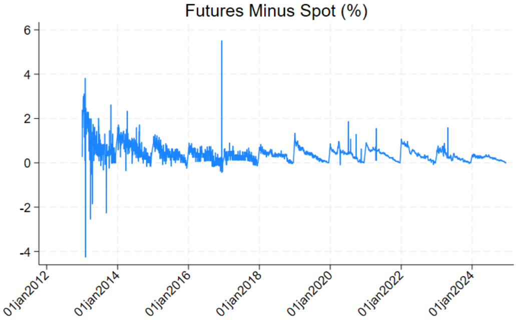
Fact 4: Deviation from the Law of One Price

- **Permit futures trade at a discount relative to spot**
  - Basis ≈ 80 bps per year



- Interpretation: Asset pricing with financial frictions (Gromb & Vayanos 2002, Biais, Hombert & Weill 2021)

2. Model

Approach

- First, positive: take caps as given, study equilibrium
- Then, normative: determine optimal policy

Model

- Two dates
  - $t = 0$: $\overline{n}_0$ permits, agents trade
  - $t = 1$: $\overline{n}_1$ permits, agents produce and consume
- Two states at $t = 1$
  - $s = h$: high cap $\overline{n}_0 + \overline{n}_{1h}$
  - $s = \ell$: low cap $\overline{n}_0 + \overline{n}_{1\ell}$
- Two types of agents
  - Emitters: choose e_s at $t = 1$, to produce $f(e_s)$, $f' > 0$, $f'' < 0$
  - Financials: endowment y at $t = 1$
- Utility of agent $i = E, F$ at $t = 1$ in state s: $u(c_{is}) - \delta_s \overline{e}_s$
  - $\delta_s \overline{e}_s$: social cost of aggregate emissions

Time 0

- Government issues $\overline{n}_0$ permits and rebates proceeds to emitters

- Emitters and financials trade **permits** and **Arrow securities for each state**

$$\text{Emitters' budget constraint:} \quad \underbrace{p_0 n_E}_{\text{permits holdings}} + \underbrace{\sum_{s=\ell,h} q_s a_{Es}}_{\text{Arrow sec. holdings}} \leq \underbrace{p_0 \overline{n}_0}_{\text{rebate}}$$

- Prices of permits and Arrow securities are determined by market clearing

Time 1, state s

- Government issues $\overline{n}_s$ permits and rebates proceeds to emitters

- Agents trade and surrender permits, produce, and consume

$$\text{Emitters' budget constraint: } \underset{\text{cons.}}{c_{Es}} \leq \underset{\text{prod.}}{f(e_s)} - \underset{\substack{\text{cost of}\\\text{permits}}}{p_s e_s} + \underset{\text{rebate}}{p_s \overline{n}_s} + \underset{\substack{\text{permits}\\\text{held}}}{p_s n_E} + \underset{\substack{\text{Arrow}\\\text{held}}}{a_{Es}}$$

- $t = 1$ permit price is determined by market clearing: low cap $\Rightarrow$ high price

- Uncertain cap $\Rightarrow$ uncertain permit price (consistent with Fact 1)

Hedging

- Despite full rebate, emitters are exposed to risk of low cap, due to low production
- Emitters produce less in state $\ell \Rightarrow$ at time 0 emitters purchase insurance against state ℓ from financials
  - In the model: Arrow securities
  - In practice: derivatives
- Consistent with Fact 2 (emitters are long permit futures, financials short)

Incentive Constraint

- Idea
  - At time 0, financials sell insurance against state ℓ
  - If state ℓ arises, financials are tempted to renege on their promise
- Formally, we assume that (as in Alvarez & Jermann 2000, Rampini & Viswanathan 2010, Biais, Hombert & Weill 2021)
  - At time 1 agents can abscond with fraction θ of resources
  - Therefore, at time 0 agents cannot promise to pay more than fraction $1-\theta$ of time 1 resources $\Rightarrow$ Incentive constraint:

$$\begin{array}{ll} \text{(Emitters)} & c_{Es} \geq \theta\big[f(e_s) + p_s n_E\big] \\ \text{(Financials)} & c_{Fs} \geq \theta\big[y + p_s n_F\big] \end{array}$$

Imperfect Hedging

- Incentive constraint limits risk sharing
  - In state ℓ, emitters produce little, financials transfer resources to emitters, but not as much as in the first best because financials' IC binds
  - In state h, emitters produce a lot and transfer resources to financials, but not as much as in the first best because emitters' IC binds

Deviation from Law of One Price

- Buying permits at time 0 tightens IC
- As a result, permits trade at a discount that reflects the shadow cost of IC
- Consistent with Fact 4

Model Extension: Heterogeneous Emitters

- Consider two types of emitters with different endowment at time 0
- Emitters with lower endowment $\Rightarrow$ higher liabilities $\Rightarrow$ tighter IC $\Rightarrow$ buy less permits at time 0
- Consistent with Fact 3 (less capitalized emitters buy less permits)

Optimal Emissions Policy

- So far: We took emissions cap as given, and showed that ensuing market equilibrium is consistent with data

- Now: Determine optimal policy, and how it is affected by financial constraints

Optimal Emissions Policy

- Planner chooses consumption and emissions to maximize

$$\sum_{i=E,F} \alpha_i E\left[u(c_{is}) - \delta_s e_s\right]$$

subject to resource constraint $c_{Es} + c_{Fs} \leq f(e_s) + y$

and incentive constraints $\begin{array}{l} c_{Es} \leq \theta\, f(e_s) \\ c_{Fs} \leq \theta\, y \end{array}$

- Social cost of carbon is higher in state ℓ than in state h: $\delta_\ell > \delta_h$

- Compare the planner's solution without IC (first best) and with IC (constrained optimum)

Optimal Emissions Policy

1. In first best and constrained optimum: Optimal emissions are lower in state ℓ than in state h

2. In constrained optimum: Emissions are not as low in state ℓ, and not as high in state h, as in the first best

   - When SCC is high, emitters produce little $\Rightarrow$ Transfer resources from financials to emitters but limited by IC $\Rightarrow$ Allow emitters to produce more than in first best to transfer utility from financials to emitters

   - Conversely, when SCC is low, emitters produce a lot $\Rightarrow$ Transfer resources from emitters to financials but limited by IC $\Rightarrow$ Force emitters to produce less than in first best to transfer utility from emitters to financials

$\Rightarrow$ When firms can imperfectly hedge transition risk, it is optimal to lower the variance of emissions caps

Optimal Emissions Policy

3. In constrained optimum: Emissions depend on Pareto weights, whereas they don't in the first best

    - In first best: SCC pins down emissions, Pareto weights pin down transfers between agents

    - In constrained optimum: transfers are constrained, distort emissions to transfer utility

$\Rightarrow$ When transfers are constrained, optimal emissions depend on political influence

Implementation

4. Both first best and constrained optimum can be implemented with cap-and-trade and transfers

5. Constrained optimum requires zero issuance of permits at time 0

   - Because storage of permits from time 0 to time 1 tightens IC

⇒ Optimal not to front-load permits issuance (consistent with EU's policy)

Permit Price

6. While constrained-optimal emissions are higher in ℓ and lower in h than in first best, the corresponding permit price is always lower than in first best

- When SCC is high: constrained-optimal emissions are higher than in first best $\Rightarrow$ permit price is lower

- When SCC is low: emitters' IC bind, which reduce their demand for permits $\Rightarrow$ permit price is lower

$\Rightarrow$ The impact of financial constraints on policy strictness depends on the metric (price or quantity)

Wrap-Up

- Cap and trade generates risk and hedging
- Financial constraints hinder hedging
- Imperfect hedging distorts optimal policy