Carbon Pricing and Inflation Expectations

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Carbon pricing is central to climate policy

- Carbon pricing — emissions trading systems (ETS) or carbon taxes — forces emitters to internalize the social cost of greenhouse gas emissions
- Widely regarded as the most **cost-effective** policy tool for decarbonization
  - EU ETS, California cap-and-trade, China national ETS, carbon taxes in Canada, Chile, Colombia, …
- But carbon pricing raises energy costs $\rightarrow$ potential **inflationary pressure**
- Key question for central banks: Is this "greenflation" transitory or persistent?
  - If transitory: central bank can "look through" the shock
  - If persistent: monetary policy may need to respond

Effects on actual inflation: no clear consensus

- Theory is **ambiguous**: cost pass-through vs. demand effects, structural adjustment vs. green innovation, climate damages vs. adaptation
  - Ferrari and Nispi Landi (2025), Del Negro et al. (2023)
- Empirical studies of carbon pricing and realized inflation report **mixed findings**:
  - Positive but short-lived effects: Breitenfellner et al. (2022), Känzig (2025), Känzig and Konradt (2024), Semik (2025), Ortubai et al. (2025)
  - Little or no impact on headline inflation: Konradt and Weder di Mauro (2023), De Silva and Tenreyro (2021), McKibbin et al. (2022), Konradt et al. (2024), Moessner (2025)
- All based on VAR/LP methods with monthly/quarterly data

Why focus on inflation expectations?

- **Relevance for monetary policy**
  - Anchored expectations $\rightarrow$ supply shocks remain transitory
  - Unanchored expectations $\rightarrow$ second-round effects, persistent inflation
  - Optimal policy response to a supply shock depends on its **expected persistence**
- Some mixed evidence using survey-based inflation expectations, generally short-lasting effects (Frank 2025, Hensel et al. 2024, Mangiante 2026)
- **Measurement advantages of market-based expectations**
  - Available at **daily frequency** $\rightarrow$ pair naturally with high-frequency event studies
  - Full **term structure** (2y–10y) $\rightarrow$ direct read on persistence, no model extrapolation
  - "Skin in the game": prices reflect investor expectations and risk premia
  - Multiple instruments and markets (BEI, swaps; euro area, France, U.K.) $\rightarrow$ cross-checks
- So far no market-based evidence on inflation effects of climate policy.

This paper

- **Question:** Do unanticipated carbon price shocks affect short- and long-term inflation expectations? And how do financial markets expect monetary policy to respond?
- **Data:** term structure of inflation-linked and nominal financial instruments
  - Inflation swaps and breakeven inflation rates (euro area, France, U.K.)
  - OIS rates and government/zero-coupon yield curves
  - Energy futures (carbon, electricity, gas, oil) at quarterly and annual horizons
- **Methodology:** high-frequency event study around EU ETS regulatory announcements
  - Build on Känzig (2025), who developed and validated this identification strategy in a macro-VAR setting
  - Extend event set through 2024 and apply the surprises to financial-market outcomes

Preview of results

- **Energy futures:** carbon price shocks generate level shifts in EUA term structure, with sizable pass-through to electricity (20–40%), gas ($\sim$20%), and oil (5–17%, declining with maturity)
- **Inflation expectations:** significant and **persistent** response of inflation compensation
    - 1–3 bp increase per 1% carbon policy surprise, peak $\sim$2.5 bp
    - Effects extend to ten-year maturities, across BEI and swaps, in euro area, France, and U.K.
    - More persistent than VAR/survey-based evidence on realized inflation
- **Nominal rates:** no appreciable response to carbon policy surprises
    - Investors do not anticipate that the ECB will lean against greenflation
    - Apparent tension with optimal-policy prescriptions for persistent supply shocks

Related literature

- Survey-based evidence on carbon shocks and inflation expectations:
  - Household and firm expectations elevated for several years following ETS shocks
  - Frank (2025), Hensel et al. (2024), Mangiante (2026), Patzelt and Reis (2024)
- High-frequency identification in monetary economics:
  - Kuttner (2001), Gürkaynak et al. (2005), Bauer and Swanson (2023)
- Carbon shocks and other financial markets:
  - Equity markets: Hengge et al. (2023), Di Giovanni et al. (2025)
  - Market-based r-star: Jezequel-Royer and Levieuge (2025)

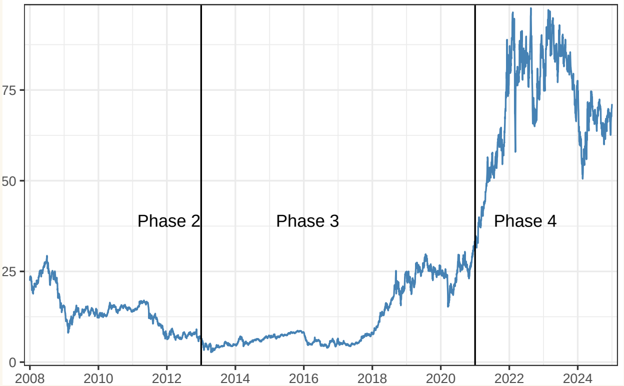
Background:

The EU Emissions Trading System

What is the European Union Emissions Trading System?

- Largest carbon market in the world (launched 2005)
  - Covers $\sim$40% of EU greenhouse gas emissions
  - Sectors: power generation, heavy industry, aviation
- **Cap-and-trade** mechanism:
  - Government sets overall emissions cap
  - Issues European Union Allowances (EUAs) — 1 EUA = right to emit 1 ton CO_2
  - Companies trade allowances $\rightarrow$ market-determined carbon price
  - Cap decreases over time $\rightarrow$ carbon price expected to rise
- EUAs traded on spot, futures, and options markets (ICE, EEX)
- Carbon price has varied enormously: from near zero (2012–2017) to €100+ (2023)

EU ETS phases and carbon price history



EUA futures price (front-quarter), 2008–2024.

- **Phase 2**: Oversupply; price collapse
- **Phase 3**: EU-wide cap; auctioning; Market Stability Reserve
- **Phase 4**: Stricter cap, broader coverage
- Our baseline sample: 2013–2024

Methodology:
High-Frequency Event Studies

The identification problem

- Naïve regression of inflation expectations on carbon prices $\rightarrow$ **biased**
- Why? Carbon prices are **endogenous**:
  - Strong economy $\rightarrow$ more production $\rightarrow$ more emissions $\rightarrow$ higher carbon price
  - Strong economy $\rightarrow$ higher inflation expectations
  - Correlation $\neq$ causation
- Same problem as in monetary economics:
  - Interest rates and inflation are correlated, but correlation tells us nothing about the causal effects of monetary policy
  - Solution there: high-frequency surprises around central bank announcements
  - Kuttner (2001), Gürkaynak et al. (2005), Bauer and Swanson (2023)
  - Acosta et al. (2025): **U.S. Monetary Policy Event-Study Database** (USMPD)
- Our approach: apply the **same event-study logic** to carbon policy

High-frequency event-study identification

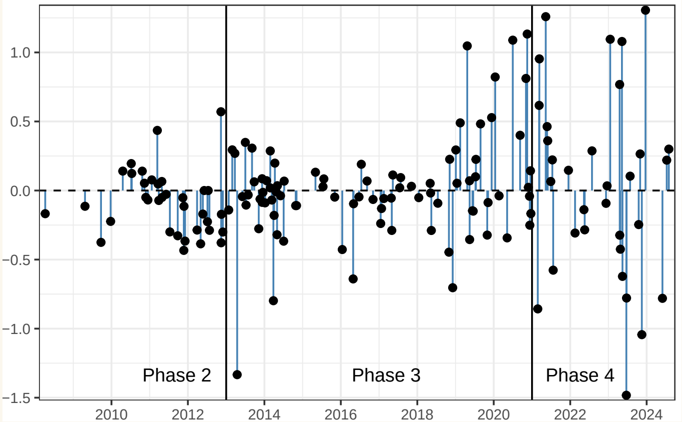
- Känzig (2025) introduced this strategy for ETS carbon policy: regulatory decisions about allowance supply and auction calendars cause **discrete jumps** in carbon prices
- Measure carbon price changes in **narrow daily windows** around these announcements
- **Key identifying assumptions:**
  1. **Relevance:** regulatory news generates material carbon price movements
  2. **Exogeneity:** other shocks are predetermined within the event window
- Känzig validates exogeneity: macro news has no predictive power for cps_t, so ETS regulatory news plausibly exogenous to euro-area macro conditions.

Constructing carbon policy surprises (Känzig, 2025)

$$cps_t = 100 \cdot \frac{f_t^{carbon} - f_{t-1}^{carbon}}{p_{t-1}^{elec}}$$

- f_t^{carbon}: EUA front-quarter futures price on event day t
- p_{t-1}^{elec}: wholesale electricity price on the day before the event
- Scaling by electricity price: economically interpretable units (carbon cost as share of electricity cost)
- Känzig (2025) used cps_t to identify carbon policy shocks in a structural VAR; we'll use them in financial market event studies
- We extend the Känzig event set through 2024 (+45 events) for **152** regulatory events 2008–2024 (117 in baseline sample from 2013)
  - Parliament votes, Commission decisions, auction calendar publications, Market Stability Reserve updates, Phase transitions

Carbon policy surprises



Carbon policy surprises (cps_t), following Känzig (2025). Units: carbon price change relative to wholesale electricity price, in percent. 152 ETS regulatory events, 2008–2024.

The event-study regression

$$\Delta y_t^{(n)} = \alpha^{(n)} + \beta^{(n)}\, cps_t + \varepsilon_t^{(n)}$$

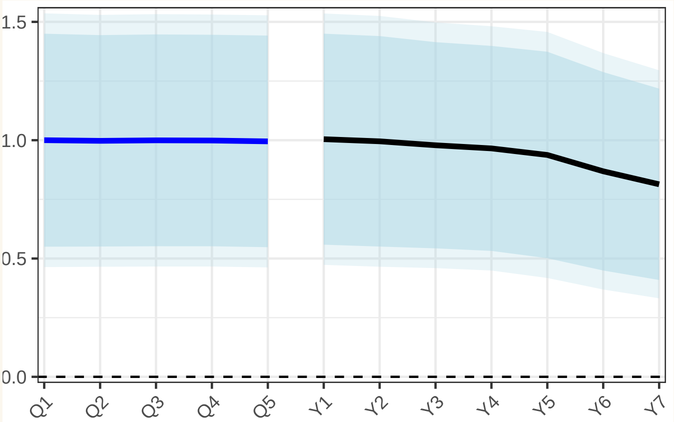
- $\Delta y_t^{(n)}$: one-day change in financial variable (maturity n) on event day t
- cps_t: carbon policy surprise
- $\beta^{(n)}$: **causal effect** of carbon price shock on outcome variable
- We estimate this for different dependent variables:
    - Energy futures returns (carbon, electricity, gas, oil)
    - Inflation swap rates and breakeven inflation rates (2y–10y)
    - Nominal interest rates (OIS, government bond yields)
- White (heteroskedasticity-consistent) standard errors

Effects on Energy Markets

Why look at energy futures?

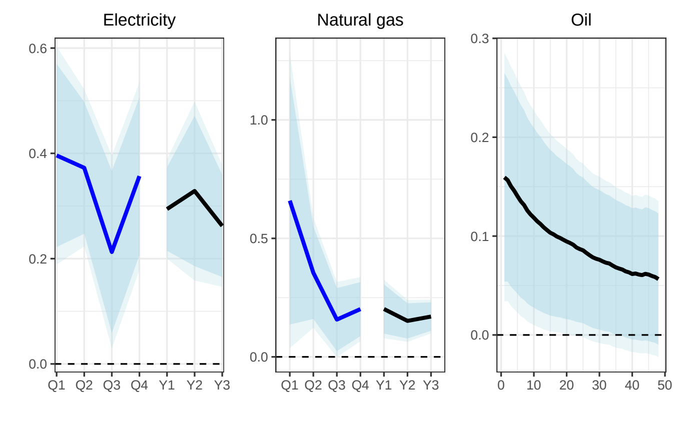
- Carbon pricing affects inflation primarily through **energy costs**
  - ETS covers power generation $\rightarrow$ higher carbon price raises electricity costs
  - Spillovers to gas (fuel switching) and oil (refining, transport covered by ETS)
- Energy futures allow us to trace the **transmission channel**:
  - Carbon price $\rightarrow$ electricity/gas/oil prices $\rightarrow$ aggregate inflation
  - Term structure of futures $\rightarrow$ pass-through across horizons
- First question: does our carbon policy surprise move the entire term structure of carbon futures?
  - Surprise is constructed from front-quarter contract
  - EUAs are fungible across time $\rightarrow$ supply news should cause level shifts
- Here we **normalize** surprise to have unit impact on front-quarter EUA $\rightarrow$ coefficients = pass-through elasticities

Carbon policy surprises shift the entire carbon futures curve



Price response (percent) of EUA futures to carbon policy surprises. Coefficients normalized so front-quarter response = 1. 90% and 95% CIs, White SEs. 117 events, 2013–2024.

Energy price pass-through: electricity, gas, and oil



Price response (percent) of energy futures to carbon policy surprises. 90% and 95% CIs, White SEs. 117 events, 2013–2024.

Energy futures: summary

- Carbon futures respond nearly **one-for-one** across all maturities
  - Regulatory news causes a level shift in the carbon price term structure
  - Market views these shocks as permanent changes in carbon cost
- Significant pass-through to other energy markets:
  - **Electricity**: 20–40% pass-through (carbon sets marginal generation cost)
  - **Natural gas**: $\sim$20% spillover (fuel switching from coal to gas)
  - **Oil**: 5–17%, declining with maturity (global market dilutes EU-specific shock)
- These energy price effects are the mechanism through which carbon pricing can raise aggregate inflation

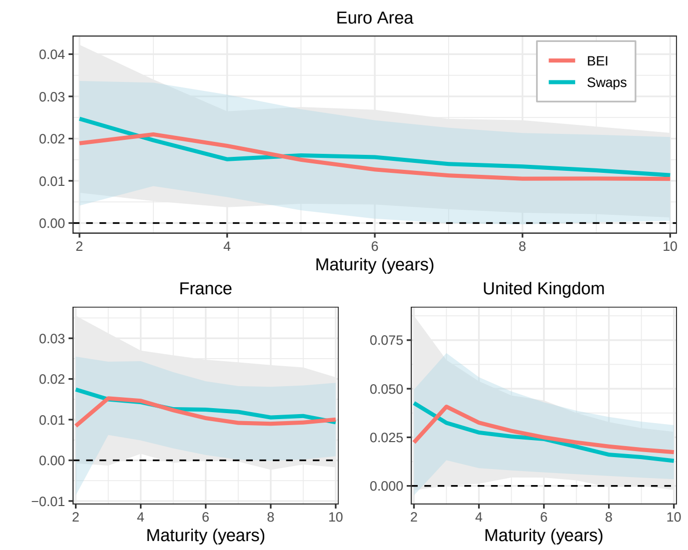
Market-Based Inflation Expectations

Measuring inflation expectations from financial markets

- **Breakeven inflation (BEI):** $BEI^{(n)} = y_n^{nominal} - y_n^{real}$
  - Inflation rate that makes investor indifferent between nominal and indexed bonds
- **Inflation swap rate:** fixed rate exchanged for realized inflation
  - Less affected by bond market liquidity; available at many maturities

- Both reflect expected inflation $+$ risk premium
- Both available at **daily frequency** across the term structure (2y–10y)
- Advantages over surveys: daily, full term structure, “skin in the game”
- We use **multiple instruments** (BEI + swaps) across **multiple markets** (euro area, France, U.K.) for robustness

Market-based inflation expectations respond persistently



Response of inflation compensation (pp) to carbon policy surprises.

95% CIs, White SEs.

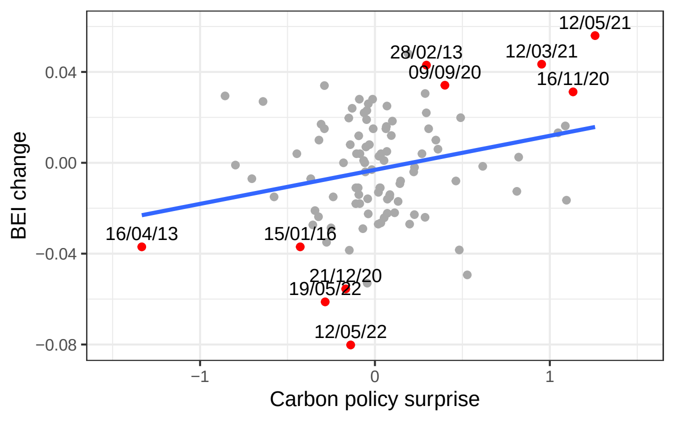
Euro/France: 102 events (2013–2023).

U.K.: 85 events (2013–2020).

Key result: persistent effects across the term structure

- A 1% carbon policy surprise raises inflation expectations by **1–3 basis points**
  - Peak effect in euro area: $\sim$2.5 bp
  - Significant from 2-year to 10-year maturities
- **Persistence is the key finding:**
  - Effects do not die out at longer horizons
  - Consistent across instruments (BEI, swaps) and markets (euro area, France, U.K.)
- Contrasts with VAR evidence: realized inflation effects dissipate within 1–2 years
- Markets price **more persistent** effects than historical data would imply

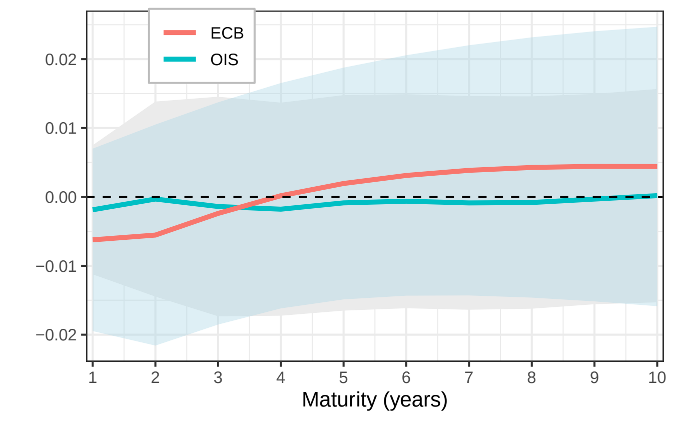
The relationship in the data



Changes in 5-year euro area BEI vs. carbon policy surprises. Red: 10 most influential observations (by DFBETA). 102 ETS events, 2013–2023.

Nominal Interest Rates and Monetary Policy Expectations

No response of nominal interest rates to carbon shocks



Response of OIS rates and ECB zero-coupon yields to carbon policy surprises. 95% CIs, White SEs. 114 events, 2013–2024.

Investors do not anticipate ECB tightening

- Despite persistent effects on inflation expectations, **no response** of nominal rates
    - Robust across OIS, benchmark yields, German yields, ECB zero-coupon curve
- Implication: markets do not expect the ECB to lean against greenflation
- **Puzzle:** contradicts standard optimal policy prescriptions
    - Taylor rule would imply $\sim$3 bp rise in expected rates; our CIs exclude this
    - ECB has stated it may not "look through" persistent carbon shocks (Schnabel, 2022)

Practical Lessons and Applicability

How to apply this methodology in other contexts

- **Step 1: Identify exogenous policy events**
  - Regulatory/policy announcements, legislative votes, auction calendars
  - Key: events should be *exogenous* (not a response to demand/macro conditions)
  - Compile event dates carefully from official sources
- **Step 2: Construct surprises**
  - Measure asset price changes in narrow windows around events
  - Choose normalization that makes units economically interpretable
- **Step 3: Estimate event-study regressions**
  - Regress financial-market outcome variable on surprises (event days only)
  - Use robust standard errors (White)
  - Examine the term structure of responses across maturities

Practical challenges and lessons learned

- **Data requirements:**
  - Daily financial market data at multiple maturities
  - Careful event dating (announcement time vs. market hours)
  - Sufficient number of events for statistical power ($N > 50$)
- **Confounding events:**
  - Check for coincident macro/central bank/geopolitical news
  - Show robustness to excluding contaminated dates
- **Interpretation:**
  - BEI and swap rates include risk premia (not pure expectations)
  - Use multiple instruments and markets as cross-checks

Relevance for South American central banks

- Carbon pricing is expanding in the region:
  - Chile, Colombia: carbon taxes already in place
  - Mexico, Brazil: carbon markets under development
- **Methodology is transferable:**
  - Applicable to any discrete policy shock (carbon tax changes, regulatory announcements, ETS launches)
  - Can study effects on local bond yields, inflation expectations, exchange rates
- Key lesson: even in a well-anchored regime, carbon policy surprises can shift **long-term** inflation expectations
- Central banks should monitor this channel as carbon pricing scales up

Conclusion

- Carbon policy surprises have **significant and persistent** effects on market-based inflation expectations
  - 1–3 bp response across 2-year to 10-year horizons
  - Consistent across instruments (BEI, swaps) and markets (euro area, France, U.K.)
- Despite this, **no response of nominal interest rates**
  - Markets do not anticipate ECB tightening in response to carbon shocks
- Implications for central banks:
  - Carbon pricing can affect long-term inflation expectations
  - Expectations channel of greenflation deserves monitoring
  - Puzzle: ECB not expected to lean against persistent greenflation

Appendix

Robustness: alternative samples and measures

- Results robust to:
    - Longer sample starting in Phase 2 (2008)
    - Excluding events with potentially confounding news (ECB decisions, geopolitical events)
    - Alternative surprise measure (relative carbon price change instead of electricity-normalized)
    - Phase 3 vs. Phase 4 sample split (no significant heterogeneity)
- Forward inflation rates (not just yields) also show significant positive response
- U.K. results consistent (sample ends 2020 with Brexit/EU ETS exit)

Oil shocks and inflation expectations

- The persistent response of inflation compensation to carbon shocks mirrors evidence from oil markets
- Using OPEC surprises (Känzig, 2021): oil price shocks also generate persistent increases in BEI term structure
- Possible mechanisms:
  - Behavioural updating: agents extrapolate from salient energy price movements
  - Inflation risk premia: investors demand compensation for greater inflation uncertainty
  - Both channels may contribute

Comparison with existing estimates

- **Känzig (2025)** structural VAR with the same carbon policy surprises: peak headline inflation $\sim$15–20 bp, dissipating within 1–2 years (also Ortubai et al. 2025, Frank 2025)
- Survey-based evidence (Frank et al., Hensel, Mangiante): household/firm expectations elevated for 2–3 years
- Our estimates: peak $\sim$9 bp (rescaled), but **much more persistent**
- Possible reconciliation:
  - Past ETS had very low carbon prices; future policy likely more ambitious
  - Historical inflation responses may understate future effects
  - Financial markets may be forward-looking about the green transition trajectory

Data sources

- **Carbon:** EUA futures (ICE Futures Europe, front-quarter contract)
- **Electricity:** German power futures (EEX)
- **Gas:** TTF Natural Gas futures (ICE Endex / EEX)
- **Oil:** Brent crude futures (ICE Futures Europe)
- **Inflation swaps:** Bloomberg (HICP for euro area, CPI for France, RPI for U.K.)
- **BEI rates:** French OAT/OATi fitted curves (Grishchenko et al.); U.K. Bank of England
- **Nominal rates:** Euro OIS (EONIA/€STR), LSEG benchmarks, ECB AAA curve, Bundesbank zero-coupon curve
- **Events:** Känzig (2025) + our 2020–2024 extension (45 additional events)