The Heterogeneous Effects of Carbon Policies: Macro and Micro Evidence

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MOTIVATION

- In light of climate crisis, increasingly clear that more policies *will be* implemented
- Transition risk is relevant for the *business cycle*
- The EU has had a carbon market for twenty years
  - Cap-and-trade schemes likely to be increasingly important (fit-for-55)
  - Yet, limited (but growing) existing evidence
- Heterogenous effects
  - What are their *economic* and *financial* effects?
  - Who are the winners and the losers?
  - Can general equilibrium forces attenuate aggregate responses?
- Answers to the these questions necessary steps to inform policymakers
  - How important are climate-related shocks? Are these shocks trade-off inducing? Can heterogeneity dampen aggregate responses?

THIS PAPER

- Focus on the EU Carbon ETS Market - **exogenous variations in carbon pricing**
  - ⇒ Identification of carbon pricing shocks following Känzig (2025)

- Macro evidence running panel local-projections
  1. Uncover average effects (across countries)
  2. Exploit cross-country heterogeneity

- Micro evidence using firm-level equity prices and local-projection type regressions
  1. Validate firm-level analysis with country analysis
  2. Is there evidence of general-equilibrium attenuation?

- A *two-type firm* model to understand mechanism and reconcile the evidence and identify potential sources of attenuation

PREVIEW OF RESULTS

- Average international effects
  - Carbon pricing shocks resemble negative supply shocks, with particularly strong impact on asset prices
- Heterogeneous effects
  - Macro: countries with higher CO_2 intensity suffer more
  - Micro: within a sector, high-CO_2 emission firms (brown *firms*) suffer more
    - We uncover attenuation due to general-equilibrium forces
- Rationalization
  - Carbon pricing shocks $\uparrow$ costs to brown firms, $\uparrow$ inflation $\downarrow$ output. Lower relative green prices $\uparrow$ demand and output. $\downarrow$ profits and asset prices
  - Model re-calibration $\Rightarrow$ we find that countries with high CO_2 are hit hardest
  - We use the model to shed light on the drivers of attenuation: substitution, composition and heterogeneity (green-brown technological gap)

SHOCKS

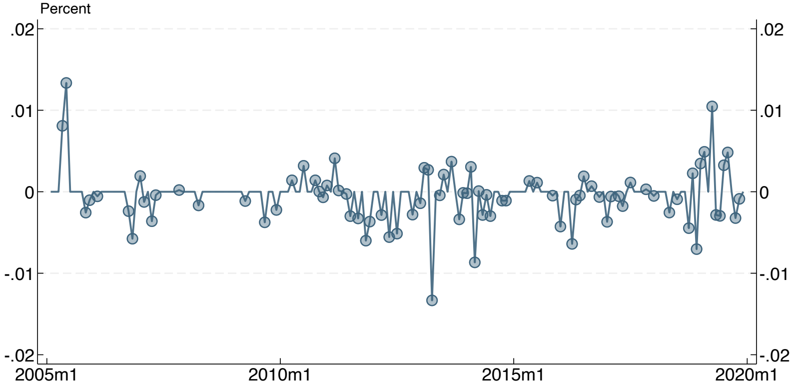
IDENTIFICATION OF SURPRISES

- Carbon EU ETS Market (largest carbon market in the world)
  - Covers over 11,000 heavy energy-using installations and airlines
  - Regulates around 40-45% of EU GHG emissions
  - Cap-and-trade system : market price for carbon and liquid futures market
  - Companies receive allowances through auctions and free allocations, which they trade (establishing a carbon market). Allowances are storable. Compliance through fines.
  - Känzig (2025) identifies *114 regulatory announcements* and examines the price change of futures in a tight window (one day) around the events

$$CPS_t = \begin{cases} \frac{F_{t,d} - F_{t,d-1}}{P^{elec}_{t,d-1}} & \text{if there is an event} \\ 0 & \text{otherwise} \end{cases}$$

THE CARBON POLICY SURPRISE SERIES

▸ FUTURES PRICES ▸ CPSLOG



- Following Känzig (2025), we extract the shock from a VAR for the EU using surprises as an external instrument for energy component of HICP

MACRO AND MICRO EVIDENCE

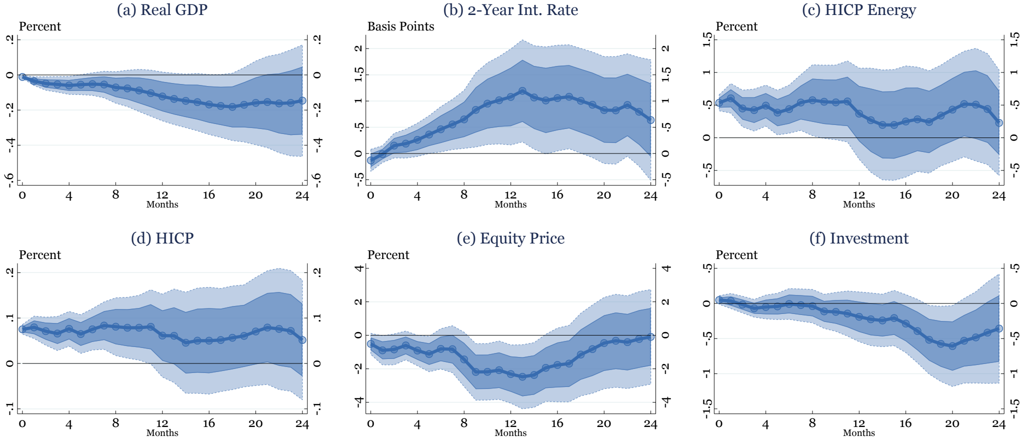
MACRO EVIDENCE

Panel Local Projections :

$$y_{i,t+h} - y_{i,t-1} = \alpha_i^h + \beta^h CPS_t + \sum_{p=1}^{P} \Gamma_p^h X_{i,t-p} + u_{i,t+h},$$

- Baseline : 15 countries members of EU ETS & Sample : 1999M1 to 2019M12
- α_i^h country fixed effects
- β^h captures the response of outcome variable to the CPS_t
- $X_{i,t}$ additional controls: lags of the outcome variable, other macro aggregates, linear trend
- Standard errors are computed following Driscoll and Kraay (1998)
- *What is the average dynamic effect of an exogenous increase in carbon price?*

MACRO LOCAL PROJECTIONS - AVERAGE ECONOMY



CROSS-SECTIONAL RESULTS

- Average results mask significant degree of heterogeneity
- Do countries reliant on CO_2 for production suffer more from climate policies?
- if resources cannot be reallocated easily, carbon policies hurt the economy harder
  $\Rightarrow$ "browner" countries are likely to suffer more
- Use country CO_2 intensity as a proxy (World Bank)

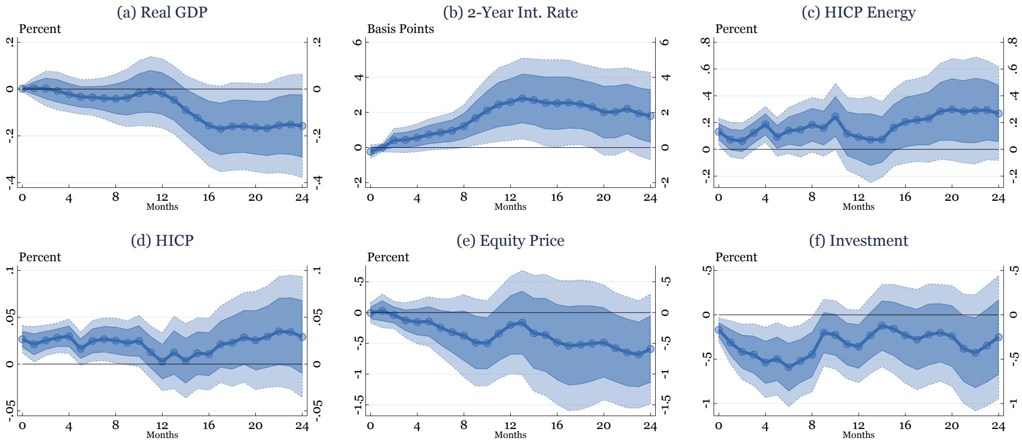
CROSS-COUNTRY HETEROGENEITY

Effects of carbon pricing depending on a country's CO_2 intensity :

$$y_{i,t+h} - y_{i,t-1} = \alpha_i^h + \alpha_t^h + \gamma^h \left(CPS_t \times CO2_{i,t-1}^{High} \right) + \sum_{p=1}^{P} \Gamma_p^h X_{i,t-p} + u_{i,t+h},$$

- α_i^h are country fixed effect at horizon h
- α_t^h is a time fixed effect at horizon h
- $CO2_{i,t}$ is the country-level carbon intensity
- standardize the country carbon intensity variable over the entire sample
- Interpretation γ^h : captures the dynamic effects of a one std dev. shock (CPS) on macro aggregates and asset prices (at horizon h) for a high-emission country
- Standard errors are computed following Driscoll and Kraay (1998)

MACRO LOCAL PROJECTIONS - HIGH EMISSION COUNTRIES



FIRM-LEVEL EVIDENCE

- Granular firm-level daily equity prices :
  - We collect data for the main firms in the equity index for a panel of 15 countries (521 unique firms)
- Event-study regressions :
  - What happens after a carbon pricing shock in the EU ETS?
  - Exploit richer cross-sectional variation
  - Local projections type regressions
  - Do brown firms suffer more?
  - Is there general-equilibrium attenuation?

FIRM RESPONSES : AVERAGE

Firm specific response

$$q_{ij,t+h} - q_{ij,t-1} = \alpha_j^h + \lambda^h CPS_t + \sum_{p=1}^{P} \Gamma_p^h X_{i,t-p} + \sum_{p=1}^{P} \Theta_p^h Z_{ij,t-p} + u_{ij,t+h},$$

- where $q_{ij,t}$ is the log equity price of firm j in country i in period t
- α_j^h is a *firm*-specific fixed effects
- $X_{i,t}$ vector of country level controls
- $Z_{ij,t}$ firm level controls
- Interpretation λ^h : impact on equity prices of carbon price shocks (CPS) at horizon h
- Standard errors are computed following Driscoll and Kraay (1998)

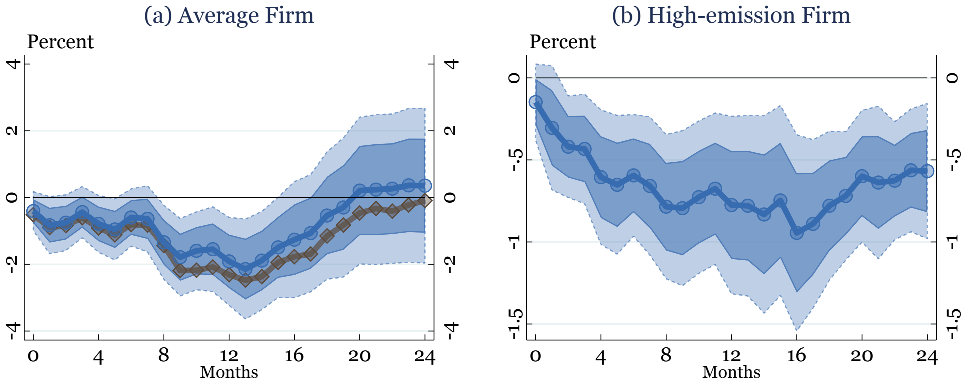
FIRM RESPONSES : HIGH EMISSION FIRMS

- Firm specific response

$$q_{ij,t+h} - q_{ij,t-1} = \alpha_j^h + \alpha_{t,i,s}^h + \phi^h (CPS_t \times CO2_{ij,t-1}^{High}) + \sum_{p=1}^{P} \Theta_p^h Z_{ij,t-p} + u_{ij,t+h},$$

- α_j^h is a *firm*-specific fixed effects
- $\alpha_{t,i,s}^h$ is a triple interacted fixed effect
- $CO2_{ij,t-1}^{high}$ equals one if firm j's carbon intensity is above the median
- interpretation ϕ^h : captures the differential effect for high-emission firms (above-median carbon intensity) relative to low-emission firms within the same countrysector-time cell
- Standard errors are computed following Driscoll and Kraay (1998)

FIRM-LEVEL EQUITY PRICES

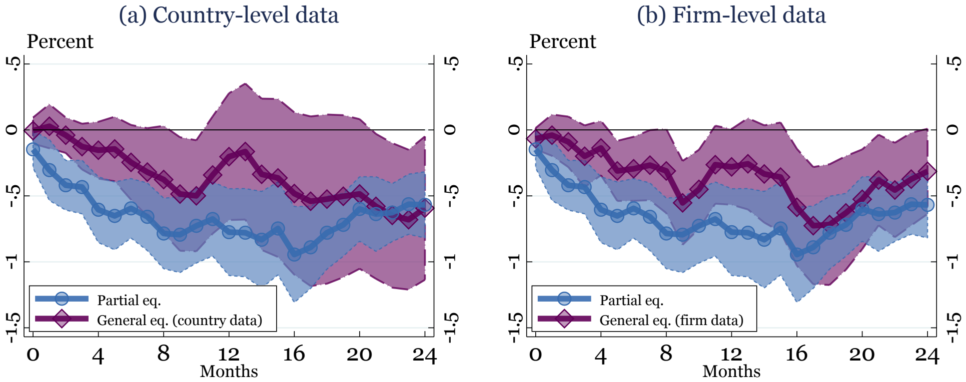


GENERAL-EQUILIBRIUM ATTENUATION

- We can test whether general-equilibrium forces dampen or amplify partial-equilibrium responses
  - ⇒ Compare our baseline within-sector estimate ϕ^h with **two** alternative specifications that allow aggregate general-equilibrium forces to operate
- The first uses the country-level specification, yielding the estimate γ^h
- The second uses firm-level data but aggregates the interaction to the country level:

$$q_{ij,t+h} - q_{ij,t-1} = \alpha_i^h + \alpha_t^h + \tilde{\gamma}^h(CPS_t \times \widetilde{CO2}_{i,t-1}^{High}) + \sum_{p=1}^{P} \Theta_p^h Z_{ij,t-p} + u_{ij,t+h}$$

General-equilibrium attenuation



TAKEAWAYS

- Non-negligible average impact on activity, smaller inflationary response
- Financial channel seems particularly large while real variables respond less
- Carbon intensive countries suffer more than their greener counterparts
- At the firm-level asset prices fall on average
  - ⇒ They drop by more for browner firms
- General equilbrium forces attenuate the aggregate impact
- We develop a model to explain these findings

E-DSGE model

MODEL WITH BROWN AND GREEN FIRMS

- Firms of type $j = \{B, G\}$ produce goods using capital and labor
- Brown firms use *emissions* (or an abatement technology) to produce final output; green are less emission intensive
- Externality $\rightarrow$ emissions harm aggregate productivity (damage function)
  - Positive profits allow us to study asset pricing for green and brown firms
- Real rigidities include *habit formation, capital adjustment costs, death shock to firms and fixed costs of production*
- Monopolistic competition, nominal price and wage rigidities
- Perfect labour mobility but imperfect capital mobility
- Study the responses to a carbon pricing shock

PRODUCTION TECHNOLOGY

- We follow Copeland and Taylor (2004) and Shapiro and Walker (2018)
- We generalize to a CES production function and embed into a DSGE model
- We introduce capital, a climate block, real and nominal frictions to study the dynamic responses to carbon pricing schocks
- Production technology :

$$Y_t^j(i) = \mathcal{Z} Z_t \left(1 - A_t^j(i)\right) \left(N_t^j(i)\right)^{1-\alpha_j} \left(K_{t-1}^j(i)\right)^{\alpha_j} - \Psi_j,$$

where $Z_t = 1 - \Gamma(\mathcal{CO}_t)$ and $\Gamma(\mathcal{CO}_t)$ is a quadratic damage function

- Atmospheric carbon evolves :

$$\mathcal{CO}_t = (1 - \varpi)\,\mathcal{CO}_{t-1} + \xi_t.$$

EMISSIONS AS INPUT

- Emissions by firms of j-type are :

$$\xi_t^j(i) = \mu_j \mathcal{Z} Z_t \left\{ \frac{\left(1 - A_t^j(i)\right)^{\frac{\zeta-1}{\zeta}} - (1-\gamma_j)}{\gamma_j} \right\}^{\frac{\zeta}{\zeta-1}} \left(N_t^j(i)\right)^{1-\alpha_j} \left(K_{t-1}^j(i)\right)^{\alpha_j}$$

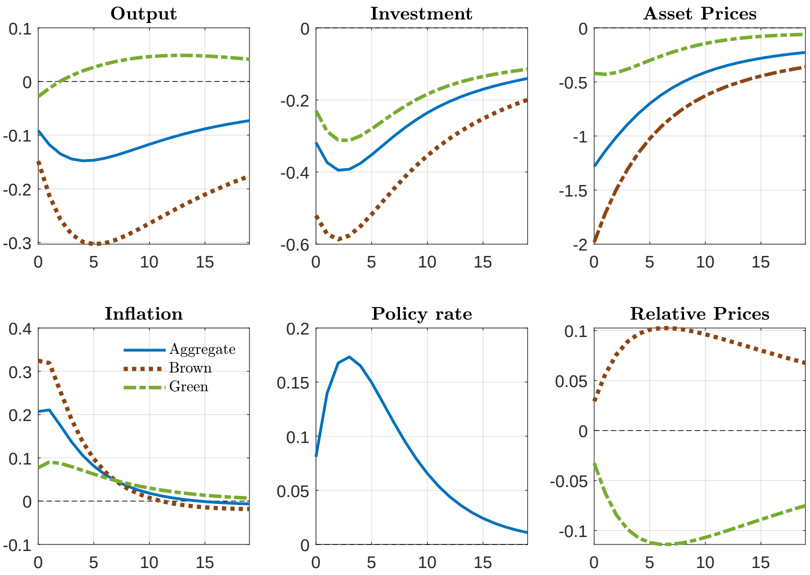
$\Rightarrow$ production by $j = B$ firms be written as

$$Y_t^j(i) = \left[\gamma_B \left(\frac{\xi_t^j(i)}{\mu_j} \right)^{\frac{\zeta-1}{\zeta}} + (1-\gamma_B) \left[\mathcal{Z} Z_t \left(N_t^j(i)\right)^{1-\alpha_j} \left(K_{t-1}^j(i)\right)^{\alpha_j} \right]^{\frac{\zeta-1}{\zeta}} \right]^{\frac{\zeta}{\zeta-1}} - \Psi_j$$

TECHNOLOGY AND POLLUTION

- From the perspective of production, diminishing returns to emission activity
- Abatement activity is effective at cutting emissions
- Shock the price of emissions θ_t
- We therefore allow for emissions to respond to the shock
- The model is calibrated at quarterly frequency and calibration follows literature
- Calibrate the shock to match the response of output at trough

MACRO VARIABLES TO A CARBON PRICING SHOCK



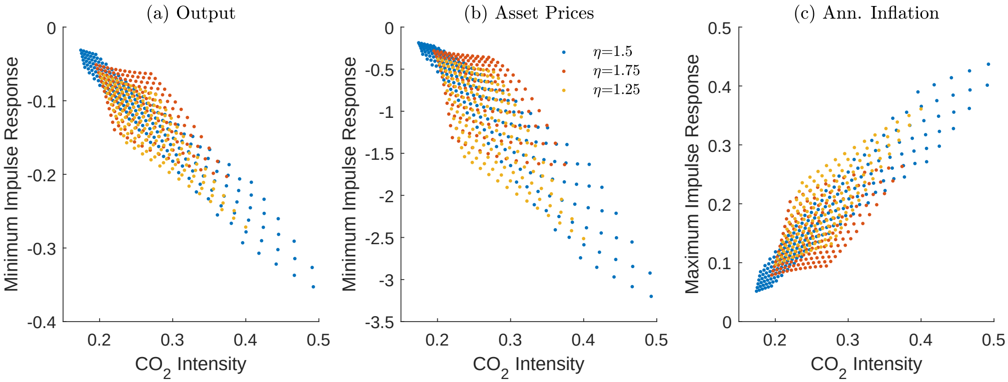
INTERPRETATION

- carbon price shock raises real marginal costs $\Rightarrow \uparrow$ inflation
- capital is costly to adjust $\Rightarrow$ in responding to the shock, firms demand less emissions (by abating more)
- complementarity $\Rightarrow$ labor demand falls and $\downarrow$ output
- green goods become cheaper, $\uparrow$ demand
- inflation $\uparrow$ slightly because whilst $\uparrow$ consumption and $\downarrow$ investment
- lower firm profitability $\Rightarrow \downarrow$ asset prices
- these patterns are broadly in line with the empirical evidence

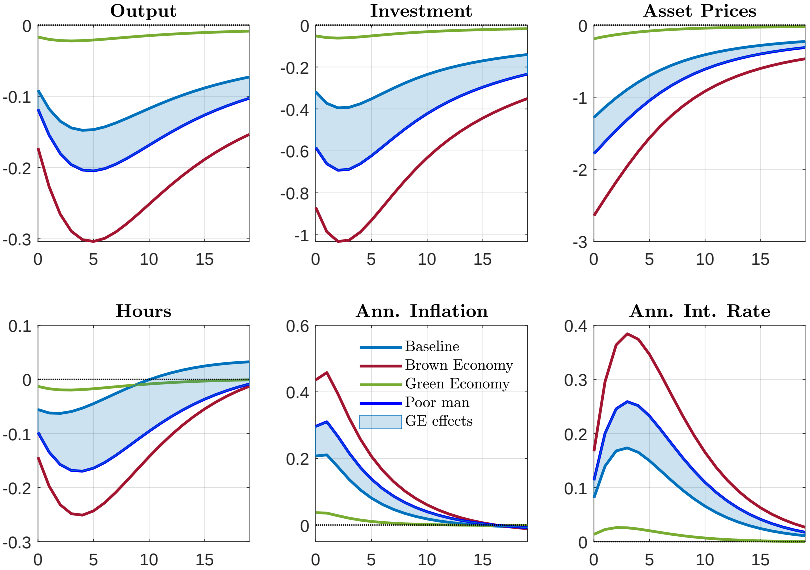
ECONOMIC IMPACT BY CARBON INTENSITY

- We recalibrate the steady state to target each country in the sample
- For a given the level of aggregate productivity ($\mathcal{Z}$), we choose different combinations of ν, γ_B and η
- Heterogeneity:
  - if the share of browner firms is larger, then aggregate impact is stronger (composition effect)
  - if γ_B is larger, greater gap between brown and green firms (technological gap)
  - if elasticity of substitution across brown and green goods is smaller, aggregate impact is larger (less substitution, less dampening)

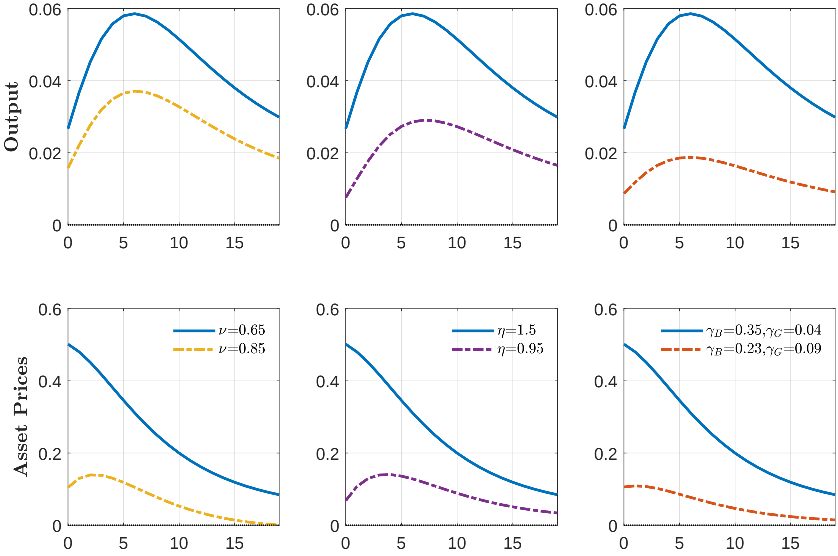
ECONOMIC IMPACT BY CARBON INTENSITY



AGGREGATION - GE ATTENUATION



Attenuation - GE/PE gap



TAKEAWAYS

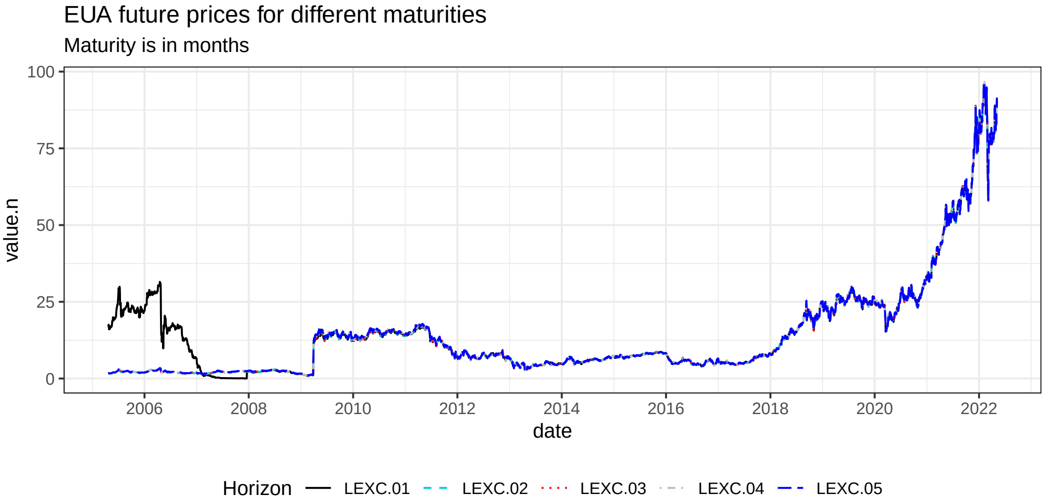
- Economy is hit on average (GE attenuation effect), brown firms suffer more than green firms
- Shock is inflationary (and in line with data)
- Brown firms are hit directly, green firms indirectly
- Asset prices fall on average with brown asset prices falling my more
- Can replicate *negative relationship* between intensity, output and asset prices
- Attenuation are due to composition, substitution and heterogeneity (tech gap between brown and green firms)

CONCLUSION

CONCLUSION

- We document stylized facts on the economic effects of carbon policy shocks
- General message:
  - Recessionary, inflationary effects and large financial effects
  - Browner countries and browner firms suffer more
  - We uncover general-equilibrium attenuation
- Results have implications for economic channels at play:
  - Brown firms suffer directly, green firms indirectly (GE) $\Rightarrow$ attenuation due to GE and composition effects
  - Asset prices fall, investment fall (more by brown firms than green firms)
  - GE-attenuation due to composition, substitution and firm-heterogeneity

PRICE OF CARBON FUTURES



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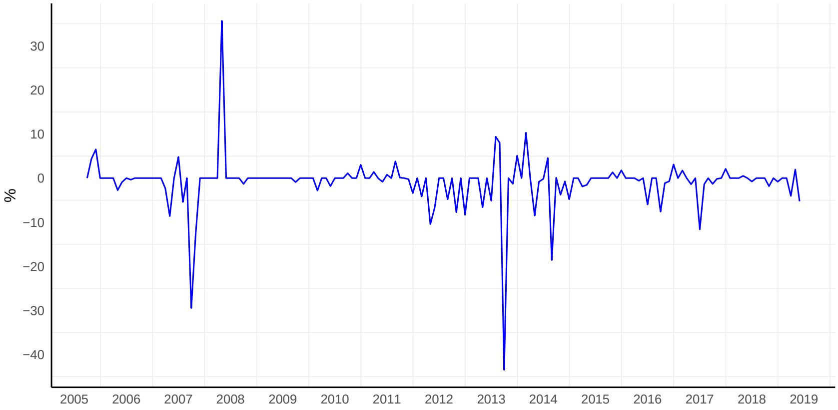
THE LOG OF THE CARBON POLICY SURPRISES SERIES



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SANITY CHECKS

MACRO ANALYSIS

- Different Lag Length : average & high emission countries
- controling for oil
- no trend : average
- mean group : average
- CPS surprises : average & high emission countries

FIRM-LEVEL ANALYSIS

- Scope 1
- Scope 2
- double interaction with leverage
- top 20
- micro vs macro: average & high emission countries

LITERATURE

- **Macroeconomic effects of climate policies** : Känzig (2023); Moessner (2022); Konradt and di Mauro (2021); Metcalf and Stock (2020); Ciccarelli and Marotta (2021); Santabarbara and Suárez-Varela (2022); Känzig and Konradt (2023)

- **Climate change and financial prices** : Hengge et al (2023); Bauer et al (2024), Giglio et al (2021); Bolton and Kacperczyk (2021); Hsu et al (2022); Ilhan et al (2021); Benmir et al (2024)

- **Macro-modelling of climate policies** : Bartz and Kelley (2008); Fischer and Springborn (2011); Annicchiarico and Di Dio (2015); Shapiro and Walker (2018); Hassler, Krussell and Olovsson (2021); Annicchiarico et al (2022); Fried et al (2022); Olovsson and Vestin (2023); Coenen, Lozej and Priftis (2023)

- **Climate change and central banks** : Rudebusch et al. (2019); Batten et al (2020); Rudebusch et al (2021);