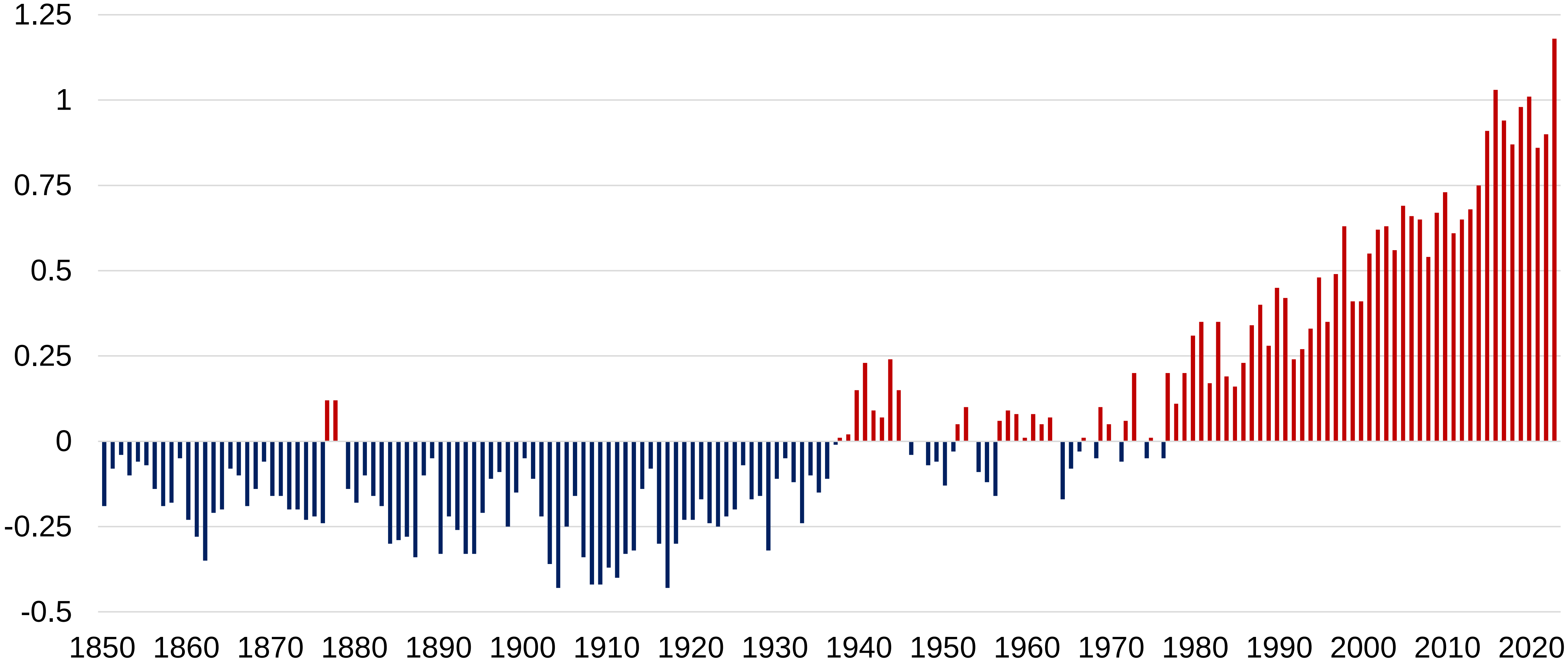
The 10 hottest years on record all occurred within the last 10 years.

Global Land and Ocean Surface Temperature Anomaly vs. Long-Term Average (NOAA 2023)



Universität Augsburg University

Drivers of Emission Prices - Disentangling Fundamental Shocks in the European Carbon Market

Andreas Maulberger and Andreas Rathgeber

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Fundamentals of the EU ETS: Participants acquire allowances via free allocation or via auctions; Political interventions can affect supply.

Supply Basics of EU ETS

The EU ETS is a Cap and Trade System:

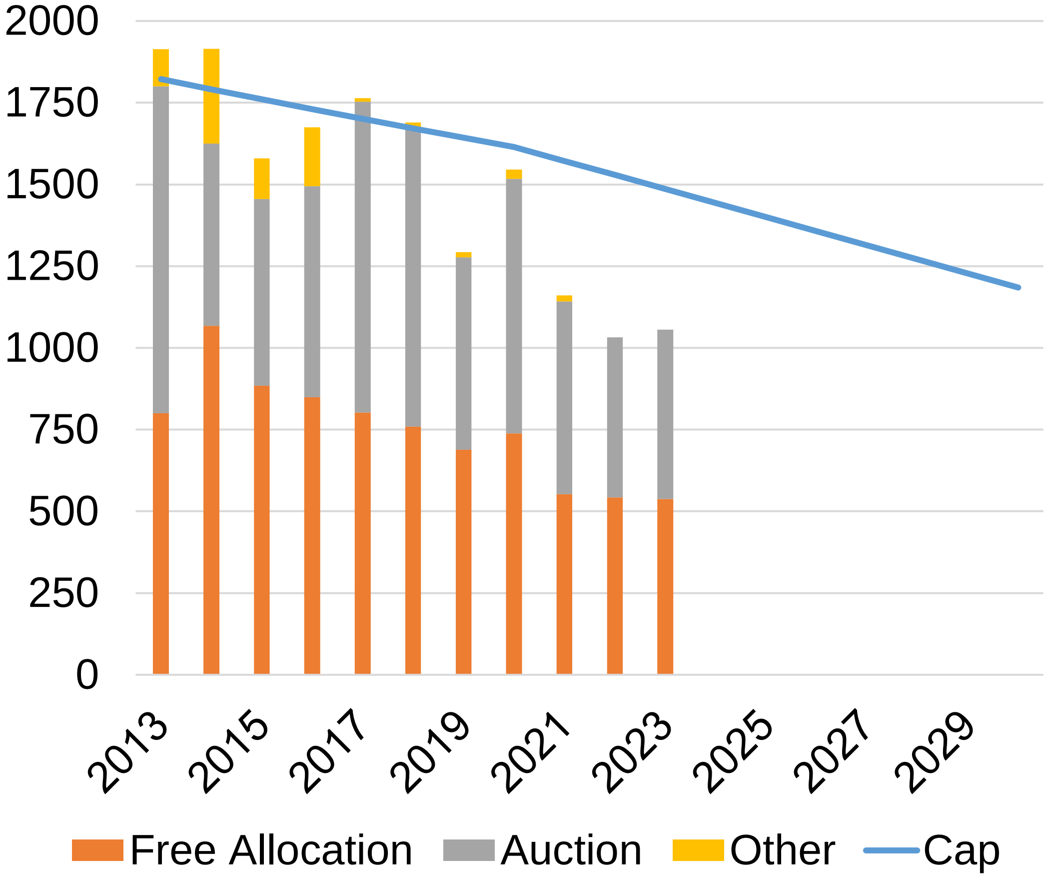
- Covered entities must offset their carbon emissions with allowances.
- Cap: Regulator sets a (decreasing) cap for overall emissions and allocates/sells allowances.

  → Primary Supply.
- Trade: Entities can trade unused allowances among each other.

  → Secondary Supply.

→ Political or operational interventions can affect short-term and long-term supply of carbon allowances.

Emission Cap and Supply Split-up



Source: European Environmental Agency (2023)

Fundamentals of the EU ETS: The power sector is a major buyer of carbon allowances.

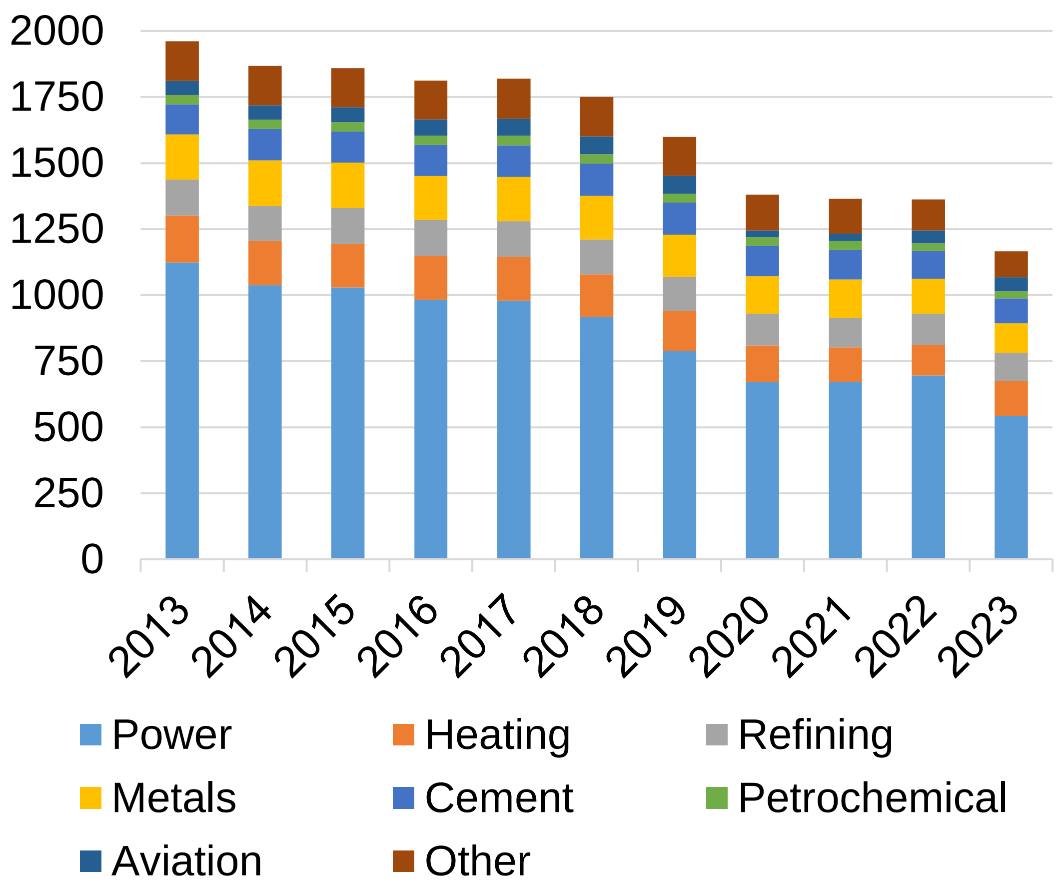
Demand Basics of EU ETS

- The electricity sector accounts for more than half of the carbon emissions within the scope.
  - Their emissions depend on overall demand for electricity and the electricity mix.
  - For fossil fuels, the fuel plays a significant role for the emission intensity: on average, coal is twice as carbon intensive as natural gas.
- Industrials emissions are closely connected to their activity level.

→ Weather effects, fuel market disturbances, or economic activity shocks might alter the demand for allowances.

→ Policy factors and speculation could play a role as well.

Historical Emissions of Covered Sectors



Source: European Environmental Agency (2023)

Literature: Research on price drivers in emission markets usually focused on policy or demand side factors in isolation.

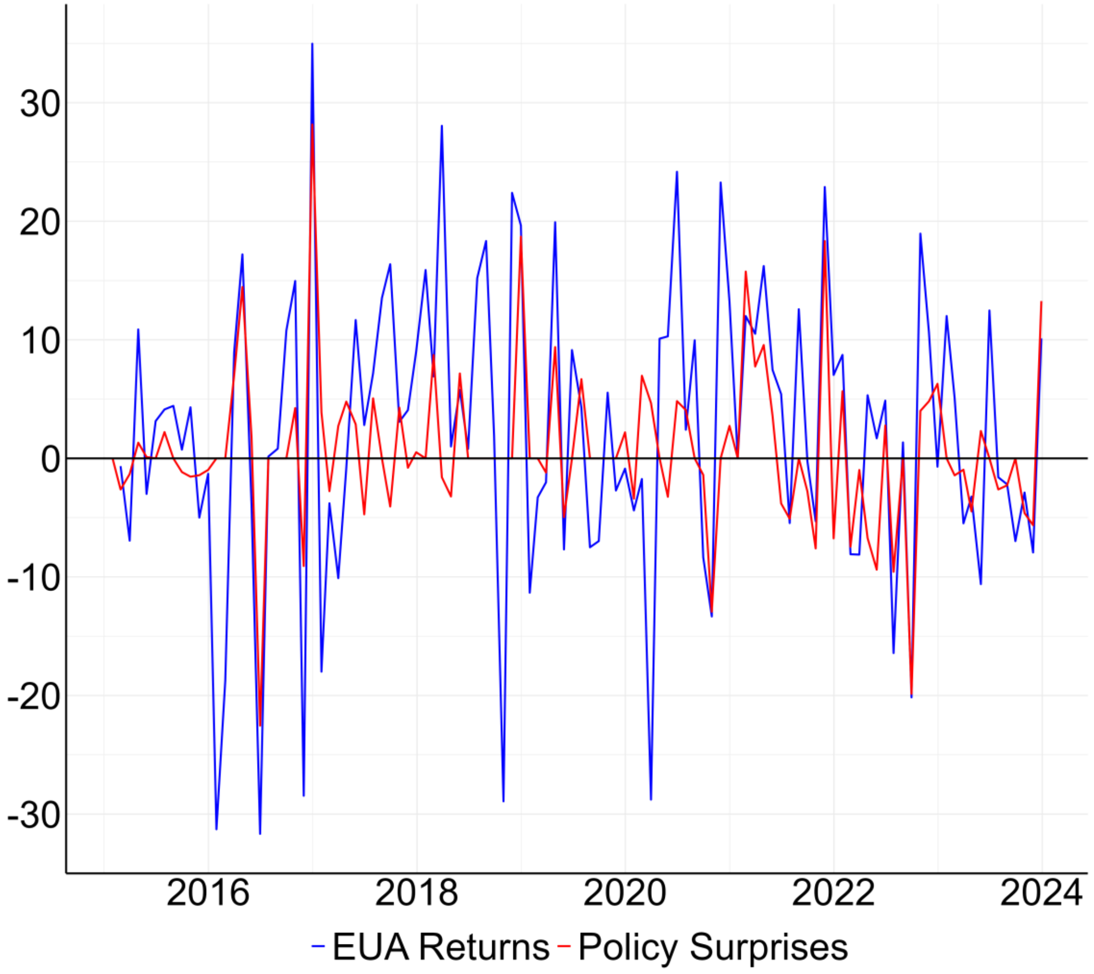
- Most empirical Papers focus either on policy or demand side factors separately:
  - Economic activity or stock markets are positively connected to EUA prices; Natural gas price increases tend to elevate EUA prices, vice versa for coal (e.g. Lovcha et al. 2022, Koch et al. 2014).
  - Policy interventions had mixed impact (e.g. Koch et al. 2016, Deeney et al. 2016).
- Bjørnland et al. (2023) combine the supply and demand side in one framework using a SVAR with sign restrictions and monthly data on EUA prices, industrial production, and temporally disaggregated annual verified emissions.
  - Long-term supply reduction led to price increase, declining economic activity and the industries transition towards carbon efficiency exerted downwards pressure.
- We present an alternative framework to disentangle fundamental shocks:
  - We include a granular split up of the demand side – especially focused on the electricity sector.
  - We explicitly account for policy events and their short-term price effects.
  - Rather than temporally disaggregating annual data, we utilize only data that is already available in a monthly frequency.

Data: Constructing a policy surprise series via a high frequency identification approach.

High frequency identification approach

- We hand-collected 144 relevant policy events within our observation period.
- Similar to Känzig (2023), we measure unexpected price changes in a window around the event to identify policy surprises.
- We consider price movements in a +/- 3-day window around the event.
- We isolate the effect of the policy event by adjusting for the expected return implied by demand side indicators, leaving us with the unexpected return.
- We sum up daily values within one month to end up with a monthly time series.

Policy Surprises vs EUA returns



Data: Measuring the electricity sector's realized and expected demand for carbon allowances.

Realized demand implied by the power mix.

- The electricity sector's emissions heavily depend on the composition of the electricity mix.
- We track the daily European electricity mix using the ENTSO-E database.
- Using the carbon intensities of the different fuel types, we calculate the realized emissions of the electricity sector.
- We account for different seasonally patterns by using Ollech's (2021) approach for daily seasonal adjustment.
- We calculate the average daily emissions over a month to aggregate to a monthly frequency.

Expected demand implied by fossil fuel prices.

- Per kWh of electricity, coal emits twice as much carbon as natural gas.

→ Switching between coal and gas can significantly alter demand for EUAs.

- Electricity producers will – within technological constraints – opt for the overall cheaper option.
- We include the fuel switching price – the hypothetical EUA price at which coal and gas are financially equally efficient for power plant operators at typical efficiency levels.

→ If EUA prices are below the fuel-switching price, electricity producers should opt for coal, they will emit more carbon, and demand for allowances should increase.

Empirical Methodology: SVAR with recursive identification inspired by Kilian's (2009) model for disentangling oil market shocks.

- An unrestricted VAR is given by:

$$y_t = \alpha + \sum_{i=1}^{p} A_i y_{t-i} + u_t \,,$$

- We apply a recursive identification approach to define structural shocks:

$$u_t = \begin{pmatrix} u_t^{policy} \\ u_t^{\Delta stoxx} \\ u_t^{\Delta FS} \\ u_t^{\Delta CO2} \\ u_t^{\Delta eua} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{policy\ shock} \\ \varepsilon_t^{economic\ activity-based\ demand\ shock} \\ \varepsilon_t^{fossil\ fuel\ market-based\ demand\ shock} \\ \varepsilon_t^{electricity\ market-based\ demand\ shock} \\ \varepsilon_t^{eua-specific\ shock} \end{pmatrix}$$

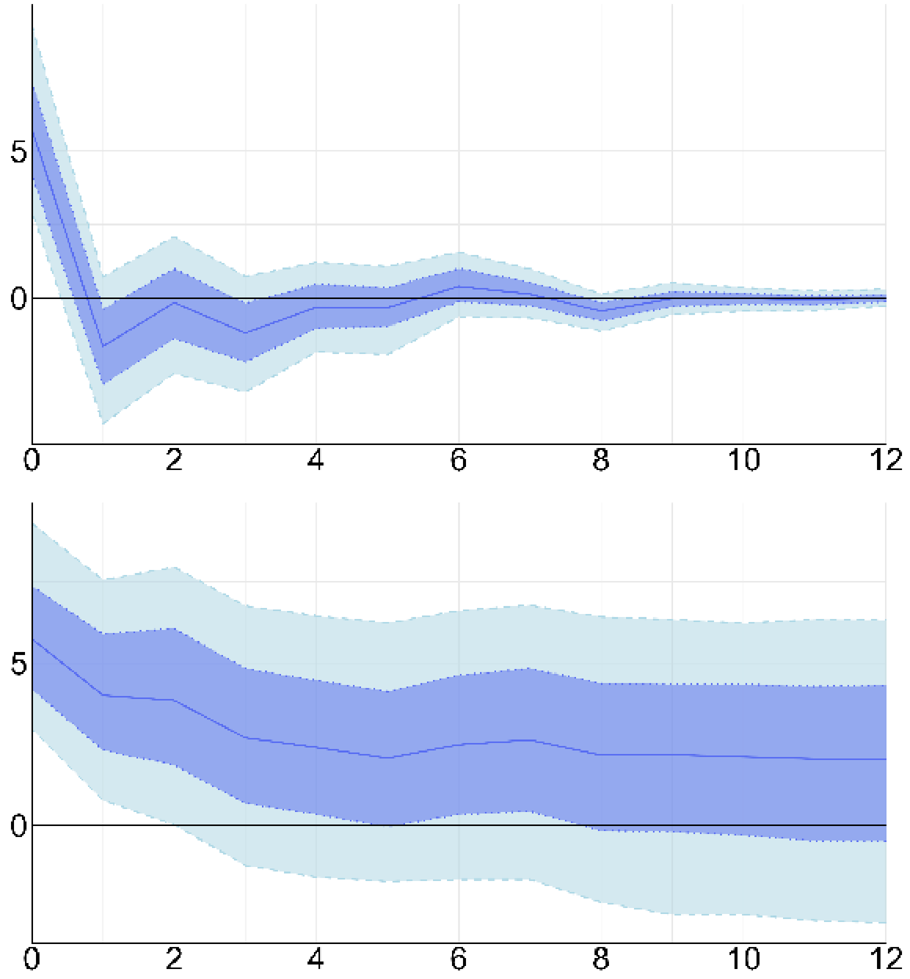
- Dependent on the ordering of the variables!

→ Variables can influence all following variables instantaneously but preceding variables only with a time lag.

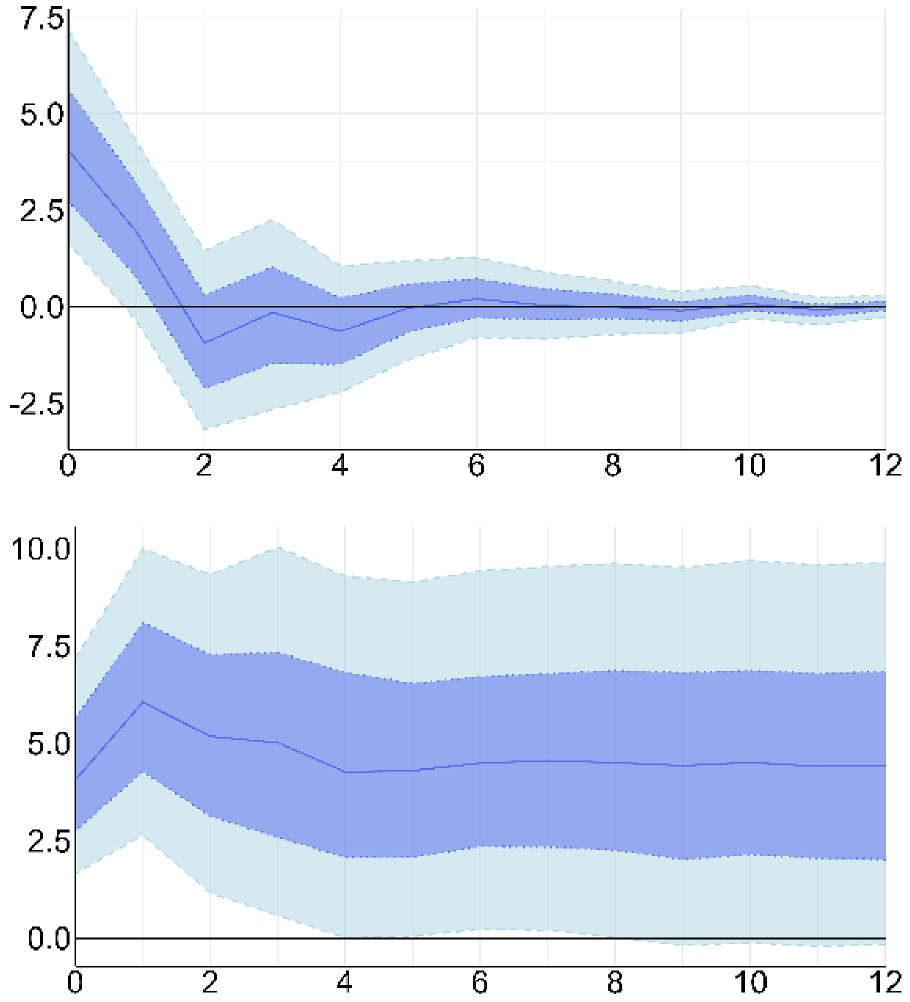
→ Order slow moving variables first and responsive variables in the end.

Results: Policy shocks and economic-activity shocks lead to instantaneous EUA price increases.

Policy Shock

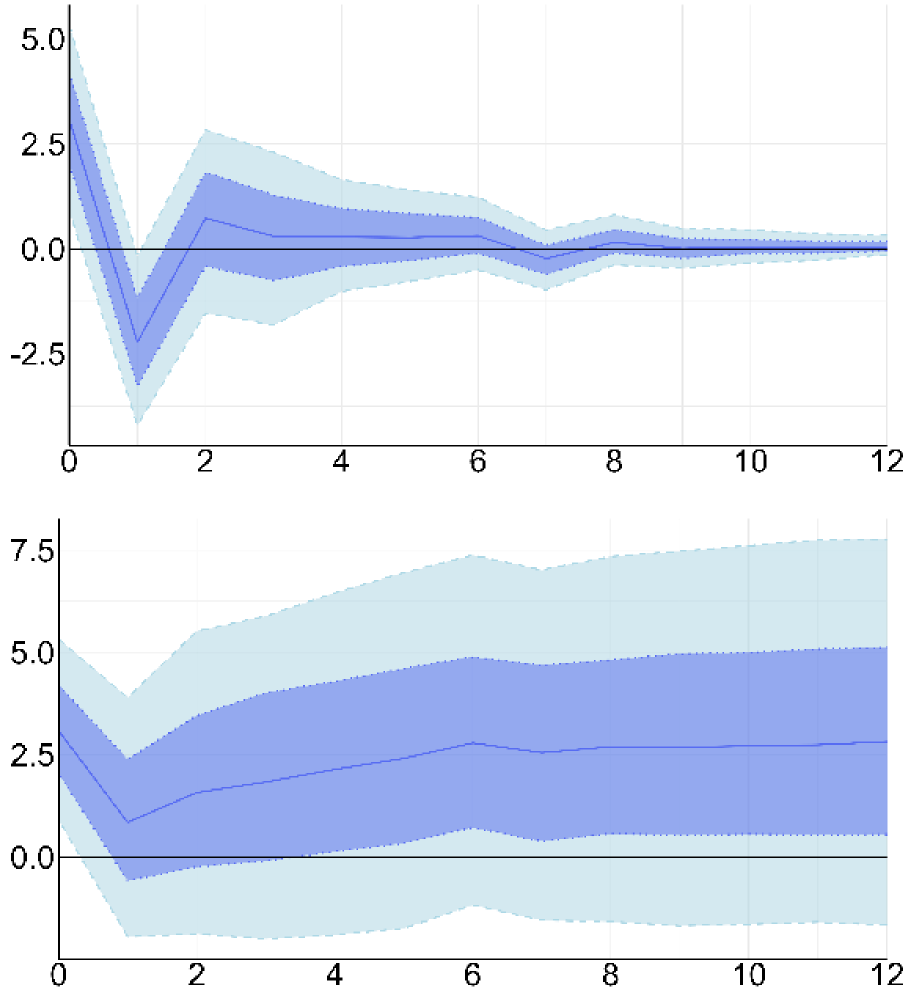


Economic activity-based demand shock

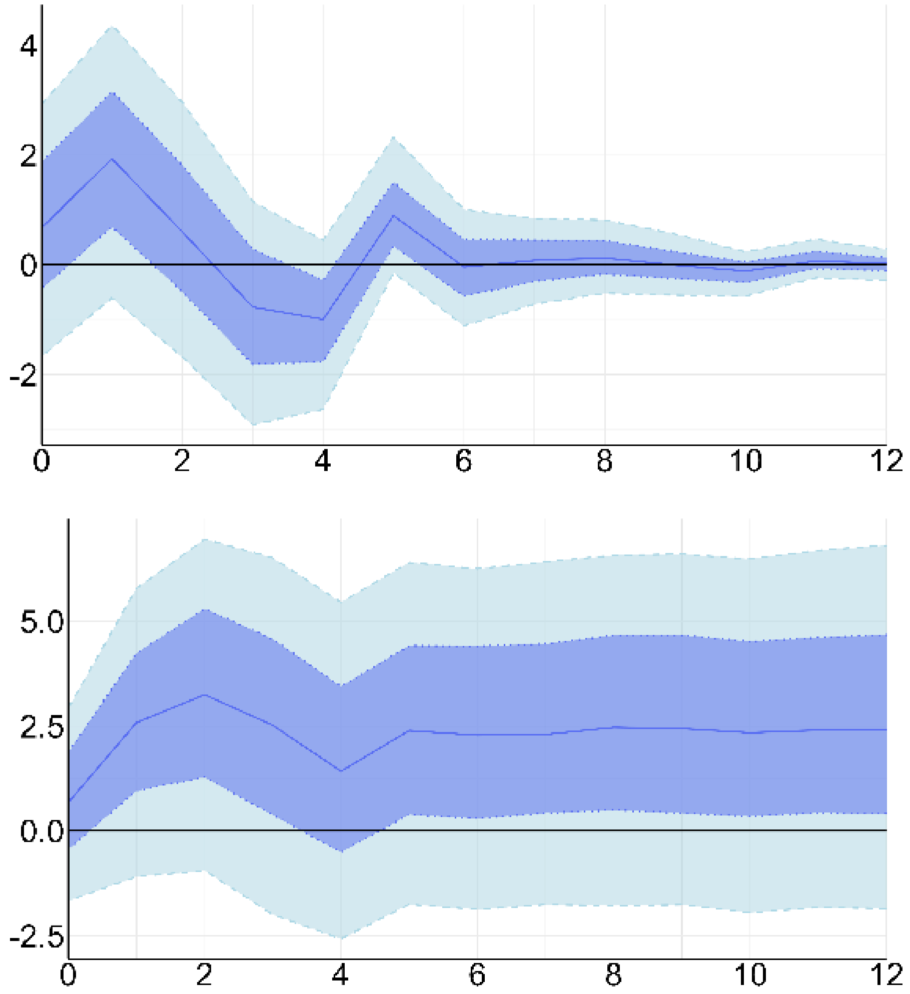


Results: EUA prices highly sensitive to fuel prices in the short-term. Realized demand shocks tend to have a lagging impact.

Fossil fuel market-based demand shock

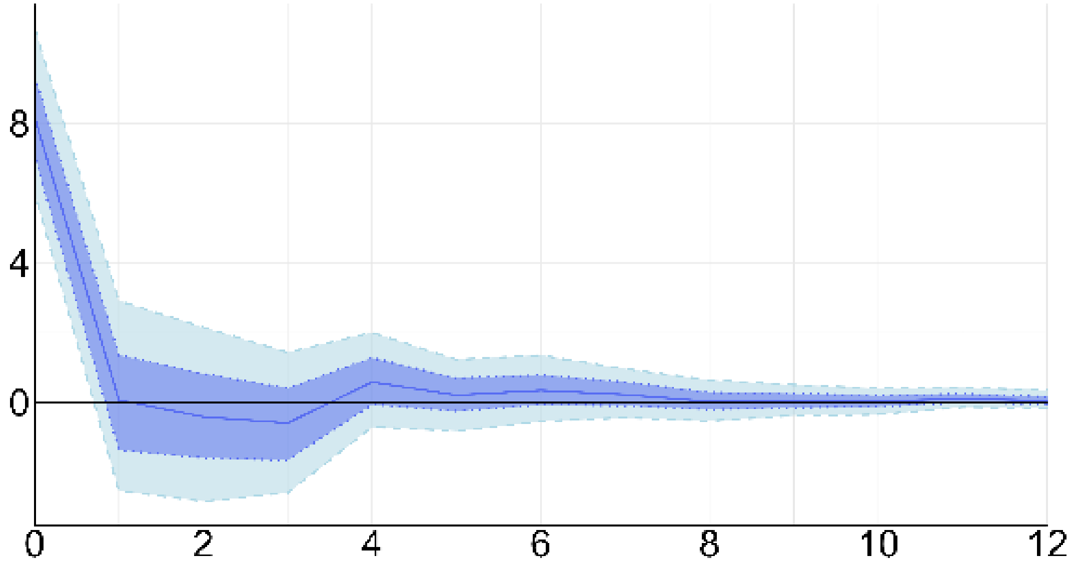


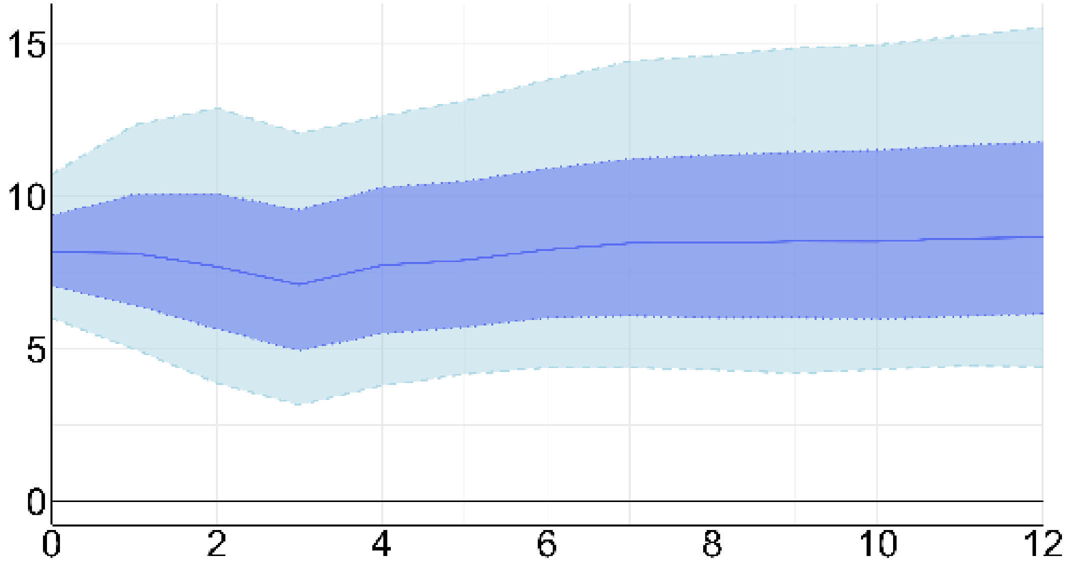
Electricity market-based demand shock



Results: Precautionary buying leads to permanent price increases.

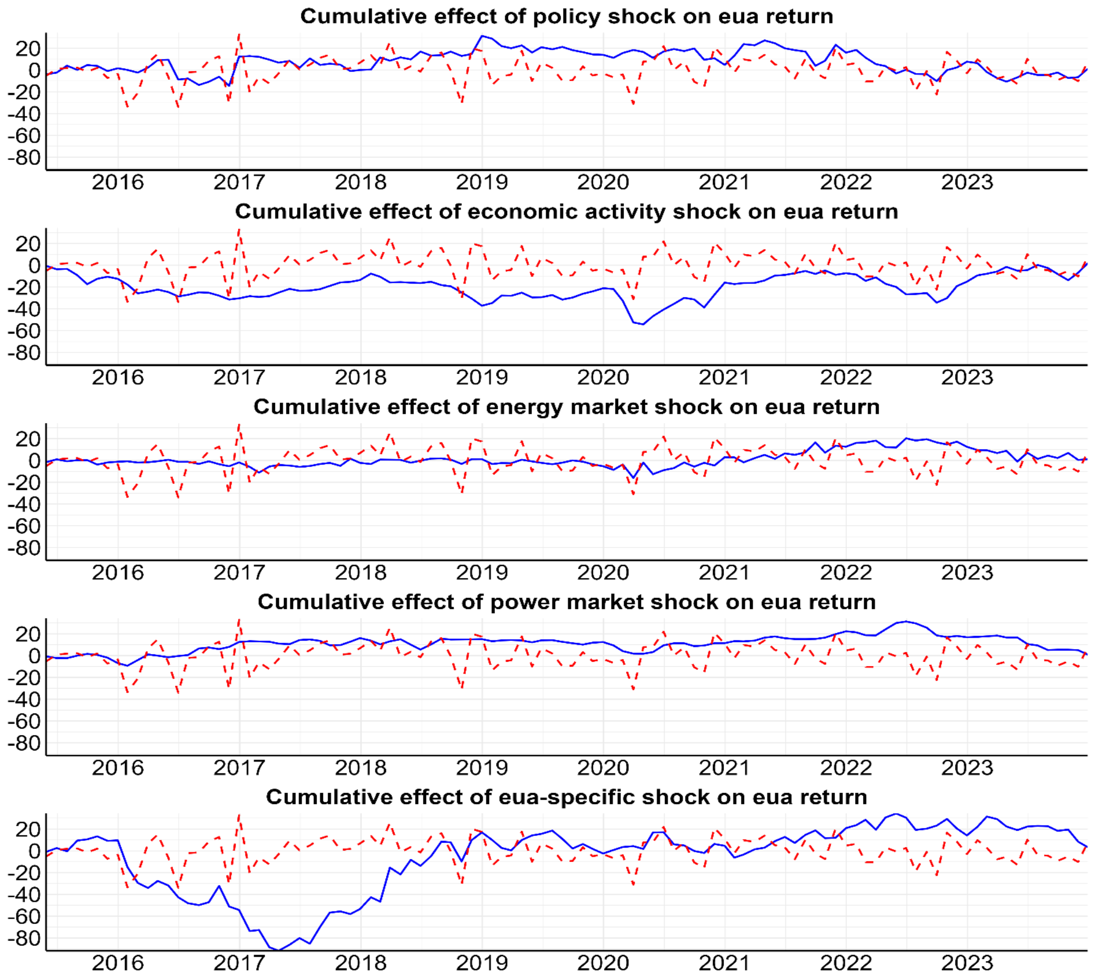
EUA-specific demand shock



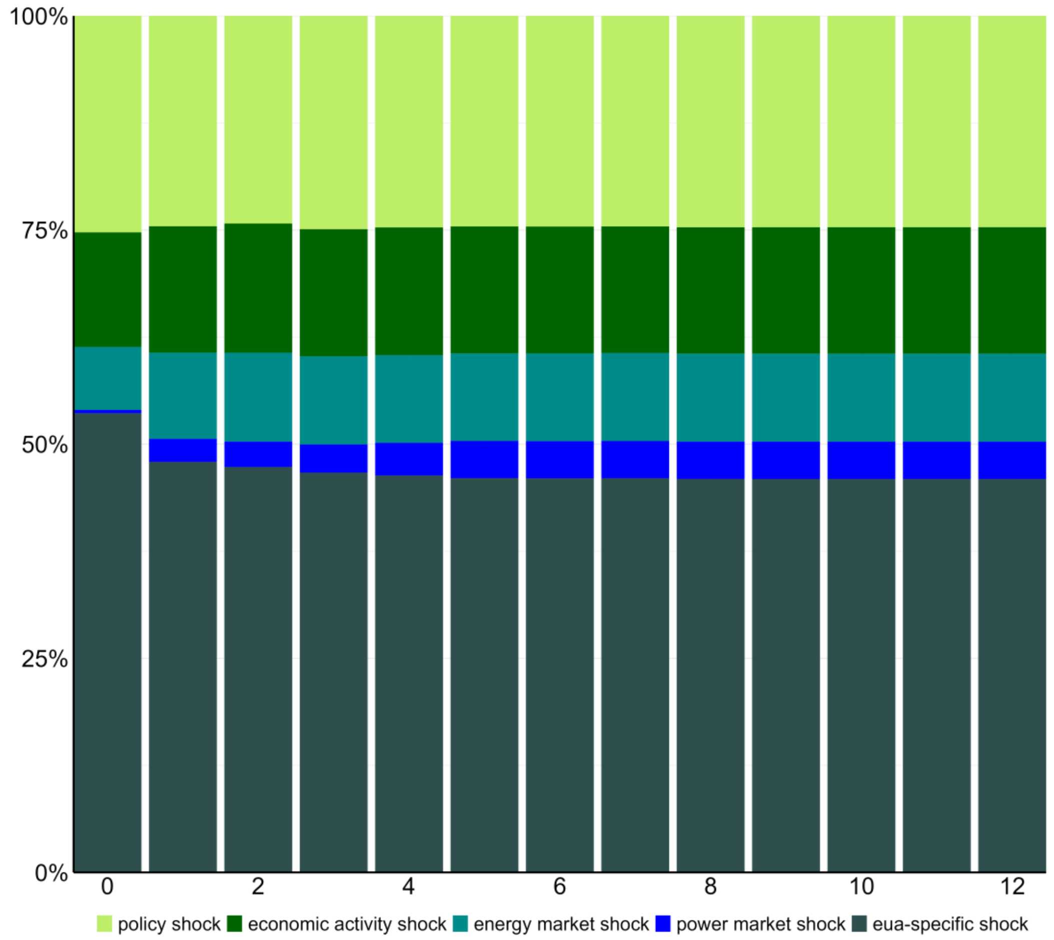


Results: EUA-specific shocks had less cumulative impact after 2019. FEVD highlights important role of precautionary buying.

Historical Decomposition of EUA returns.



FEVD of EUA returns.



Conclusion and Practical Implications.

- IRFs show that a positive shock to each of the five components leads to an increase in EUA prices.

  → The positive response to fossil fuel market-based shocks implies that EUAs correlate to traditional energy markets and can thus serve as a proxy to hedge portfolios excluding fossil fuels against energy market shocks.

- The FEVD shows that EUA market-specific demand shocks, hence, precautionary buying, account for the largest share (45.9%) of the EUA return variance. Policy shocks account for 24.7%, and economic-activity based demand shocks for 14.7%, fossil fuel market-based demand shocks for 10.3%, and electricity market based demand shocks for 4.4%

- A historical decomposition indicates a reduced influence of EUA-specific shocks post-2019.

  → This is potentially due to the introduction of the Market Stability Reserve (MSR), aligning EUA pricing more closely with demand-side factors by tackling excessive oversupply in the market.

  → Might be an important lesson for less mature Emissions Trading Systems that often tackle with oversupply.

  → Getting rid of excessive inventory could be a key to a well-functioning carbon pricing.

- Overall we observe that EUA price formation is driven by a complex interplay of policy and market dynamics. This necessitates a comprehensive understanding of both to effectively navigate the emissions market.

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