Weitzman Meets Taylor: ETS Futures Drivers and Carbpn Cap Rules

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Ex-Post Evaluation of Emission Trading – EUI

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Main question:

What are the drivers of the ETS carbon price?

Motivation

Implicit Carbon Price: Main Mitigation Tool

1. **Carbon pricing** is gaining momentum world wide

Source: International Carbon Action Partnership

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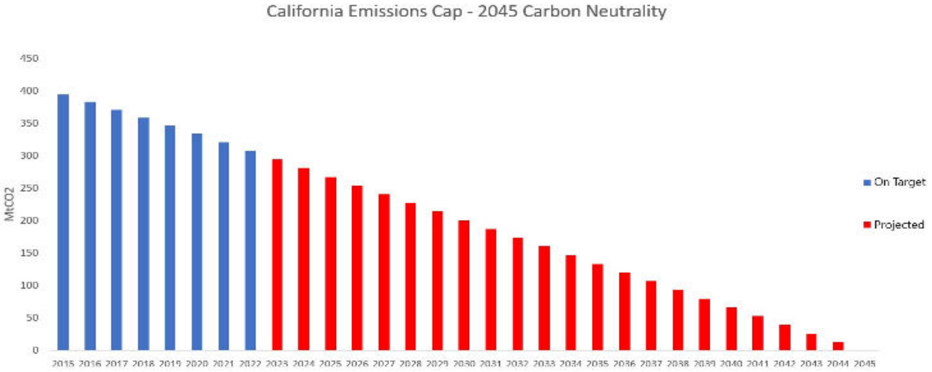
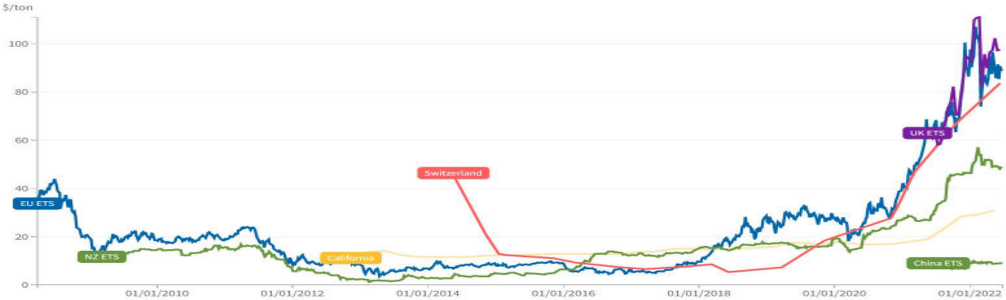
2. **Cap-and-Trade Market** is the major tool used in climate change mitigation



Constructed using International Carbon Action Partnership

Implicit Carbon Price: Main Mitigation Tool

1. **Carbon pricing** is gaining momentum world wide
2. **Cap-and-Trade Market** is the major tool used in climate change mitigation
3. The inherent **carbon price** is expected to increase to meet net-zero by 2050



World Cap and Trade System Carbon Prices (in USD)
Source: International Carbon Action Partnership

Business cycle implications of Carbon Pricing

- **Volatility** of the implicit carbon price could induce:
  - "Business cycle uncertainty" costs for firms
  - Financial stability concerns?

Financial Market Unbalances

Where We Stand

- **Cap-and-trade markets** as privilege tool to mitigate carbon

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- Potential **impacts** on business cycle, financial stability, and welfare costs associated with a high and volatile price of carbon

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$\Downarrow$

Need for a Macro-finance Framework:

- i) ETS cap policy
- ii) Energy market
- and iii) Higher frequency estimation

Paper Objectives and Main Results

What We Do

In this paper, we provide new evidence on

i) **Empirical:**

- How to estimate the ETS price drivers using a novel strategy

ii) **Theoretical:**

- How to implement carbon cap rules to reduce uncertainty over the business cycle

Main Paper Message

- The two main drivers of the EU ETS are **Abatement shocks** and **Climate Sentiment shocks**
- The EU ETS is found to be significantly **more volatile** than the SCC
- Carbon cap rule could **reduce this volatility**

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2. We use a cap policy and not a full cap-and-trade micro structure
3. We model energy as composit, whereby energy can get greener and do not explicitly model different sources of energy
4. We consider the EU as a closed economy (i.e. no carbon leakage and full cooperation)

Relevant Literature: Empirical

- **Carbon pricing and market frictions:** Goulder [2013], Jenkins [2014], Metcalf [2019], Shapiro and Metcalf [2021], and Bernard and Kichian [2021], Kanzig [2021], among others

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  ⇒ **How we differ**: We estimate abatement cost shocks and climate sentiment shocks using a novel strategy while we don't have data on abatement

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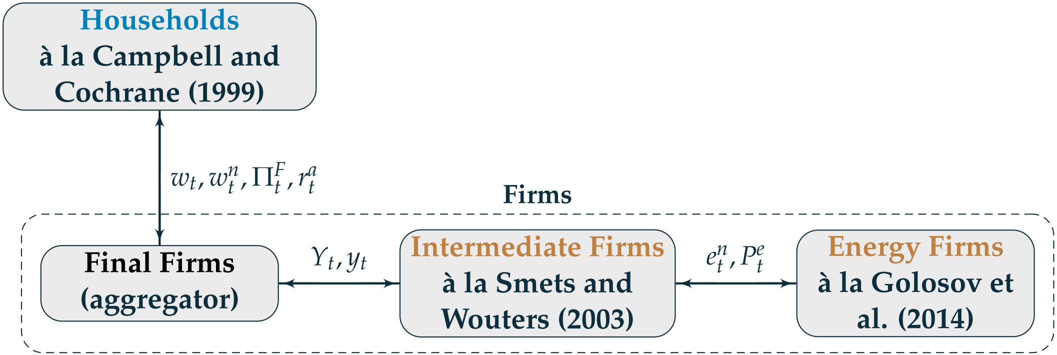
  ⇒ **How we differ**: We make use of Bayesian estimation to investigate the ETS drivers

E-DSGE

Households
à la Campbell and Cochrane (1999)


Households
à la Campbell and Cochrane (1999)
$w_t, w_t^n, \Pi_t^F, r_t^a$
Firms
Final Firms (aggregator)
Y_t, y_t
Intermediate Firms
à la Smets and Wouters (2003)
e_t^n, P_t^e
Energy Firms
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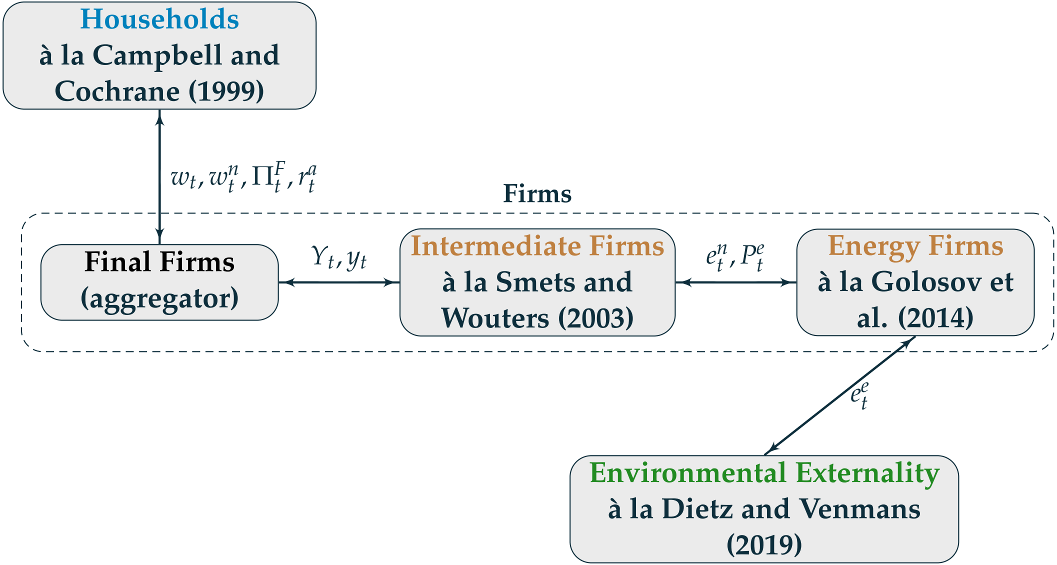
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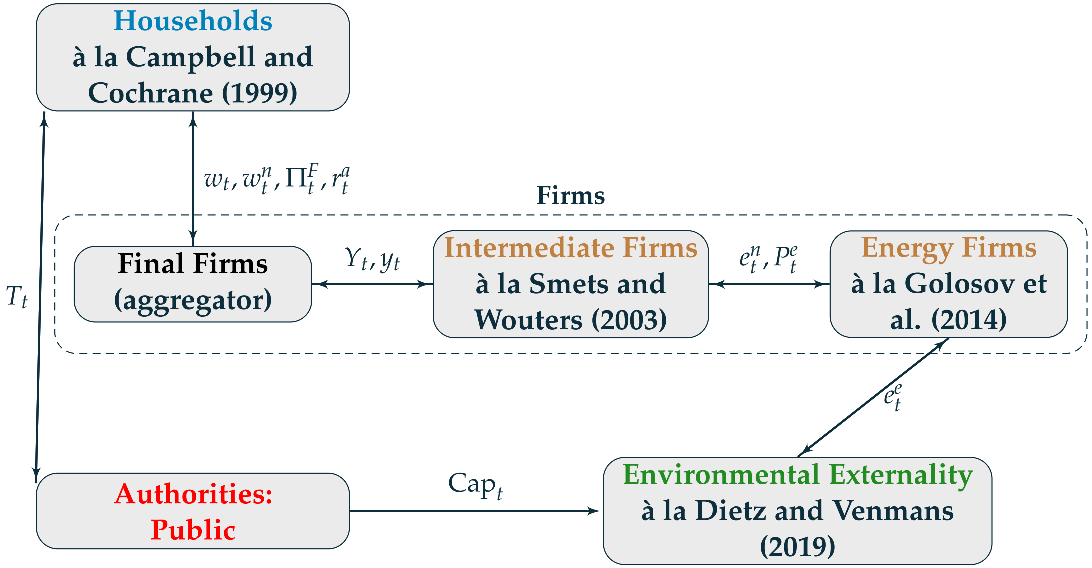
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T_t
e_t^e
Authorities: Public
Cap_t
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à la Dietz and Venmans (2019)

Full Model

- Environmental Externality: ⏩ more
- Energy Firms: ⏩ more
- Intermediate Firms: ⏩ more
- Final Firms: ⏩ more
- Households: ⏩ more
- Fiscal Authority: ⏩ more
- Monetary Authority: ⏩ more

ENVIRONMENTAL EXTERNALITY: CLIMATE DYNAMICS

- Following **Dietz and Venmans (2019)**, CO_2 cumulative emissions X_t in the atmosphere is the sum of domestic E_t and international E_t^{Row} emission flows:

$$\dot{X}_t = E_t + E_t^{Row} \tag{1}$$

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In our framework, the total emissions flow reads as:

$$E_t = \int_0^1 e_{j,t}^e dj \tag{2}$$

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- Temperature T_t^o reads as:

$$\dot{T}_t^o = \phi_1(\phi_2 X_t - T_t^o) \tag{3}$$

Energy and Non-Energy Firms: Production

Our economy is comprised of two sectors: $\{e^n, y\}$

- The energy firms employ capital and labour to produce energy, which is then supplied to the intermediate non-energy firms (all other sectors):

$$e^n_{j,t} = A^n_t {k^n_{j,t}}^{\alpha_n} {l^n_{j,t}}^{1-\alpha_n} \tag{4}$$

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- Intermediate non-energy firms produce goods using energy, capital and labour as follows:

$$y_{j,t} = A_t \underbrace{d(T^o_t)}_{\text{Convex Damages}} {k^y_{j,t}}^{\alpha_1} {e^n_{j,t}}^{\alpha_2} {l^y_{j,t}}^{1-\alpha_1-\alpha_2} \tag{5}$$

where A_t and A^n_t the TFPs are driven by a Brownian motion B_t (e.g. $dA_t = \mu(A_t)dt + \eta(A_t)dB_t$).

Energy Firms: Emissions and Abatement Investment

- Energy firms emit CO_2 emissions $e^e_{j,t}$ when they produce goods:

$$e^e_{j,t} = \underbrace{\left(1 - \mu^n_{j,t}\right)}_{\text{Abatement efforts}} \varphi^n_t e^n_{j,t} \tag{6}$$

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- Abatement technology is costly for firms and is assumed to be a fraction of their total production:

$$\underbrace{F(\mu^e_{j,t})}_{\text{Convex cost function}} = \theta_1 {\mu^e_{j,t}}^{\theta_2} \tag{7}$$

Energy and Non-Energy: Profit

- The energy producers' profit reads as follows: more

$$\Pi^E_{j,t} = \underbrace{p^e_t e^n_{j,t}}_{\text{energy price and output}} - \underbrace{w^n_t l^n_{j,t}}_{\text{labour wages}} - \underbrace{i^n_{j,t}}_{\text{capital investment}} - \underbrace{f(\mu^n_{j,t}) e^n_{j,t}}_{\text{abatement cost}} - \underbrace{\epsilon^\tau_t \tau_t e^n_{j,t}}_{\text{carbon price}} \tag{8}$$

where ϵ^τ_t is a carbon price shock driven by a Brownian motion B_t $(d\epsilon^\tau_t = \mu(\epsilon^\tau_t)dt + \eta(\epsilon^\tau_t)dB_t)$.

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- The non-energy firms' profit reads as: more

$$\Pi^F_{j,t} = y_{j,t} - w^y_t l^y_{j,t} - i^y_{j,t} \quad (9)$$

HOUSEHOLDS

- The households choose consumption expenditures c_t:

$$\max_{\{c_t\}} E_0 \int_0^\infty \epsilon_t^B e^{-\rho t} u(C_t) dt$$

where $\rho \geq 0$ is the time discount factor and $u(C_t)$ is CRRA. ϵ_t^B is a preference shock driven by a Brownian motion B_t ($d\epsilon_t^B = \mu(\epsilon_t^B)dt + \eta(\epsilon_t^B)dB_t$).

- The representative household budget constraint reads:

$$\dot{B^G}_t = r_t B_t^G + w_t^y L_t^y + w_t^n L_t^n + \sum_s \Pi_t^s + T_t - C_t$$

Fiscal Authorities

- The public authority sets an emissions cap as follows:

$$E_t = \epsilon_t^{Cap} \text{Carbon Cap}_t \tag{10}$$

where ϵ_t^{Cap} is a climate sentiment shock driven by a Brownian motion B_t ($d\epsilon_t^{Cap} = \mu(\epsilon_t^{Cap})dt + \eta(\epsilon_t^{Cap})dB_t$).

- The government uses the environmental policy revenues $\tau_t E_t$ to finance exogenous expenditures G_t and transfers to households T_t:

$$G_t + T_t = \tau_t E_t \tag{11}$$

Estimation Strategy and Data

- We estimate our model structural shocks, trends, and risk aversion, using Bayesian methods on monthly EU data from January 2013 to December 2018 corresponding to the third phase of the EU Emissions Trading System (ETS)
- We use date on carbon price, industrial production, consumption surveys, energy production, and CO_2 emissions
- We estimate our model's parameters using the Metropolis Hastings algorithm to sample from the distribution. We use four chains of 50,000 draws each.

Estimated Parameters

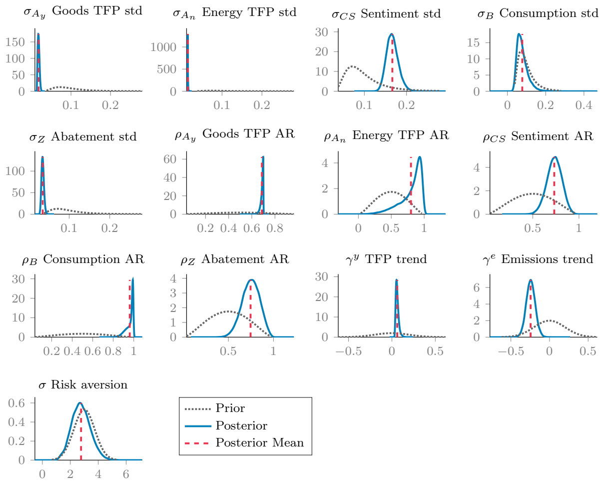

Figure: Priors, posteriors, and posterior means

Calibration

Table: Calibration

Parameter	β	α_1	α_2	α_n	δ	$\frac{g}{y}$	a	b	φ	η	ζ_1^o	ζ_2^o	θ_1	θ_2
Value	0.999	0.333	0.040	0.333	0.008	0.220	1.000	0.040	0.830	0.002	0.500	0.001	0.100	2.700

Table: Moments matching

Variable	Label	Model Steady-State	Model Conditional Mean	Data	Source
ETS Mean Carbon Price	$E(\tau)$	7.39	18.31	7.54	World Bank
Emission to Output Ratio	$E\left(\frac{E}{Y}\right)$	0.24	0.20	0.24	Authors' Calculations
Share of Energy in Output	$E\left(\frac{p^n Y^n}{Y}\right)$	0.04	0.04	0.04	Authors' Calculations
Temperature	$E(T^o)$	1.00	1.00	1.00	NOAA
Cumulative Emission	$E(X)$	801	803	800	Copernicus (EC)

Results 1a: Uncovering Drivers in the ETS Futures Market

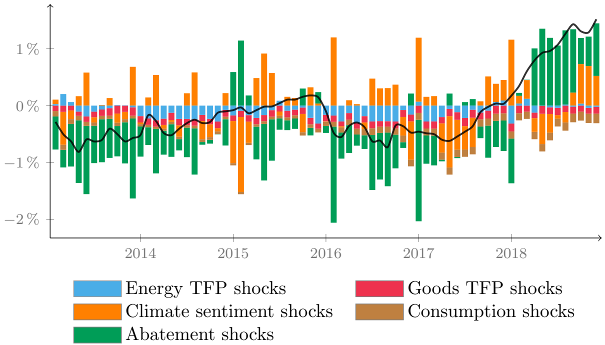

Figure: ETS Futures Historical Decomposition

Notes: The figure shows the path of the ETS carbon price (black line) decomposed into various drivers over the estimated period (2013 – 2019).

Results 1b: Uncovering Drivers in the ETS Futures Market

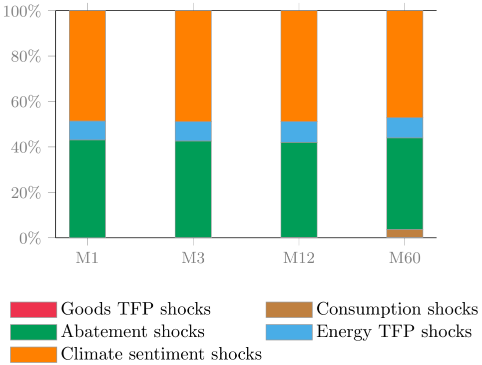

Figure: ETS Futures Variance Decomposition

Notes: The figure shows the ETS price variance decomposition conditional on different horizons: one month, three months, one year, and five years. This is the theoretical variance decomposition of the carbon price, taking into account the estimated variances of shocks.

How is The ETS Compared to the SCC

- We proceed to compare the estimated carbon price with an optimal benchmark, which assumes that a social planner would set a tax to the social cost of carbon.
- To simulate the optimal scenario, we use the estimated parameters and shock series and replace our carbon price equation with the social cost of carbon.
- We also eliminate the climate sentiment shock since there is no uncertainty about the joint path of carbon price and emissions in this scenario.

RESULTS 2: ETS AND OPTIMAL POLICY

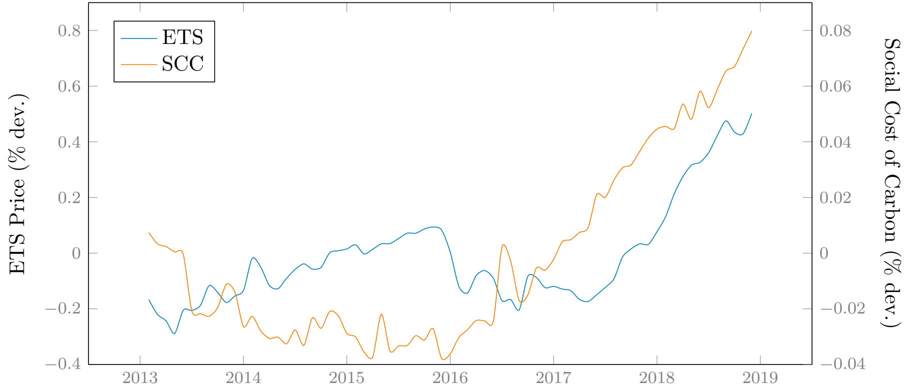

Figure: ETS Price vs SCC Variations

Notes: The figure shows the deviations of the estimated ETS price and the counterfactual SCC in percentage deviations from their respective steady states.

Carbon Cap Rules

- We propose a carbon cap rule that can be considered the equivalent of a Taylor rule for environmental policy.
- In our model, the de-trended carbon cap is no longer fixed and can deviate slightly from the value consistent with the Paris Agreement in the short run. The equation for the carbon cap rule becomes:

$$\text{Cap Level}_t = \overline{\text{Cap Level}} + \phi_e * 100(e_t - \bar{e}) + \phi_z * 100(z_t - \bar{z}),$$

where $\bar{e}$ and $\bar{z}$ are the de-trended steady-state emissions and abatement cost, respectively.

Results 3a: Carbon Cap Rules (CCR)

	ETS Cap Policy Estimated Column (1)	Social Cost of Carbon Optimal Column (2)	Carbon Cap Rule $\phi_z = 13.11$ and $\phi_e = .15$ Column (3)
Welfare (% change w.r.t. SCC)	-1.74 %	0 %	-1.74 %
Welfare (Std. Dev.)	1.03 %	1.03 %	1.02 %
Emissions (Std. Dev.)	3.18 %	6.48 %	4.54 %
Abatement Cost (Std. Dev.)	19.13 %	11.88 %	11.94 %
Marginal Abatement Cost (Std. Dev.)	21.85 %	15.95 %	15.54 %
Carbon Price (in euros)	17.49	29.12	18.07
Carbon Price (Std. Dev.)	18.66 %	2.96 %	4.24 %

Table: Policy Scenarios Estimated Second Moments

Notes: The table reports various moments under a set of scenarios. The first column corresponds to the estimated model, the second column corresponds to the counterfactual optimal case, and the third column corresponds to the counterfactual carbon cap rule. The carbon cap rule is $\text{Cap Level}_t = \overline{\text{Cap Level}} + \phi_e * 100(e_t - \bar{e}) + \phi_z * 100(z_t - \bar{z})$.

Results 3b: ETS, SCC, and CCR Variation

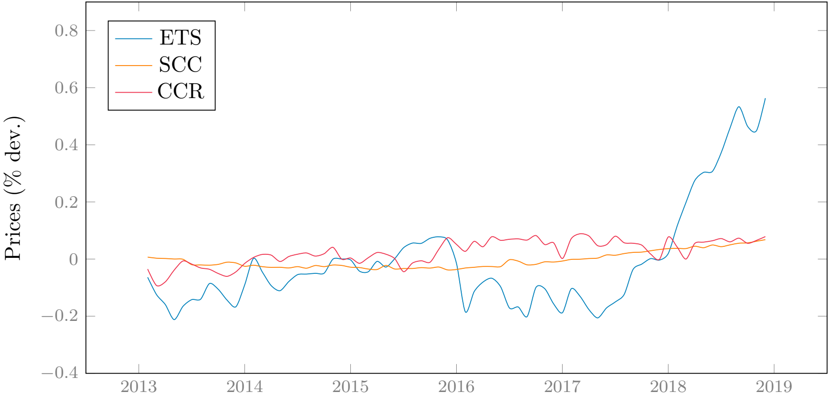

Figure: ETS vs SCC vs CCR Variations

Notes: The figure shows the deviations of the estimated ETS price, the counterfactual SCC, and the counterfactual CCR in percentage deviations from their respective steady states.

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2. Our results highlight that **abatement cost shocks**, **climate sentiment shocks** are the main factors driving carbon pricing
3. We also demonstrate that reducing price uncertainty can help close the gap with respect to the optimal policy

THANK YOU!