Allowance prices in the EU ETS
- price drivers and the recent upward trend -

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Development of EUA prices in Phases II and III

EUA December futures from Jan 2008 to Oct 2018
EU ETS empirical (price drivers) literature

• **Theory**: most important price drivers are *coal prices* (-) and *gas prices* (+). Potentially, economic activity/oil prices (+), weather variables (+) and renewables (-)

• **Practice**: hard to find empirical evidence

• **Previous studies**:
  - ✓ find insignificant coefficient of coal (e.g. Hintermann (2010), Koch et al. (2014))
  - ✓ split the sample in parts, include dummy variables
  - ✓ find a positive and significant effect of gas
  - ✓ allow for different pricing regimes (Lutz et al. (2013))
  - ✓ find positive effect of coal (Lutz et al. (2013), Rickels et al. (2014))

• so far, no paper has looked empirically at the *recent upward trend*
Our analysis - Overview

• **Step 1**: fundamental price drivers
  ✓ a possible explanation for previous findings might be an unstable relationship between the allowance price and its fundamental drivers
  ✓ we look at the relationship in a time-varying regression approach
  ✓ we find evidence of time variation in the coefficients
  ✓ hypothesis: fundamentals become more relevant drivers when allowances get scarce(r)?

• **Step 2**: testing for explosive behavior
  ✓ we empirically investigate the recent upward trend with the help of Phillips, Shi and Yu (2015)’s ”bubble detection test”
  ✓ we find clear evidence of unusual, explosive behavior
Step 1: Price drivers

- we use the following model:

\[ r_{EUA,t} = \beta_{0,t} + \beta_{1,t} x_{1,t} + \beta_{2,t} x_{2,t} + \cdots + \beta_{m,t} x_{m,t} + \epsilon_t, \]

- \( x_{j,t} \) (for \( j = 1, \ldots, m \)) represent the stationary price drivers
- we consider (a) \( \beta_{j,t} = \beta_j \) and (b) \( \beta_{j,t} = \beta_j(t) \)
- estimation in (a) OLS, in (b) nonparametric kernel methods
- 95\% confidence intervals in (b) obtained using an autoregressive wild bootstrap approach

\[ \Rightarrow \] flexible, time-varying approach, robust to serial correlation and heteroskedasticity
The Data

• $y_t = EUA_t$ (Emission Allowances, Dec Futures from EEX)
• $x_t = \{\text{coal}_t, \text{gas}_t, \text{oil}_t, \text{stocks}_t, \text{temperature}_t\}$
  ✓ month-ahead coal futures (API2)
  ✓ month-ahead gas futures (TTF)
  ✓ month-ahead oil futures (Brent)
  ✓ Euro STOXX50/STOXX600 index
  ✓ temperature data from ECA&D

• weekly data from January 2008 to October 2018
  ✓ Phases II and III

• >500 observations

• results are obtained using returns rather than price data due to nonstationarity
The Data

(a) Coal

(b) Gas

(c) Oil

(d) Stoxx 50

Marina Friedrich and Michael Pahle  Transformation Pathways
## Linear Regression

### OLS regression results

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
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<th>(2)</th>
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<th>(3)</th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>$\beta_j$</td>
<td>$se_{NW}$</td>
<td>$p$-value</td>
<td>$\beta_j$</td>
<td>$se_{NW}$</td>
<td>$p$-value</td>
</tr>
<tr>
<td>Coal</td>
<td>-0.119</td>
<td>0.094</td>
<td>0.206</td>
<td>-0.061</td>
<td>0.097</td>
<td>0.528</td>
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<tr>
<td>Gas</td>
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<td>0.012</td>
<td>0.198</td>
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<tr>
<td>Oil</td>
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<td>0.069</td>
<td>0.002</td>
<td>–</td>
<td>–</td>
<td>–</td>
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<tr>
<td>Temp</td>
<td>-0.001</td>
<td>0.001</td>
<td>0.572</td>
<td>-0.001</td>
<td>0.001</td>
<td>0.450</td>
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<tr>
<td>Stoxx 50</td>
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<td>–</td>
<td>–</td>
<td>0.139</td>
<td>0.103</td>
<td>0.031</td>
</tr>
<tr>
<td>Stoxx 600</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

**Table:** Linear regression results. The dependent variable is the return on EUAs and the set of (stationary) regressors changes in each specification. The standard errors are of the Newey-West type.
Results - Time-varying coefficients

(e) Trend

(f) Coal

(g) Gas

(h) Oil
Step 2: The recent upward trend

• we use the recently developed right-sided unit root tests by Phillips, Shi and Yu (2015)

• \( H_0 \): unit root (\( \beta = 0 \)) vs. \( H_1 \): explosive behavior (\( \beta > 0 \))

• based on the regression model, for \( t \in [\lfloor r_1 T \rfloor, \lfloor r_2 T \rfloor] \)

\[
\Delta y_t = \alpha_{r_1,r_2} + \beta_{r_1,r_2} y_{t-1} + \sum_{j=1}^{k} \phi_{r_1,r_2}^{j} \Delta y_{t-j} + \epsilon_t,
\]

• the tests compare \( \text{ADF}_{r_2}^{r_1} \) statistics on a forward and backward expanding window (GSADF)
  ✓ Generalized Supremum Augmented Dickey-Fuller test

• date stamping: calculate for every end point \( r_2 \) (BSADF_{r_2})
  ✓ Backward Supremum Augmented Dickey-Fuller test
Results - GSADF Tests

<table>
<thead>
<tr>
<th>Test statistics</th>
<th>Critical values (90%, 95%, 99%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series</td>
<td>GSADF</td>
</tr>
<tr>
<td>EUA</td>
<td>3.998</td>
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<tr>
<td>Coal</td>
<td>1.676</td>
</tr>
<tr>
<td>Gas</td>
<td>1.299</td>
</tr>
<tr>
<td>Oil</td>
<td>2.722</td>
</tr>
<tr>
<td>Stoxx 50</td>
<td>0.782</td>
</tr>
<tr>
<td>Stoxx 600</td>
<td>0.953</td>
</tr>
</tbody>
</table>

Table: The GSADF test statistics with simulated critical values (2000 repetitions) and bootstrapped critical values (5000 repetitions).

⇒ unit root null hypothesis rejected for EUA and oil price series
Results - Date Stamping - BSADF Test EUA

test statistics (blue) – critical values (orange)
Results - Date Stamping - BSADF Test Oil

test statistics (blue) – critical values (orange)
Step 2 - Summary

- The test detects an ongoing period of exuberance in line with the recent upward trend, starting in March 2018.
- This is by far the longest of such periods found by the test.
- Previous study looks at daily data from 2005 to 2014 and finds explosive periods to last at most a few days (Creti and Joëts (2017)).
- Test detects no simultaneous explosive behavior in fundamental price drivers.
Overall Summary

- we look at the effect of the classical price drivers of EUA prices
- we find time variation and/or periods of insignificance
- we also find a significant (unexplained) upward trend since the end of 2017
- a formal test provides evidence of ongoing explosive behavior
- fundamentals do not seem to provide an explanation for this
- adaptation to new equilibrium price level that can appear explosive (Harvey et al. 2016), or overreaction to reform leading to a speculative bubble?
Contagious stories?

• many bubble-generating mechanisms identified in behavioral finance literature, including contagious stories
  ✓ "rapid price increases boost the contagion rate of popular stories justifying that increase, heightening demand and more price increases" (Shiller 2017)
  ✓ "EUAs are structurally bullish [due to MSR], just waiting for [...] any story that reinforces the argument." (CarbonPulse)

• analysts forecasts about reform impacts as contagious stories?


Backup - Estimation

- estimation is performed using nonparametric, local linear kernel estimator (Cai (2007)) \( \hat{\theta} = (\hat{\beta} \quad \hat{\beta}^{(1)})' \)

\[
\hat{\theta}(\tau) = \left( \begin{array}{ccc}
S_{n,0}(\tau) & S'_{n,1}(\tau) \\
S_{n,1}(\tau) & S_{n,2}(\tau)
\end{array} \right)^{-1} \left( \begin{array}{c}
T_{n,0}(\tau) \\
T_{n,1}(\tau)
\end{array} \right),
\]

- where for \( k = 0, 1, 2 \):

\[
S_{n,k}(\tau) = \frac{1}{n} \sum_{t=1}^{T} x_t x_t' \left( \frac{t}{n} - \tau \right)^k K_h \left( \frac{t}{n} - \bar{\tau} \right)
\]

\[
T_{n,k}(\tau) = \frac{1}{n} \sum_{t=1}^{T} x_t \left( \frac{t}{n} - \bar{\tau} \right)^k K_h \left( \frac{t}{n} - \bar{\tau} \right) y_t
\]

- confidence intervals are constructed with the help of autoregressive wild bootstrap
Backup - Bootstrap algorithm

**Step 1** Calculate $\hat{u}_t = y_t - x_t' \hat{\theta}(\tau)$

**Step 2** For $0 < \gamma < 1$, generate $\nu_1^*, \ldots, \nu_n^*$ as i.i.d. $\mathcal{N}(0, 1 - \gamma^2)$ and let

$$\xi_t^* = \gamma \xi_{t-1}^* + \nu_t^* \quad \text{with} \quad \xi_1^* \sim \mathcal{N}(0, 1)$$

**Step 3** Calculate the bootstrap errors $u_t^*$ as $u_t^* = \xi_t^* \hat{z}_t$ and generate the bootstrap observations by

$$y_t^* = x_t' \hat{\theta}(\tau) + u_t^*$$

**Step 4** Repeat Steps 2 and 3 $B$ times and apply the nonparametric estimator to obtain the quantiles

$$\hat{q}_{\alpha,j}(\tau) = \inf \left\{ u \in \mathbb{R} : \mathbb{P}^* \left[ \hat{\beta}_j^*(\tau) - \hat{\beta}_j(\tau) \leq u \right] \geq \alpha \right\}$$
Results - Time-varying coefficients (temperature)
Step 2: The recent upward trend

- we use the recently developed **right-sided unit root tests** by Phillips, Shi and Yu (2015)
- based on the regression model, for \( t \in [\lfloor r_1 T \rfloor, \lceil r_2 T \rceil] \)

\[
\Delta y_t = \alpha_{r_1, r_2} + \beta_{r_1, r_2} y_{t-1} + \sum_{j=1}^{k} \phi_{r_1, r_2} \Delta y_{t-j} + \epsilon_t,
\]

- the tests compare \( ADF_{r_2}^r \) statistics on a forward and backward expanding window

\[
GSADF(r_0) = \sup_{r_2 \in [r_0, 1]} \sup_{r_1 \in [0, r_2 - r_0]} ADF_{r_1}^{r_2}
\]

- Locating explosive periods, calculate for every end point \( r_2 \):

\[
BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} ADF_{r_1}^{r_2}
\]