

# Fundamental Drivers of Regime-switching: An Analysis of German Power Prices

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# Background

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Discussion

- German electricity supply is undergoing rapid change:
  - ① share of electricity from renewables increases steadily
  - ② accelerated nuclear phase-out after the Fukushima accident
- Since negative bids have been allowed at the day-ahead market of the EPEX, substantial price drops are prevalent
  - the most extreme case: -500 EUR/MWh

## Related work

Regime-switching models for positive price spikes:

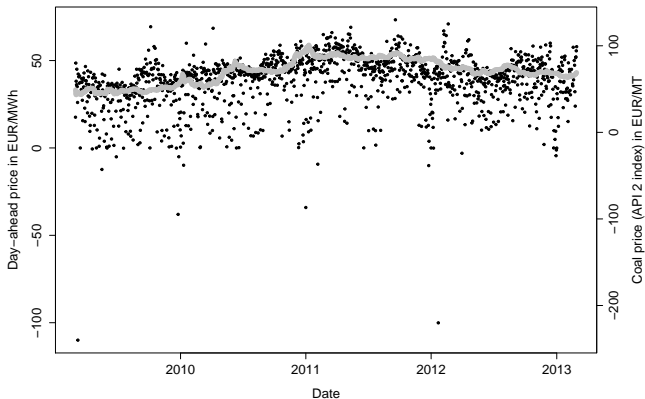
- Mount et al (2006): fundamental data (reserve margin) can be successfully used to model positive price spikes
- Huisman (2008): temperature data can be used as a proxy

Descriptive analyses of negative price events:

- Nicolosi (2010): residual load is a key driver of negative prices

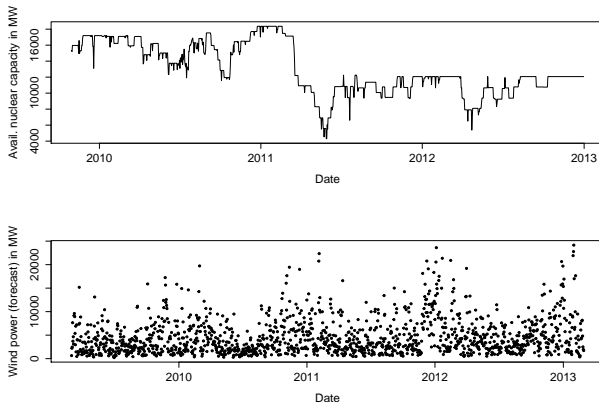
- hourly day-ahead prices during the off-peak period (8 p.m. and 8 a.m.)
- time period: 1<sup>st</sup> of March, 2009, until 1<sup>st</sup> of March, 2013
- fundamental data:
  - ① fuel prices
  - ② electricity infeed from renewables
  - ③ load
  - ④ nuclear unavailabilities

## Day-ahead prices



**Figure:** Day-ahead prices in trading hour 7 (black points) and coal prices (grey line). Prices smaller than -110 EUR/MWh not displayed.

# Wind power and nuclear availabilities



**Figure:** Available nuclear capacities between 30/10/2009 and 28/02/2013 and day-ahead forecasts of wind power during trading hour 7 between 01/03/2009 and 28/02/2013.

## Day-ahead prices and residual load

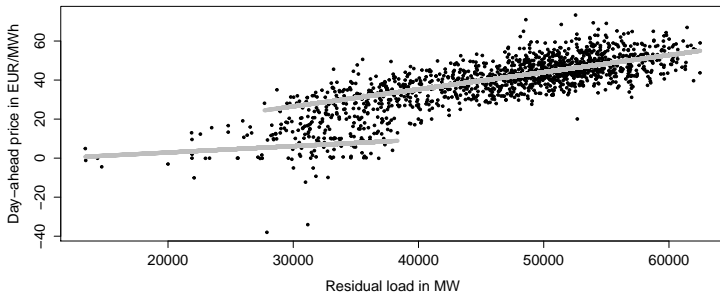
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**Figure:** Residual load and day-ahead prices in trading hour 7. Prices smaller than -40 EUR/MMh not displayed.

# Markov regime-switching model

Base regime: AR(1) with time-varying mean

- $(p_t^b - \mu_t) = \phi(p_{t-1}^b - \mu_{t-1}) + \epsilon_t$
- $\mu_t = \alpha + \beta \text{resload}_t + \gamma \text{coal}_t$

Low-price regime: shifted log-normal

- $(p_t^l - \mu_t) = \delta - LN_t,$

Time-varying switching probabilities: logistic function

- $P^{bb}(\text{resload}_t, \text{mora}_t) = \frac{\exp(a^b + b^b \text{resload}_t + c^b \text{mora}_t)}{1 + \exp(a^b + b^b \text{resload}_t + c^b \text{mora}_t)}$



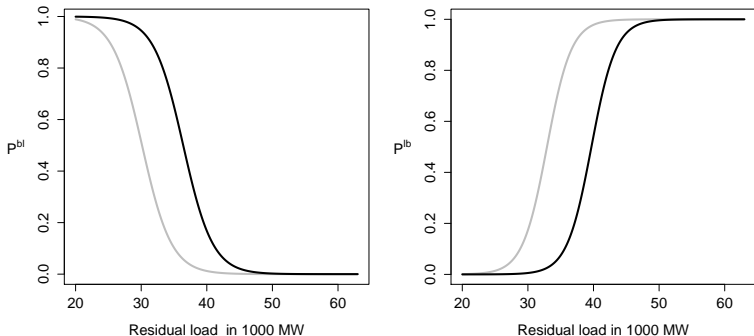
## Results

- switching probabilities decrease in residual load and are smaller after the Nuclear Moratorium
- a separate second regime is found for all off-peak trading hours except for the trading hours 21-23 and 8

		hour 7
<i>Parameters of the switching probabilities</i>	$\hat{a}^b$	-16.20*** (1.94)
	$\hat{a}^l$	21.32*** (4.16)
	$\hat{b}^b$	4.45*** (0.52)
	$\hat{b}^l$	-5.37*** (1.05)
	$\hat{c}^b$	2.79*** (0.43)
	$\hat{c}^l$	-3.64*** (1.15)
<i>Log-likelihood</i>		-4643.81

**Table:** Estimation results. Asymptotic standard errors in parantheses. \*, \*\*, \*\*\* denote stat. significance at the 10 %, 5 %, 1 % level.

## Visualization of results



**Figure:** Switching probabilities for hour 7.  $P^{bl}$  represents the probability to switch from the base regime to the low-price regime. Switching probabilities after the nuclear moratorium are represented by the grey line.

Shift of switching probabilities  
after the Moratorium

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	hour 1	hour 2	hour 3	hour 4
$P^{bl}:\Delta resload$	-4,239	-5,303	-5,245	-5,590

	hour 5	hour 6	hour 7	hour 24
$P^{bl}:\Delta resload$	-5,819	-6,532	-6,151	-3,958

**Table:** Shift of the switching probabilities, in MW.  $P^{bl}$  represents the probability to switch from the base to the low-price regime.

## Investigation of the regimes

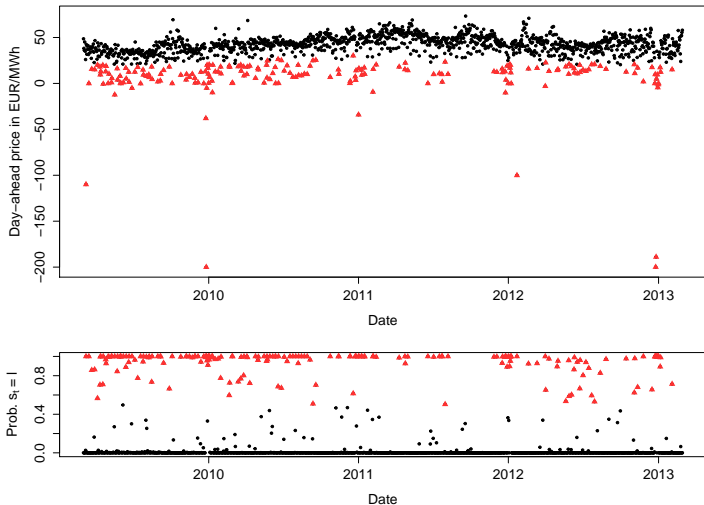


Figure: Day-ahead prices in trading hour 7 and (smoothed) probabilities that observations belong to the low-price regime  $P(s_t = l)$ .

## Conclusion and discussion

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- for the majority of off-peak trading hours the model distinguishes a low-price regime
- low-price regime includes positive prices (fuel switch between hard coal and lignite?)
- results indicate that higher RES-E levels increases low-price event probabilities
- results indicate that Nuclear Moratorium reduced low-price event probabilities

Thank you for your attention!