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Information Premium and the German Atom-Moratorium

Joint work with Rüdiger Kiesel and Fred E. Benth
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The Information Approach

Introduction

- Research topic: What is the relationship between Spot and Forward prices on electricity exchanges?
- We apply stochastic models and methods from Financial Mathematics and consider special properties of electricity
- We propose a new spot-forward relationship to better understand how prices are constructed
- We illustrate by examining the German "Atom Moratorium", implemented after the Fukushima earthquake 2011
- This legislation will thoroughly transform the fuel-mix and electricity prices in Germany (Europe?)
- ... but we will see that its immediate effect was quite surprising

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Spot-Forward Relationship: Classical theory

- The classical spot-forward relationship is

$$F(t, T) = \mathbb{E}^{\mathbb{Q}}[S_T|\mathcal{F}_t]$$

where

  - S_t denotes the spot on day t and $F(t, T)$ is the forward price with delivery in T
  - $\mathcal{F}_t$ is information generated by the spot price until time t (i.e. the historical filtration)
  - $\mathbb{Q}$ is a risk-neutral probability

- The underlying electricity is non-storable
- Buy-and-hold argument does not work
- Spot-forward relationship invalid!

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Consequences and Examples

- Future information about the market will not affect the current spot price...
- but will affect forward prices

- Stylized examples:
  - planned outage of a power plant in one month
  - extreme weather forecasts
- Introduction of EEX CO_2 certificates in 2008
  - End of 2007: forwards adjusted to certificates but not spot
- German "Atom Moratorium" 2011
  - Government decides to shut down eight nuclear reactors following earthquake in Japan for three months

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Information Approach

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$$\mathcal{F}_t = \sigma(S_s, s \leq t)$$

is not sufficient as forward looking info is ignored

- Idea: enlarge the filtration!
- ... by information about the spot at some future time T_Υ

- Note: This idea has been used to model insider trading on stock exchanges

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Filtrations and Spot-Forward-Relationship

- We introduce a new filtration $\mathcal{G}$ that includes knowledge of the past as well as publicly available info about the spot at T_Υ
- Formally: $\mathcal{G}_t \subset \mathcal{F}_t \vee \sigma(S_{T_\Upsilon})$
- We will call $\mathcal{G}$ the market filtration
- Hence, we propose:

New Spot-Forward-Relationship

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The Information Premium - Definition

- The traditional Spot-Forward relationship motivates the famous concept of the Risk Premium
- Similarly, we define the main object:

Information Premium

The Information Premium is defined to be

$$\begin{aligned} I_{\mathcal{G}}(t,T) &= \mathbb{E}[S_T|\mathcal{G}_t] - \mathbb{E}[S_T|\mathcal{F}_t] \\ &= F_{\mathcal{G}}(t,T) - F_{\mathcal{F}}(t,T) \end{aligned}$$

i.e. the difference between the prices of forwards under $\mathcal{G}$ and $\mathcal{F}$.

- This premium will quantify the impact of publicly known future info

The Information Premium - Property

Lemma

The information premium has expectation zero under filtration $\mathcal{F}$.

Proof:

$$\mathbb{E}[I_{\mathcal{G}}(t,T) \mid \mathcal{F}_t] = \mathbb{E}[\ \ \mathbb{E}[S(T) \mid \mathcal{G}_t] - \mathbb{E}[S(T) \mid \mathcal{F}_t]\ \ \mid \mathcal{F}_t] = 0$$

- This becomes very important when we want to show existence of the premium empirically!
- In Financial Maths we usually change measure to attain objects like the *risk premium*
- Due to the above, this is impossible for the *information premium*

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Outlook

- Analytically, the theory of enlargement of filtrations provides the toolbox to find, for stochastic spot models, expressions for the info premium
- An example can be found in the paper
- Now, though, we want discuss the German ”Atom Moratorium” more closely...
- ... and then present a method to show that what we observe on the market actually is an info premium

Outlook

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- ... and then present a method to show that what we observe on the market actually is an info premium

The German ”Atom Moratorium”

German Moratorium - The story

- 11/03/2011 - Earthquake in Fukushima
- 14/03/2011 - "Atom Moratorium"
  - German government decides to shut down seven (old) nuclear power plants (eight reactors) for three months to reevaluate nuclear policy
  - Capacity: more than 8 GW!
- 31/05/2011 - Decision for permanent shut-down of plants
  - Furthermore, complete nuclear phaseout in Germany until 2022
- 15/06/2011 - Official end to Moratorium

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Example: 2011 German Moratorium - Spot

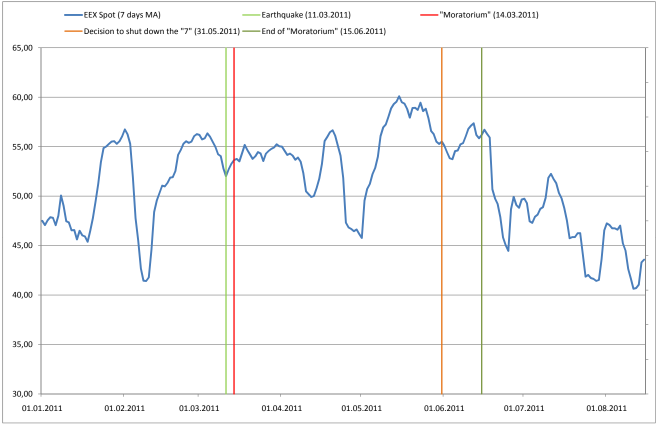

Figure: EEX day-ahead baseload (spot) prices 2011 (7 days MA)

- No significant impact on spot prices around 14/03/2011

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Example: 2011 German Moratorium - Forward

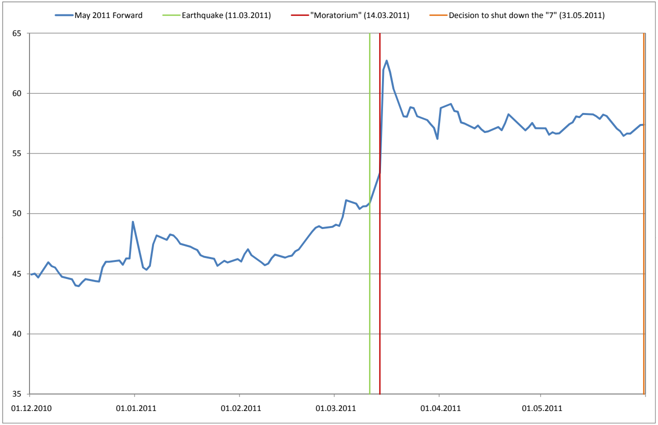

Figure: EEX May 2011 forward price

- Permanent increase from 14/03/2011

No reaction in Spot prices

- Hence, we see forwards anticipating higher prices while spot is as before - information premium?
- Why is there no increase in spot prices?
  - Brunsbüttel and Krümel offline anyway (800 MW + 1400 MW)
  - Biblis B in regular revision (another 1300 MW)
- This leaves around 4000 MW that were switched off immediately
- Still, it seems that there was no change in price setting technology!?

Renewables

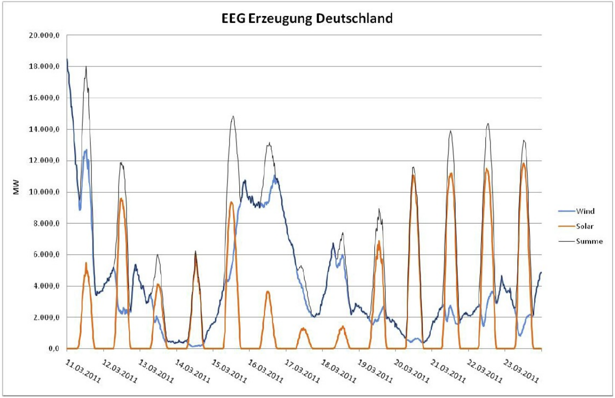

Figure: Wind and solar (report from BNA for BMWi)

- Some nuclear energy replaced by wind first, then solar...

Import/Export

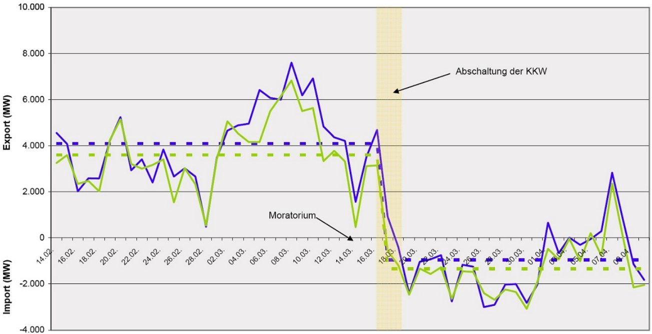

Figure: Cross-border trading (report from BNA for BMWi)

- ... and some brought in from France

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Showing the Existence of the Information Premium Empirically

Statistical test 1/2

- We want to develop a test to show and identify the info premium empirically

- Agenda:
  1. Calibrate a spot model to observed data (EEX)
  2. Calculate expectations under $\mathbb{P}$
  3. Conduct for each class of month-forwards a constant distance-minimising change of measure (ls-sense)
  4. Calculate expectation under $\mathbb{Q}$
  5. Assume observed forward price $\hat{F}(t, T_1, T_2)$ is $F_{\mathcal{G}}^{\mathbb{Q}}(t, T_1, T_2)$
  6. For the life-time of different forwards calculate

$$\hat{I}_{\mathcal{G}}^{\mathbb{Q}}(t, T_1, T_2) = \hat{F}(t, T_1, T_2) - F_{\mathcal{F}}^{\mathbb{Q}}(t, T_1, T_2)$$

Statistical test 2/2

- $\hat{I}_{\mathcal{G}}^{\mathbb{Q}}(t, T_1, T_2)$ is our best guess for $I(t, T_1, T_2)$!

  7. We need to show that:

     7.1 $\hat{I}_{\mathcal{G}}^{\mathbb{Q}} \neq 0$

     7.2 $\hat{I}_{\mathcal{G}}^{\mathbb{Q}}$ satisfies $\mathbb{E}[\hat{I}_{\mathcal{G}}^{\mathbb{Q}}|\mathcal{F}_t] = 0$

- 7.1 is testing for white noise basically
- This is easily done using Ljung-Box or even graphically

- 7.2 is more complicated!

How do we show non-measurability?

- How to show $\mathbb{E}[\hat{I}^{\mathbb{Q}}_{\mathcal{G}}(t, T_1, T_2)|\mathcal{F}_t] = 0$?
- Problem: We cannot simulate $\hat{I}^{\mathbb{Q}}_{\mathcal{G}}(t, T_1, T_2)$ and we do not want to impose a precise structure on $\mathcal{G}_t$
- Idea:
  - Consider (stationary) first differences of the spot and the residual
  - Setting: Hilbert space $L^2(\mathcal{F}, \mathbb{Q})$ spanned by historical filtration
  - Try to express $\triangle\hat{I}^{\mathbb{Q}}_{\mathcal{G}}$ in terms of countable basis of spot differences
  - ... by means of regression from $\triangle S$ onto $\triangle\hat{I}^{\mathbb{Q}}_{\mathcal{G}}$
  - This will provide a functional form of the conditional expectation!
- Insignificant regression results and zero coefficients $\Rightarrow$ functional form has zero value $\Rightarrow$ zero expectation!

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Moratorium Dataset: Spot Calibrating

- EEX spot from 01/09/2009 to 15/08/2011

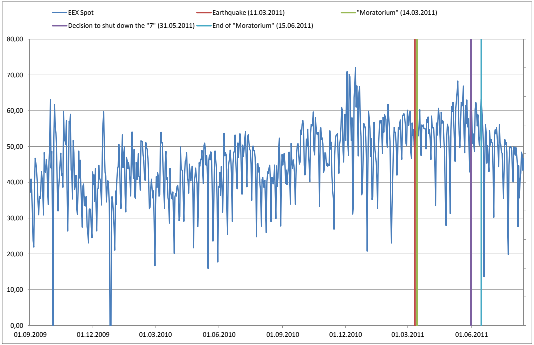

Figure: EEX spot price from 01/09/2009 until 15/08/2011

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Change of measure - Example

- Prices under $\mathbb{P}$ and $\mathbb{Q}$ and observed July 2011 forward

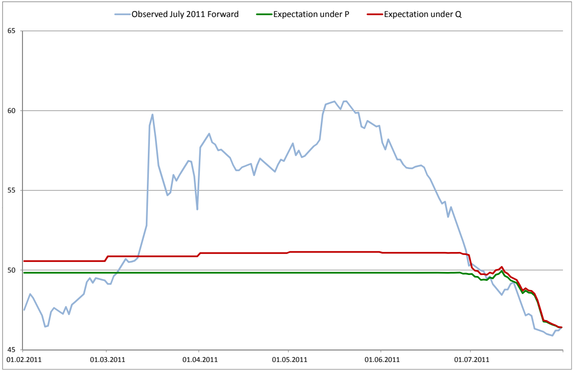
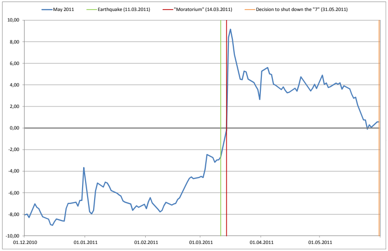
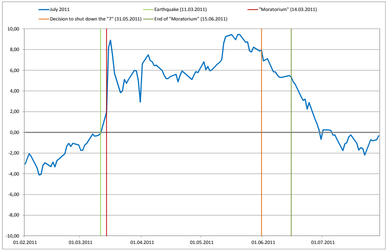


Figure: Observed, $\mathbb{E}^{\mathbb{P}}$ and $\mathbb{E}^{\mathbb{Q}}$ Prices

The residual $\hat{I}_{\mathcal{G}}^{\mathbb{Q}}(t, T_1, T_2)$



(a) May 2011: $\hat{I}_{\mathcal{G}}^{\mathbb{Q}}$



(b) July 2011: $\hat{I}_{\mathcal{G}}^{\mathbb{Q}}$

- May 2011: Steep increase after Moratorium, permanent positive info premium
- July 2011: As in May, but clear change in market sentiment. Smaller info premium after (negative) political decision
- Both clearly non-zero!

Regression results

- Regression Equation: $\triangle \hat{I}^{\mathbb{Q}}_{\mathcal{G}}(t, T_1, T_2) = \sum_{i=1}^{N} \alpha_i \triangle S^i(t) + \triangle\epsilon(t)$

Regression results for $N = 10$

	Feb 11	May 11	Jul 11
R^2	0.14	0.06	0.09
F-statistic	1.96	0.69	1.09

- F-value for 95% is 1.88, thus we cannot reject $c_1 = \ldots = c_N = 0$
- All individual t-stats suggest insignificant coefficients
- Increasing N does not alter the results
- We test $\hat{I}^{\mathbb{Q}}_{\mathcal{G}}(t, T_1, T_2)$ is not $\mathcal{F}_t$-measurable, functional is zero!
- ... we conclude $\hat{I}^{\mathbb{Q}}_{\mathcal{G}}(t, T_1, T_2)$ is the information premium!

Discussion of results

- Our test confirms the existence of a significant information premium around the Moratorium
- Steep increase for forwards after Moratorium:
  - Anticipating increased prices for May 2011
  - For July 2011, market sentiment changed once (negative) political decision was made (info premium is function of time!)
  - Better market understanding of consequences for Summer 2011
- Our estimator satisfies the properties and makes sense economically
- We propagate a new spot-forward-relationship for electricity
- We present a general method to show (non-) measurability

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References and Contact

- R. B-K, F. E. Benth, R. Kiesel *An empirical study of the information premium on electricity markets*, preprint (SSRN)
- R. B-K, F. E. Benth, R. Kiesel *Electricity options and additional information*, preprint (SSRN)

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- Thank you for your attention...

Appendix I - Forward Formula

- Risk-neutral valuation formula yields:

$$0 = \mathbb{E}^{\mathbb{Q}}\left[\int_{T_1}^{T_2} e^{-r(u-t)}(S(u) - F(t, T_1, T_2))du|\mathcal{F}_t\right]$$

- If settlements only take place at the final date T_2 one gets

$$0 = \mathbb{E}^{\mathbb{Q}}\left[\int_{T_1}^{T_2} (S(u) - F(t, T_1, T_2))du|\mathcal{F}_t\right]$$

- and finally for the futures price:

$$F(t, T_1, T_2) = \mathbb{E}^{\mathbb{Q}}\left[\int_{T_1}^{T_2} \frac{1}{T_2 - T_1} S(u)du|\mathcal{F}_t\right]$$

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Appendix II - Forward Price with Delivery

- The forward price with delivery in $[T_1, T_2]$ is then given by

$$F(t, T_1, T_2) = \frac{1}{T_2 - T_1} \left(\int_{T_1}^{T_2} \Lambda(u)du + \bar{\alpha}(t, T_1, T_2)X(t) + \bar{\beta}(t, T_1, T_2)Y(t) + \phi'(0)\hat{\beta}(t, T_1, T_2) \right)$$

- $\phi(u)$ is log-moment generating function of L and det. functions:

$$\bar{\alpha}(t, T_1, T_2) = \begin{cases} -\frac{1}{\alpha}\left(e^{-\alpha(T_2-t)} - e^{-\alpha(T_1-t)}\right) & t \leq T_1 \\ -\frac{1}{\alpha}\left(e^{-\alpha(T_2-t)} - 1\right) & t > T_1 \end{cases}$$

$$\hat{\beta}(t, T_1, T_2) = \begin{cases} \frac{1}{\beta}\left(T_2 - T_1 + \frac{1}{\beta}\left(e^{-\beta(T_2-t)} - e^{-\beta(T_1-t)}\right)\right) & t \leq T_1 \\ \frac{1}{\beta}\left(T_2 - t + \frac{1}{\beta}\left(e^{-\beta(T_2-t)} - 1\right)\right) & t > T_1 \end{cases}$$

Appendix III - Spot Price Model

- We will model the spot using a well known two-factor model:

$$S(t) = \Lambda(t) + X(t) + Y(t)$$

- where for a BM $W(t)$ and Lévy process $L(t)$

$$X(T) = e^{-\alpha(T-t)}X(t) + \sigma \int_t^T e^{\alpha(T-s)}dW(s)$$
$$Y(T) = e^{-\beta(T-t)}Y(t) + \int_t^T e^{\beta(T-s)}dL(s)$$

- I.e. X and Y are Ornstein-Uhlenbeck mean-reverting processes!

Appendix IV - Lévy Process

- Remember the Lévy part of the spot

$$dY(t) = -\beta Y(t)dt + dL(t)$$

- For the empirics, we used

$$L_t = \sum_{i=1}^{N_t} D_i$$

- where N_t is Poisson process, intensity λ, D_i are i.i.d jump sizes
- We used double-exponentially distributed (i.e. the Kou model) with density

$$f_D(x) = p\eta_1 e^{-\eta_1 x}\mathbb{1}_{x\geq 0} + q\eta_2 e^{-\eta_2 |x|}\mathbb{1}_{x\leq 0}$$

- where $p + q = 1$ and $\eta_1, \eta_2 \geq 0$.

Appendix V - Calibrated Parameters

Parameter	α	σ	β	λ	p	q	η_1	η_2
Value	0.538	11.11	0.786	0.034	0.955	0.045	0.019	0.027

Table: Fitted parameter values for the CO_2 data set

Parameter	α	σ	β	λ	p	q	η_1	η_2
Value	0.499	6.01	0.864	0.027	0.105	0.895	0.046	0.033

Table: Fitted parameter values for the Moratorium data set

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Appendix VI - Girsanov Parameters

Forward	1 m	2 m	3 m	4 m	5 m	6 m
θ_W	0.164	0.734	0.153	-0.593	-1.893	-3.199

Table: CO_2 data set: Constant Girsanov parameters.

Forward	1 m	2 m	3 m	4 m	5 m	6 m
θ_W	0.210	0.624	0.650	0.614	0.512	0.363

Table: Moratorium data set: Constant Girsanov parameters.

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Appendix VII - Method Comparison

Method	Classical LSMC	New Method
Time	fixed t	$t_k \in [t_0, T_n]$
Regressor	Simulated X_t	stationary $\triangle X_{t_k}\ \forall k$
Regressand	Simulated $F(X_{t+1})$	stationary $\triangle F(t_k)\ \forall k$
Goal	Value of cond. expectation	Quality of regression

Table: Comparison of methods