Forecasting the spread between day-ahead and real-time electricity prices

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Motivation

A small RES utility:

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- Does not have a direct effect on electricity prices
  - need to accept the market price,
  - does not propose bids.
- Decides about the quantity
  - the quantity offered day-ahead is traded in the spot market,
  - the actual production net the day-ahead offer is traded in the real-time or intra-day.

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Utility will sell in the day-ahead market less energy than it forecasts to generate if

- the real-time market price is predicted to be higher than the spot price,
- it is loss averse (wants to avoid purchases, in case of low generation).

Literature

A few publication explaining the difference between the spot and real-time (or intra-day) markets:

- RES generation forecast errors drive the price difference (Woo et al. (2016), Kiesel, Paraschiv (2017))
- The trading strategy should depend on spread and generation forecast errors (Garnier, Madlener (2015))

but ...

- No papers on forecasting the spread and its sign.

Polish electricity market

In Poland:

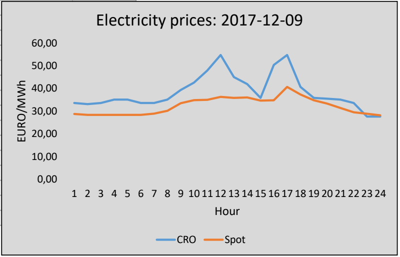
- Day-ahead market for hourly prices (run by TGE S.A., Polish Power Exchange)
- Intra-day market for hourly prices (run by TGE S.A., Polish Power Exchange)
- Balancing market (run by TSO, which sets prices)
    - single-price system (although allows for dual prices)

Data

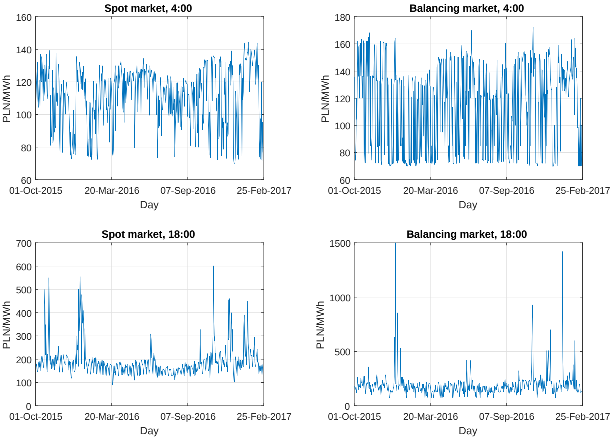
- Data span the period: 2014.10.02 - 2017.02.28
  - spot market (P_t^S)
  - balancing market (P_t^B)
- The data is divided into estimation and validation periods.
  - estimation: moving window of 365 observations,
  - validation: the remaining 511 observations (146 - for averaging, 365 for evaluation of forecast performance).

Data: balancing and spot prices on 2017.12.09

Hour	Balancing market				TGE	
	CRO [EURO/MWh]	CROs [EURO/MWh]	CROs [EURO/MWh]	Volume [MWh]	Spot [EURO/MWh]	Volume [MWh]
1	33,55	33,55	33,55	149	28,75	2 525
2	33,06	33,06	33,06	509	28,34	2 135
3	33,55	33,55	33,55	573	28,35	2 210
4	35,05	35,05	35,05	824	28,32	2 226
5	35,05	35,05	35,05	937	28,31	2 243
6	33,55	33,55	33,55	1 061	28,32	2 202
7	33,55	33,55	33,55	426	28,87	2 292
8	35,05	35,05	35,05	455	30,11	2 994
9	39,28	39,28	39,28	581	33,48	2 837
10	42,51	42,51	42,51	802		
11	47,86	47,86	47,86	860		
12	54,73	54,73	54,73	927		
13	45,00	45,00	45,00	734		
14	41,89	41,89	41,89	656		
15	35,82	35,82	35,82	750		
16	50,31	50,31	50,31	855		
17	54,73	54,73	54,73	841		
18	40,64	40,64	40,64	487		
19	35,82	35,82	35,82	337		
20	35,47	35,47	35,47	-125		
21	35,05	35,05	35,05	107		
22	33,55	33,55	33,55	0		
23	27,59	27,59	27,59	-355		
24	27,59	27,59	27,59	-295		



Balancing and spot prices



Spread: balancing - spot prices

Data features

- Balancing prices are much more volatile than the spot prices.
- The spot prices are on average lower than the balancing prices.
- There are spikes in spot prices, balancing prices and ... the spread.

prices	mean	st.dev
spot	162.18	63.75
balancing	164.74	85.61

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- Needs to decide, where to sell 1 MWh: on a day-ahead or on a real-time market.
- The decision is made conditional on the sign of the spread: $P^S_{ht} - P^B_{ht}$.
- Various strategies are considered:
    - always sell at spot (benchmark),
    - always sell at balancing,
    - condition the decision on the forecast of the spread,
    - condition the decision on the true the spread (know the future).

Problem set-up

Forecasting the sign of the spread

$$S_{ht} = \begin{cases} 1 & P^S_{ht} \geq P^B_{ht} \\ 0 & P^S_{ht} < P^B_{ht} \end{cases}$$

Some problem:

- availability of the data in time,
- forecast evaluation.

Availability of the data in time

Day $t-2$

Known prices:

- Spot price: P^S_{ht-2}
- Balancing prices: P^B_{ht-3}
- Load forecast for $t-1$

Day $t-1$

Known prices:

- Spot price: P^S_{ht-1}
- Balancing prices: P^B_{ht-2}
- Load forecasts for t

Day t

Time

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- Classification accuracy

$$p = Pr(\hat{S}_{ht} = 1 \wedge S_{ht} = 1) + Pr(\hat{S}_{ht} = 0 \wedge S_{ht} = 0)$$

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$$\pi_{ht} = (P^B_{ht} - P^S_{ht})(1 - \hat{S}_{ht})$$

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  - for a given hour $P_{ht} \rightarrow$ its c.d.f
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  - use the inverse of the c.d.f. of the normal distribution $N(0, 1)$
- Transform the data back into the original units

Forecasting

Models

- ARX models: for spread or separately for spot and balancing prices
- PC-ARX models

Forecasting

Models

- ARX models: for spread or separately for spot and balancing prices
- PC-ARX models
- 52 models: conditional on the model type, transformation, exogenous data and the lag structure

Exogenous data

Exogenous data (X):

- Forecasted demand
- Forecasted generation from JWDC units
- dummies for week days: d_1 - Monday, d_2 - Saturday, d_3 - Sunday (and a constant for remaining days)

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The general information about the day is provided by

- 3 principles components of the panel of lagged prices
- 2 principles components of the panel of the forecasted demand and generation

Top 10 models

Rank	π	p	Model	Transformation
1	5.8674	58.00%	ARX	PIT
2	5.5670	57.80%	ARX	PIT
3	5.3884	56.96%	ARX	PIT
4	5.2375	57.92%	ARX	PIT
5	5.1622	56.51%	PC-ARX	PIT
6	5.1160	56.30%	ARX	PIT
7	5.0872	54.67%	ARX	log
8	4.9788	54.94%	ARX	log
9	4.9441	55.86%	PC-ARX	PIT
10	4.8699	55.70%	PC-ARX	PIT

Forecast combination

Combining classification forecasts:

- majority vote with 0.5 threshold,
- majority vote with optimal threshold,
- weighted average,
- modified weighted average,
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Pre-filtering:

- accuracy $p > 0.55$,
- top 25% in terms of profits.

Forecast combination

Method	π	p
MA	58.00%	5.7274
MA^*	57.80%	5.9615
WA	56.96%	5.4929
WA^*	57.92%	5.9405
BA	56.51%	4.6772

Final results

Method	p	π	Yearly profit
$\hat{S}_{ht} = 1$	41.1%	0	0
$\hat{S}_{ht} = 0$	58.9%	5.4262	47533.51
$\hat{S}_{ht} = S_{ht}$	100%	19.7579	173079.20
Best	58.00%	5.8674	51398.42
WA^*	57.92%	5.9405	52038.78
MA^*	57.80%	5.9615	52222.74

Conclusions

- Optimal trading strategy of small RES utility depends on the sign of the spread between the day-ahead and the real-time electricity prices.
- The real-time prices are difficult to model and forecast, much more volatile than day-ahead prices (depend on forecast errors of fundamentals, see Woo et al. (2016)).
- Spikes of day-ahead and real-time prices are not always synchronized (leads to spikes in the spread).

Conclusions

- Econometric models outperform fixed strategies.
- The additional yearly profit is 51398.42 PLN (12850 EURO) for individual models and 52222.74 PLN (13055 EURO) for their combinations.
- The maximum potential gain is 173079.2 PLN (43270 EURO), if the future is known (... still room for improvement)