A look into the future of electricity price forecasting (EPF)

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Review

Electricity price forecasting: A review of the state-of-the-art with a look into the future

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ABSTRACT

A variety of methods and ideas have been tried for *electricity price forecasting* (EPF) over the last 15 years, with varying degrees of success. This review article aims to explain the complexity of available solutions, their strengths and weaknesses, and the opportunities and threats that the forecasting tools offer or that may be encountered. The paper also looks ahead and speculates on the directions EPF will or should take in the next decade or so. In particular, it postulates the need for objective comparative EPF studies involving (i) the same datasets, (ii) the same robust error evaluation procedures, and (iii) statistical testing of the significance of one model's outperformance of another.

IJF: The longest paper we have ever published ...

International Institute of Forecasters

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The latest IJF issue is out

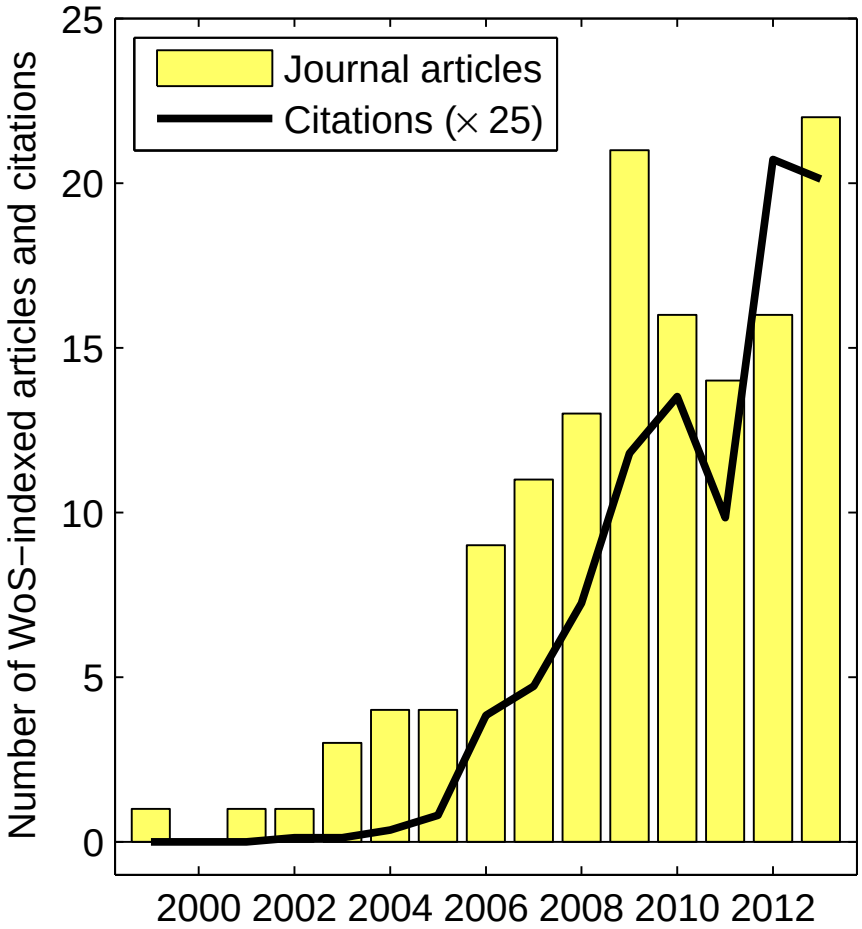
Posted on October 8, 2014 by Rob J Hyndman

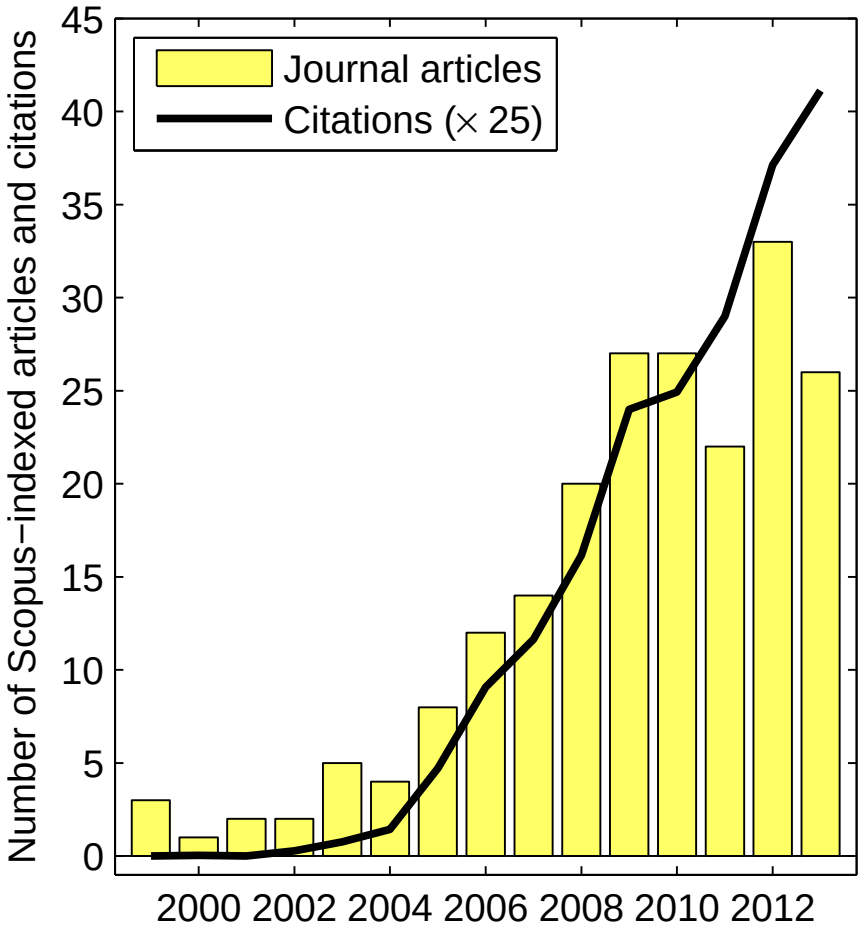
The last issue of the *International Journal of Forecasting* for 2014 is now available on ScienceDirect, and will be posted to subscribers soon.

Highlights include:

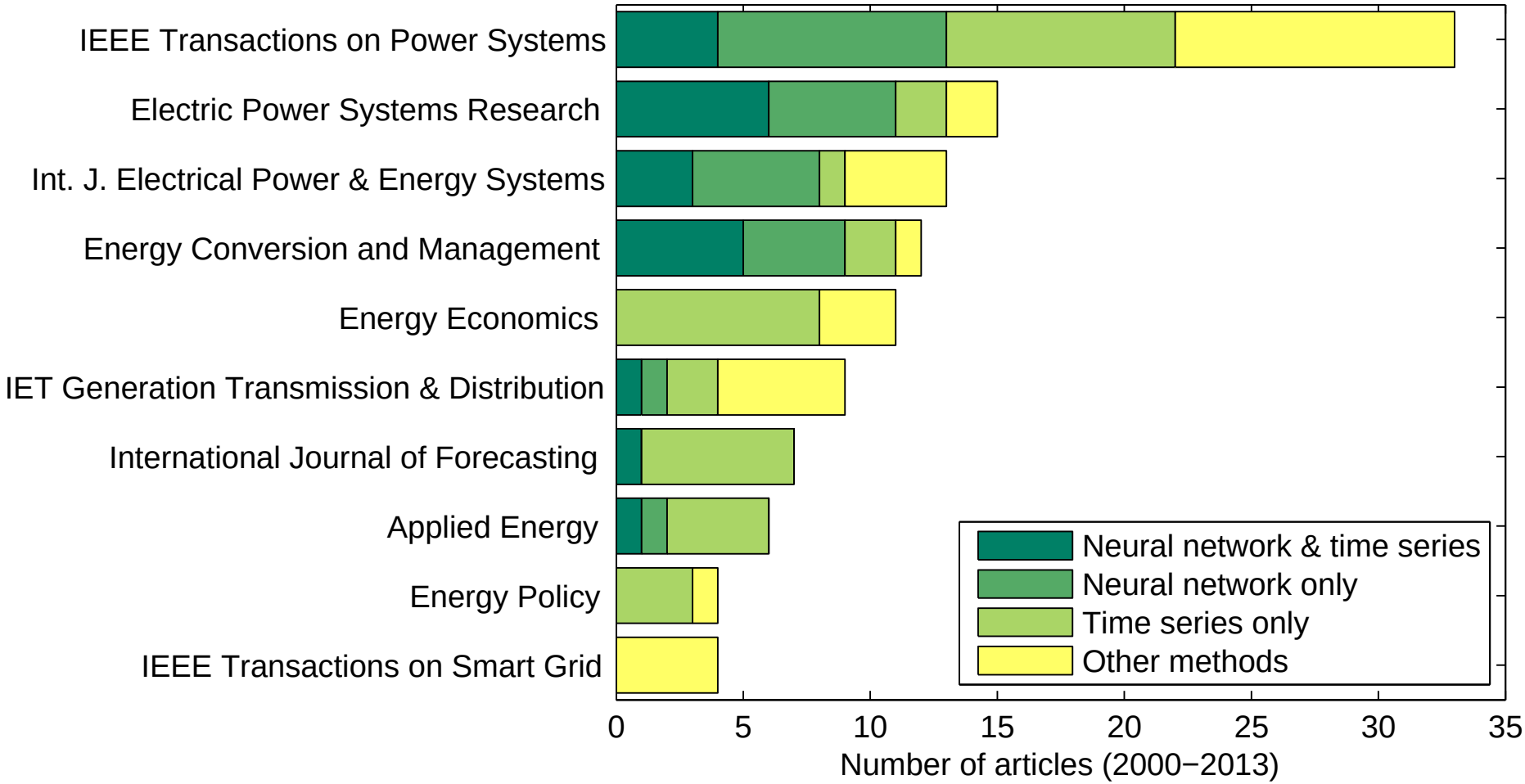
- A long review article on electricity price forecasting by Rafał Weron. I think this is the longest paper we have ever published but it was so good, I didn't want to cut it back in size and risk reducing its value. I think it will be the standard reference on electricity price forecasting for a long time.

EPF journal articles and citations to those articles





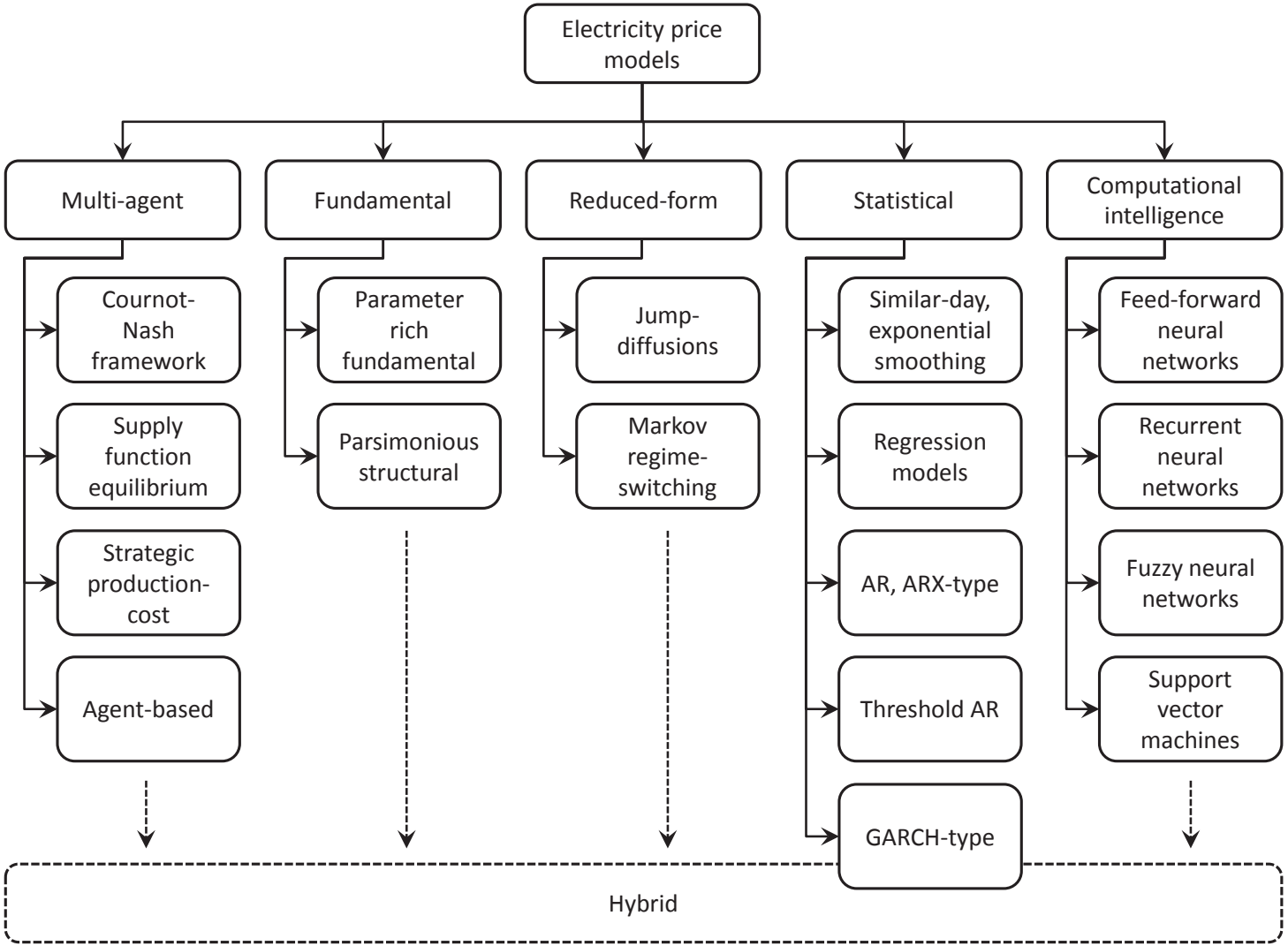
Ten most popular journals



Forecasting horizons

- Short-term
  - From a few minutes up to a few days ahead
  - Of prime importance in day-to-day market operations
- Medium-term
  - From a few days to a few months ahead
  - Balance sheet calculations, risk management, derivatives pricing
  - Inflow of 'finance solutions'
- Long-term
  - Lead times measured in months, quarters or even in years
  - Investment profitability analysis and planning
  - Beyond the scope of this review

A taxonomy of modeling approaches



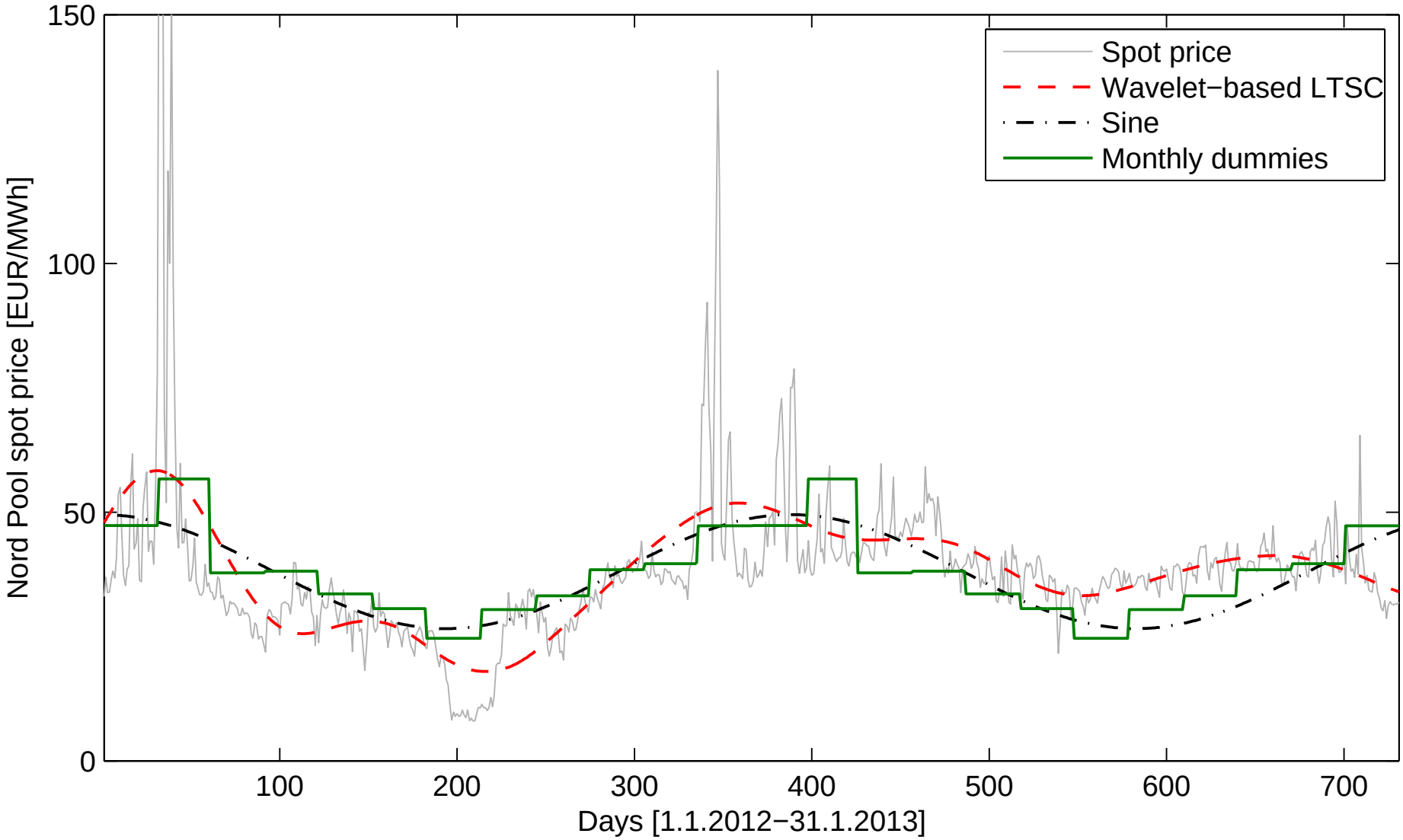
A look into the future of EPF

1. **Fundamental price drivers and input variables**
   - **Modeling and forecasting the trend-seasonal components**
   - The reserve margin and spike forecasting
2. Probabilistic forecasts ($\rightarrow$ Jakub Nowotarski's talk)
   - Interval & density forecasts
3. Combining forecasts ($\rightarrow$ Jakub Nowotarski's talk)
   - Point & probabilistic forecasts
4. Multivariate factor models ($\rightarrow$ Katarzyna Maciejowska's talk)
5. The need for an EPF-Competition
   - A universal test ground
   - Guidelines for evaluating forecasts

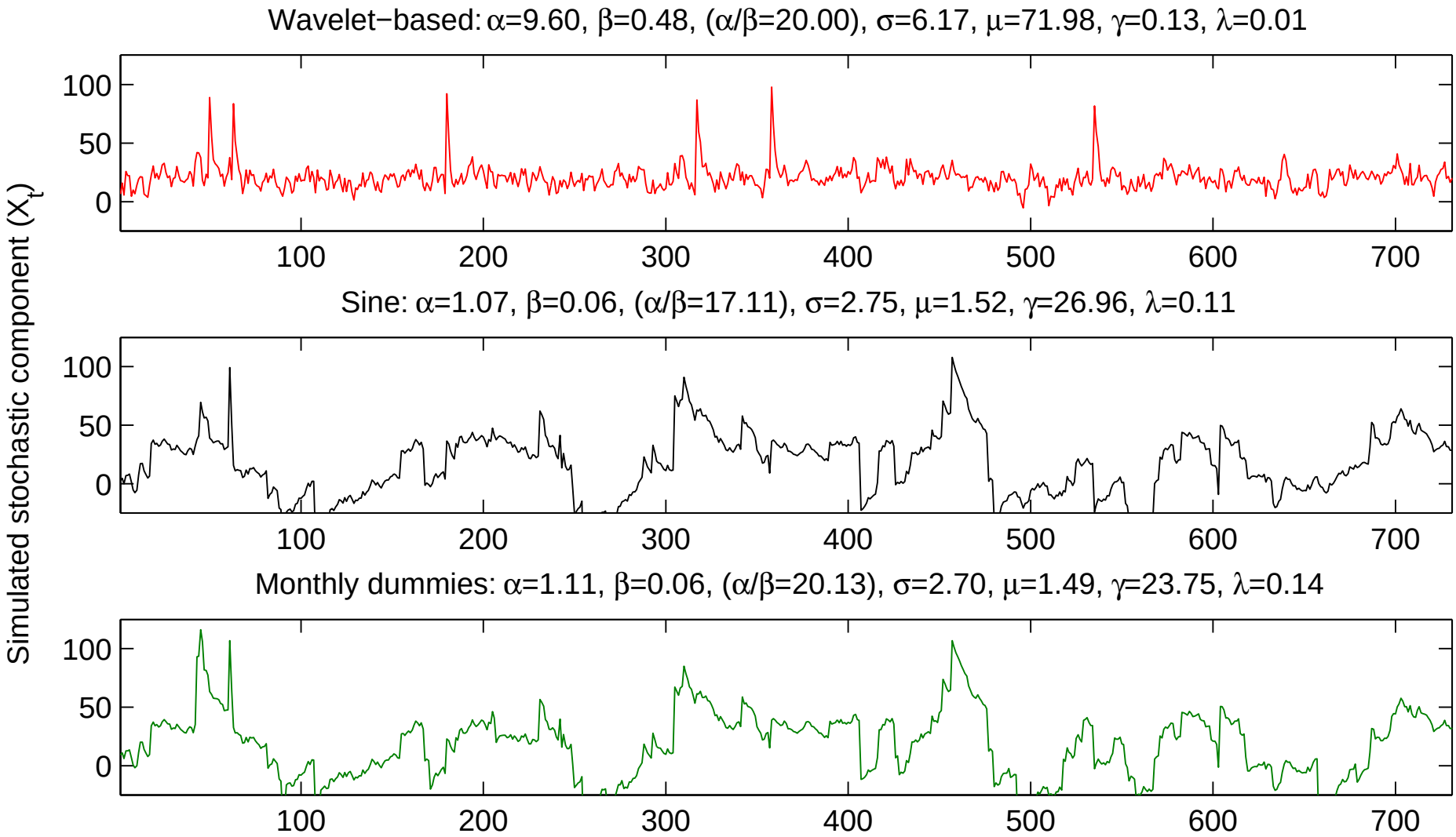
Modeling the trend-seasonal components

- Standard approach – decompose a time series of prices P_t into
  - the long-term trend-seasonal component (LTSC) T_t,
  - the short-term seasonal component (STSC) s_t,
  - and the remaining variability, error or stochastic component X_t
- The hourly/weekly STSC is usually captured by autoregression & dummies $\rightarrow$ forecasting is straightforward
- Annual seasonality is present in spot prices, but in most cases the LTSC is dominated by a more irregular cyclic component
  - Due to fuel prices, economic growth, long-term weather trends
  - See e.g. Janczura et al. (2013), Nowotarski et al. (2013b)

Modeling the LTSC

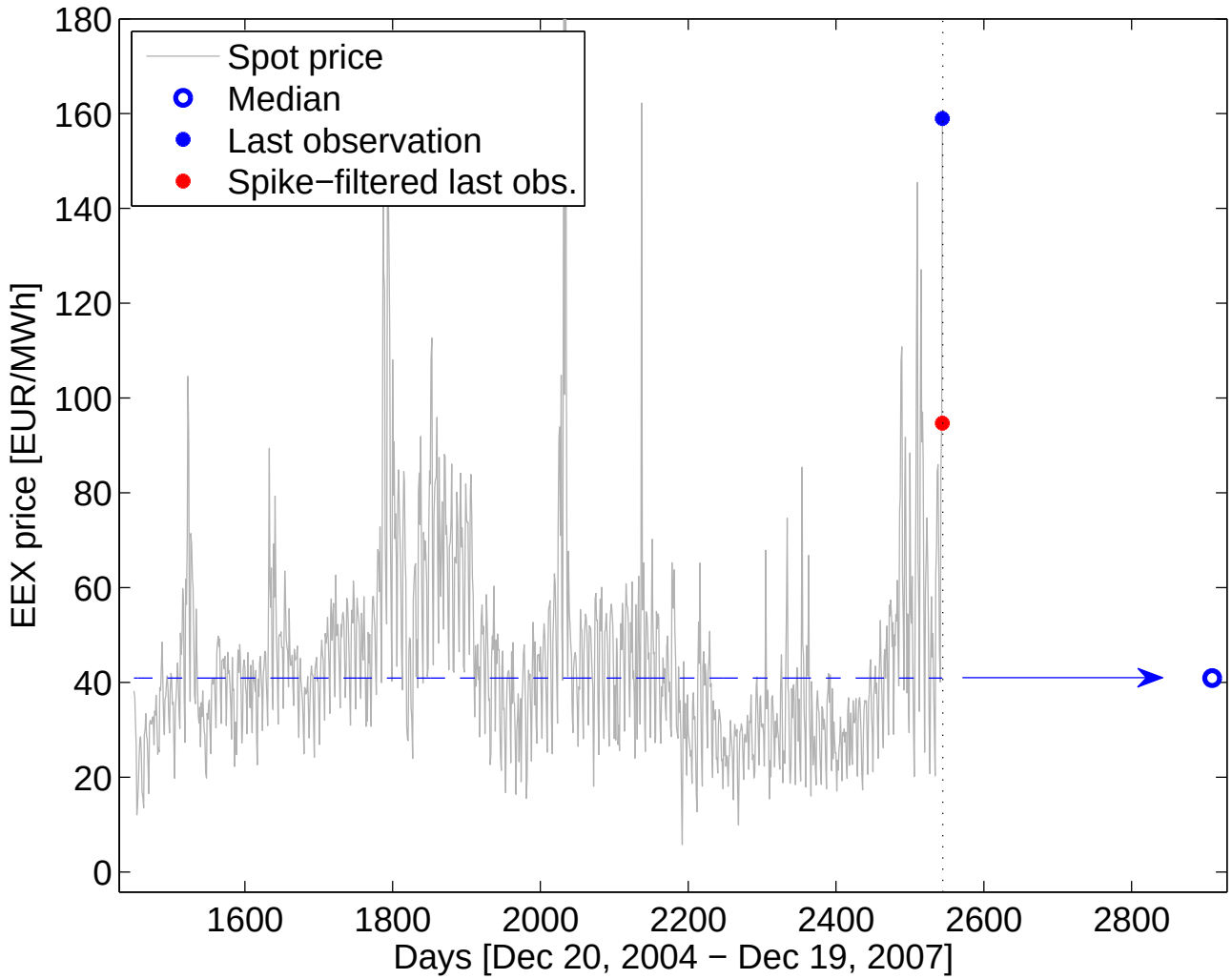


Adequate seasonal decomposition is important !



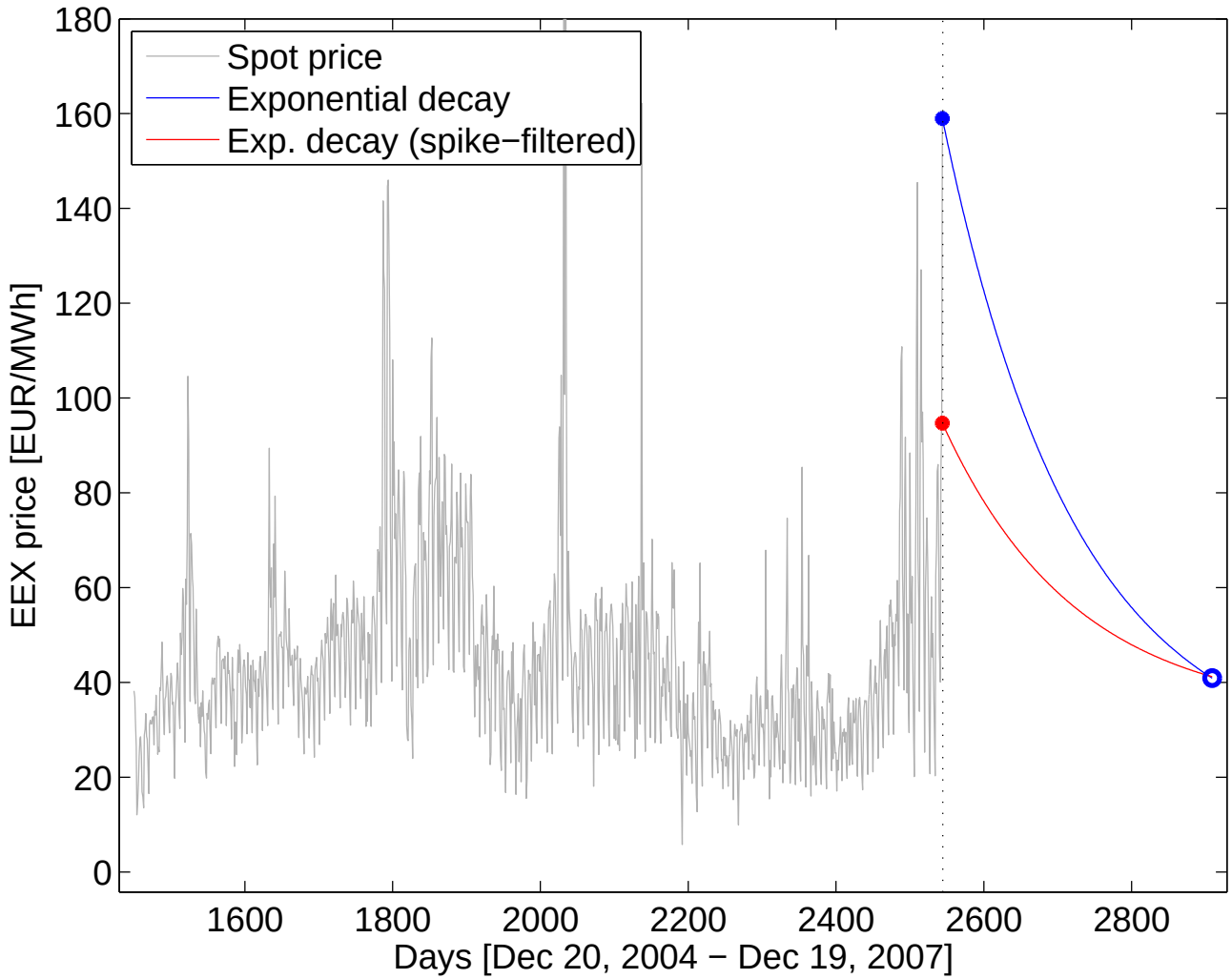
Forecasting a wavelet-based LTSC

(Nowotarski, Tomczyk & Weron, 2013, Energy Economics)



Forecasting a wavelet-based LTSC cont.

(Nowotarski, Tomczyk & Weron, 2013, Energy Economics)



Forecasting a wavelet-based LTSC cont.

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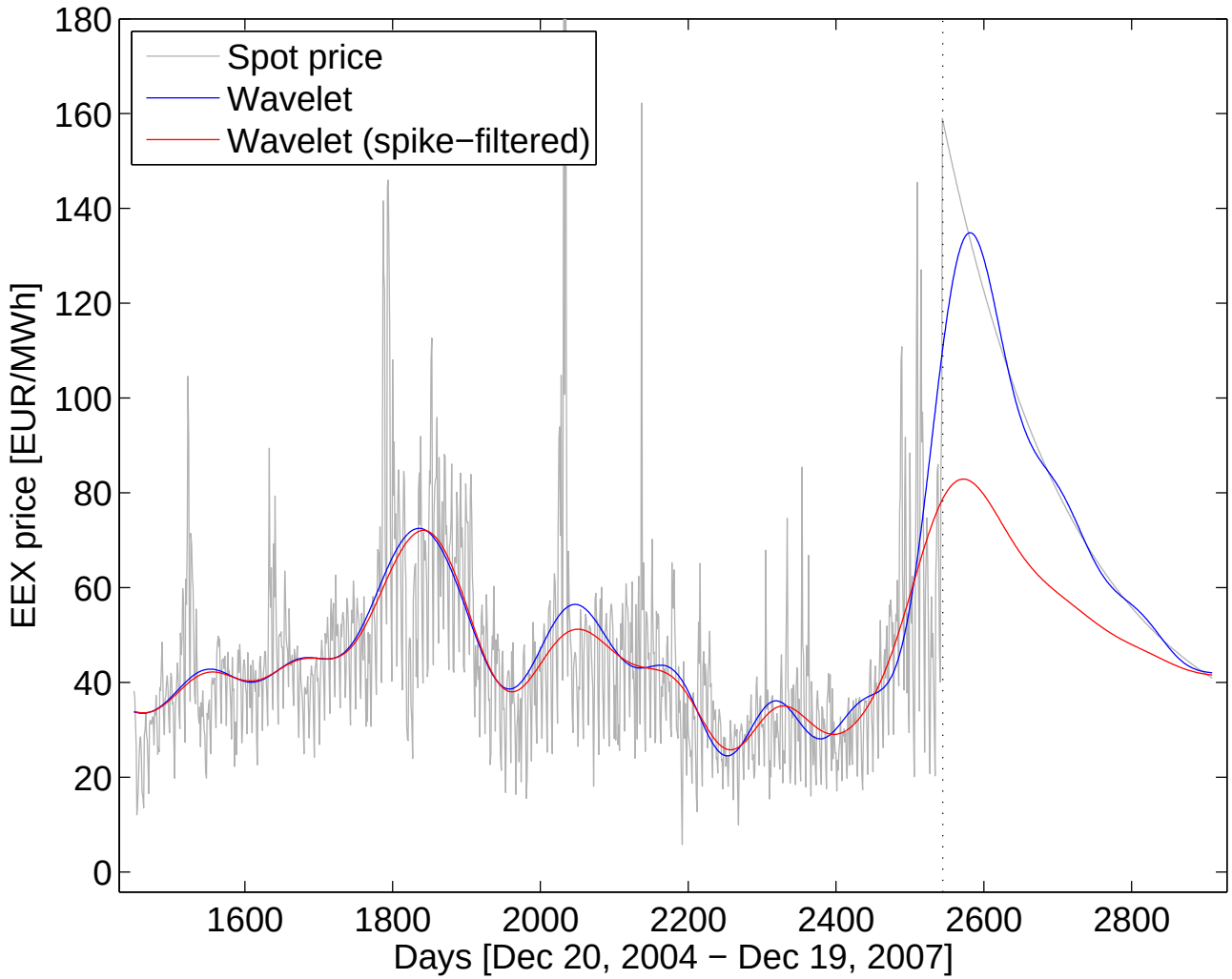
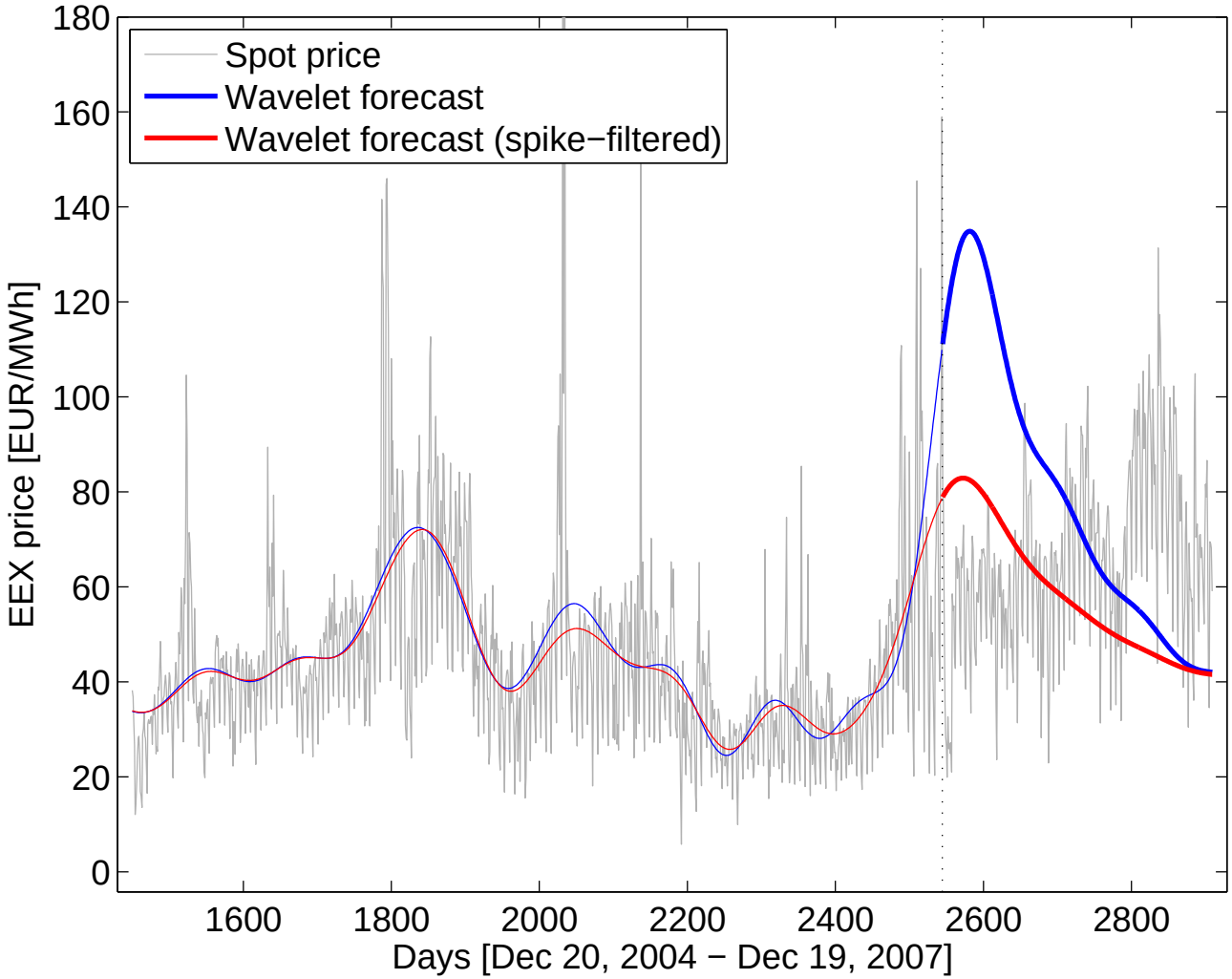


Forecasting a wavelet-based LTSC cont.

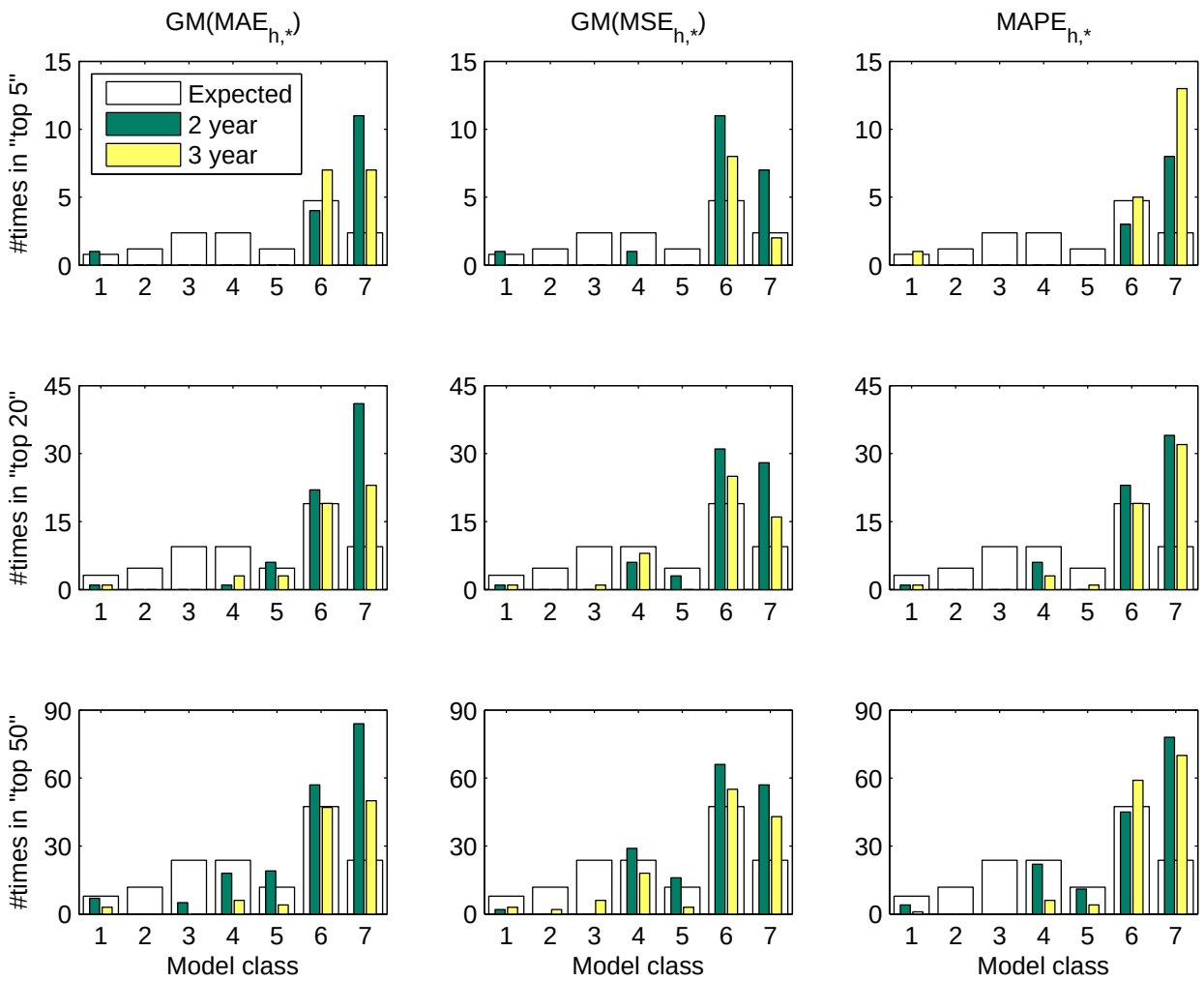
(Nowotarski, Tomczyk & Weron, 2013, Energy Economics)



Wavelets beat sines and monthly dummies

(Nowotarski, Tomczyk & Weron, 2013, Energy Economics)

The number of times models from a given family are ranked in the top 5, 20 and 50 of all 304 models according to $GM(MAE_{h,*})$, $GM(MSE_{h,*})$ and $MAPE_{h,*}$ for each of the six forecast horizons h = 1,...,6



The Hodrick-Prescott (1980, 1997) filter

A simple alternative to wavelets

- Originally proposed for decomposing GDP into a long-term growth component and a cyclical component
- Returns a smoothed series τ_t for a noisy input series y_t:

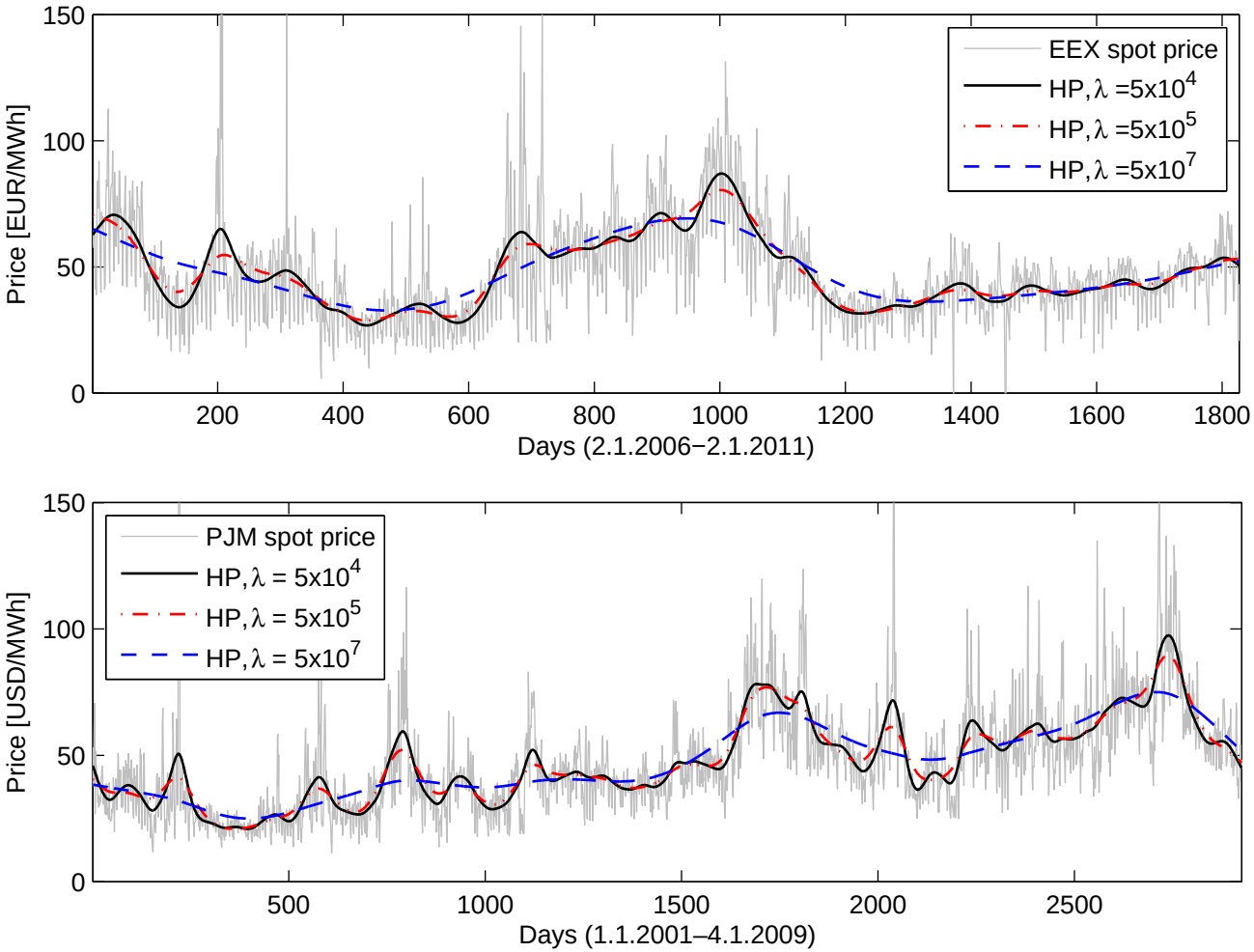
$$\min_{\tau_t} \left\{ \sum_{t=1}^{T} (y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1} \left[(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1}) \right]^2 \right\}, \tag{1}$$

Punish for:

- deviating from the original series
- roughness of the smoothed series

HP-smoothing: EEX and PJM

(Weron & Zator, 2015, Energy Economics)



HP provides a better fit than the nominal LTSC

(Weron & Zator, 2015, Energy Economics)

	Identification technique (estimated LTSC model)											
	HP filter-based ($\lambda = \ldots$)							Wavelet-based				sin-
	5×10^4	10^5	5×10^5	10^6	5×10^6	10^7	5×10^7	S_5	S_6	S_7	S_8	EWMA
Nord Pool market (3 years: 01.01.2011–31.12.2013)												
S_5	18.7	33.5	60.0	68.0	89.4	103.1	138.6	0.0	73.4	83.6	174.7	92.1
S_6	19.3	11.2	0.0	1.2	23.8	42.0	87.8	49.1	10.8	16.0	134.9	43.6
S_7	38.9	29.4	10.0	4.3	12.1	29.1	81.4	71.8	29.5	0.0	140.0	34.2
S_8	92.8	81.4	56.0	45.8	24.4	16.1	0.0	132.3	83.7	40.6	10.0	55.6
sin	22.8	16.2	3.7	0.0	3.1	13.4	50.4	48.7	19.5	2.2	97.5	11.6
EEX market (5 years: 02.01.2006–02.01.2011)												
S_5	5.1	16.4	51.5	65.8	91.5	102.5	130.9	0.0	59.3	105.3	155.7	106.1
S_6	5.3	0.0	10.4	23.1	55.5	72.4	115.2	37.7	0.2	75.8	148.4	90.6
S_7	40.4	29.1	6.9	0.0	3.6	20.4	77.9	84.8	35.1	4.4	118.3	78.0
S_8	81.2	67.3	38.9	28.3	7.1	0.0	1.1	134.6	72.1	28.2	2.6	87.3
sin	10.0	4.2	0.0	2.1	13.3	22.7	52.7	41.2	14.3	17.7	75.5	47.6
PJM market (8 years: 01.01.2001–04.01.2009)												
S_5	0.0	6.9	32.1	44.1	68.9	77.9	98.0	4.1	37.0	79.8	106.3	79.7
S_6	7.2	0.8	3.7	14.6	46.0	58.4	86.2	38.9	0.0	61.6	101.1	71.9
S_7	46.4	34.8	11.7	4.2	1.6	10.2	46.5	91.0	37.5	0.0	66.1	63.4
S_8	99.4	83.8	52.1	40.1	16.4	8.7	7.0	158.9	87.2	35.8	0.0	85.4
sin	12.7	6.7	0.0	0.6	8.5	14.5	34.5	43.2	15.0	16.4	38.1	38.7

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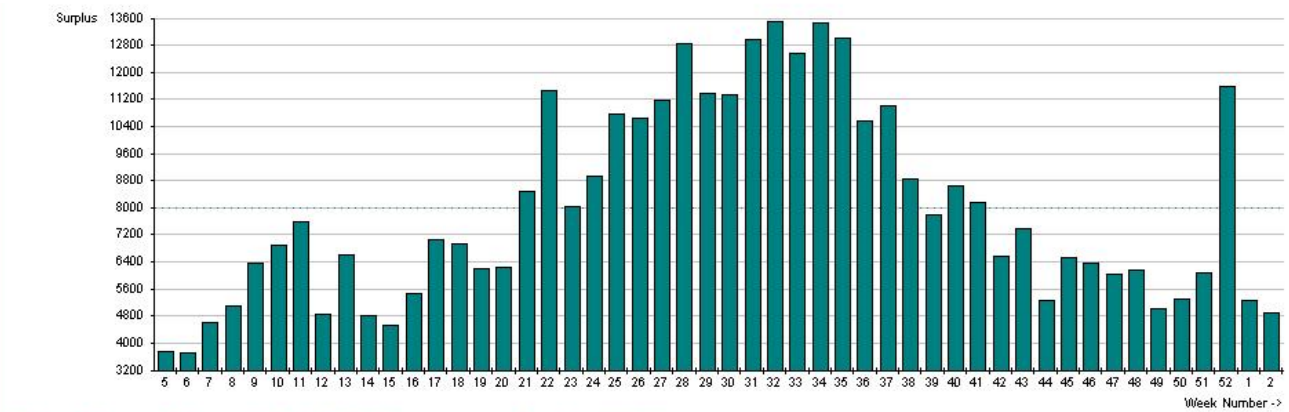
The reserve margin and spike forecasting

- *Reserve margin*, also called *surplus generation*, relates the available capacity (generation, supply), C_t, and the demand (load), D_t, at a given moment in time t
  - The traditional engineering notion: $RM = C_t - D_t$
  - Some authors prefer to work with dimensionless ratios: $\rho_t = \frac{D_t}{C_t}$, $R_t = \frac{C_t}{D_t} - 1$ or the so-called *capacity utilization* $\mathrm{CU} = 1 - \frac{D_t}{C_t}$



National Demand Forecast Week (NDFW)

Week Number	Publish Time (GMT)	Value
5	2008-01-10 14:45	58000.000
6	2008-01-10 14:45	56500.000

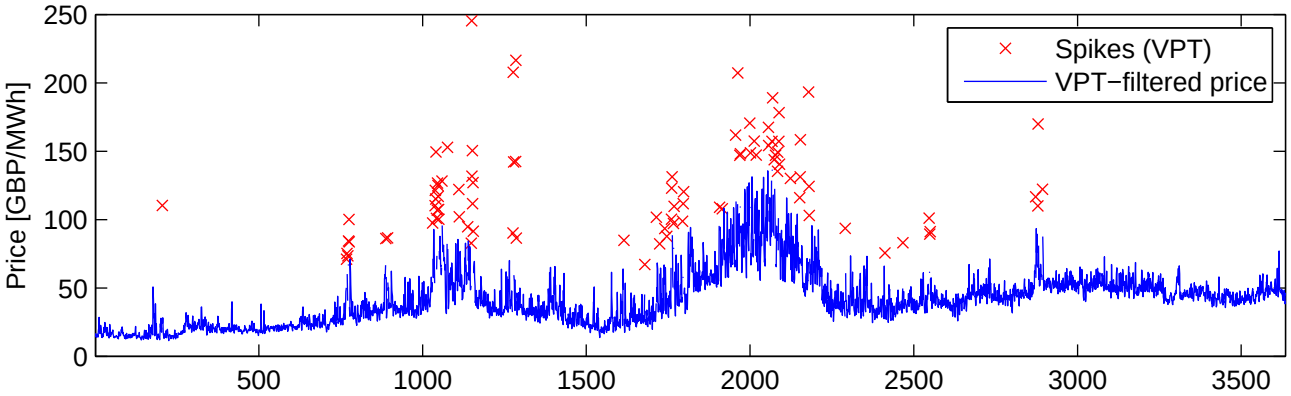
Surplus (SPLW)

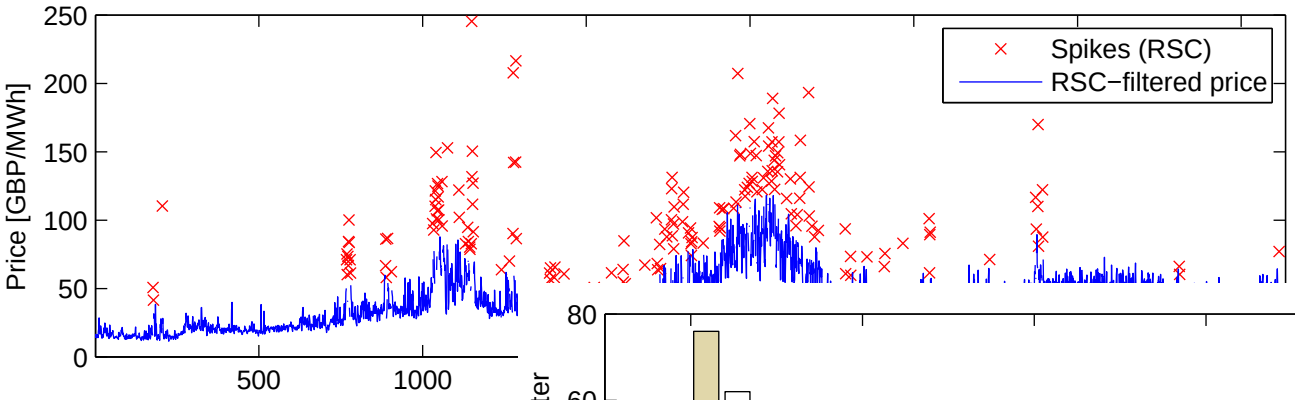
Week Number	Publish Time (GMT)	Value
5	2008-01-10 14:37	3788.000
6	2008-01-10 14:37	3770.000

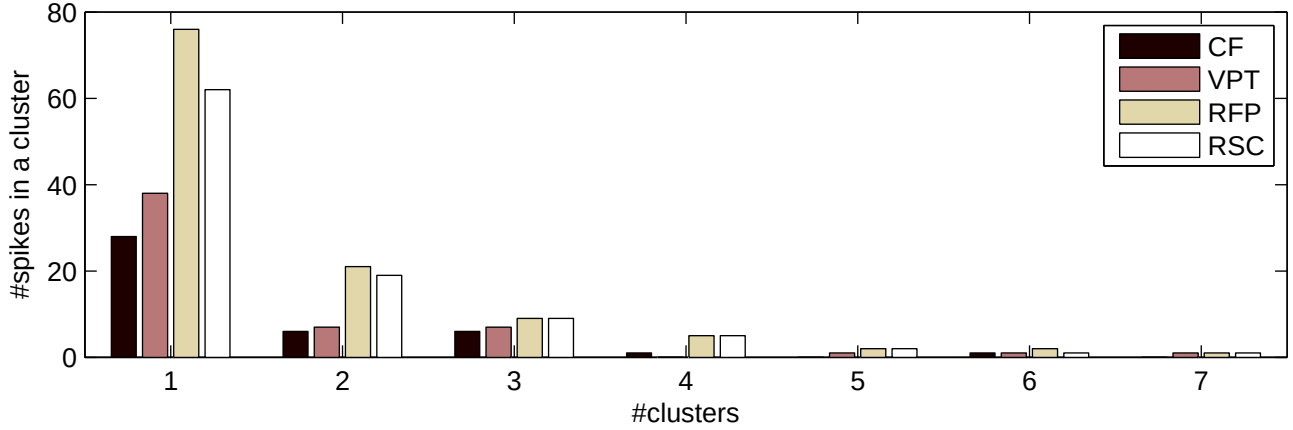
The reserve margin and spike forecasting cont.

- Consider $\rho(t_1, t_2) = \frac{D(t_1,t_2)}{C(t_1,t_2)}$
  - calculated at time t_1 (e.g. today) for an upcoming period t_2
  - $D(t_1, t_2)$ is the National Demand Forecast (Indicated Demand)
  - $C(t_1, t_2)$ is the predicted Generation Capacity (Indicated Generation, see www.bmreports.com)
  - See Cartea et al. (2009), Maryniak and Weron (2014)
- Plot $P(\text{spike}|\rho(t-\tau, t))$ for different τ's
  - Check how it depends on spike identification

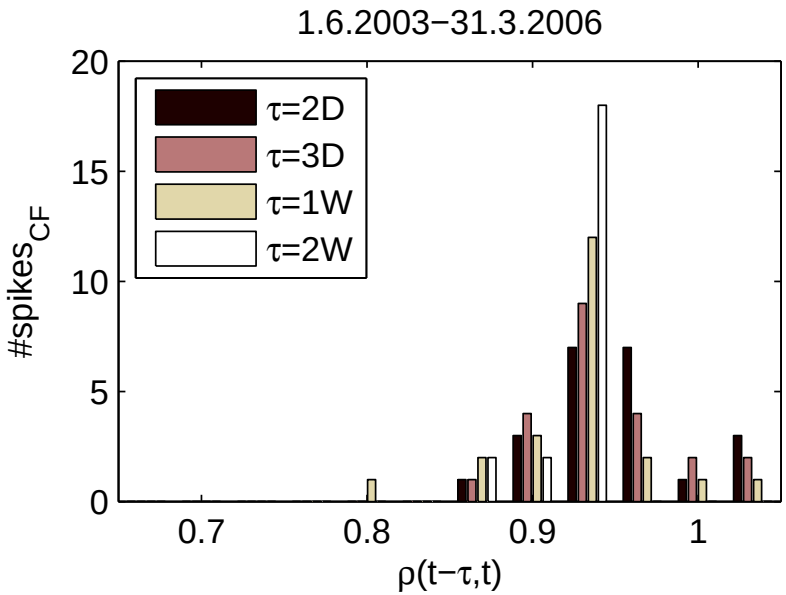
Spikes identified in UK spot prices (2003-2012)

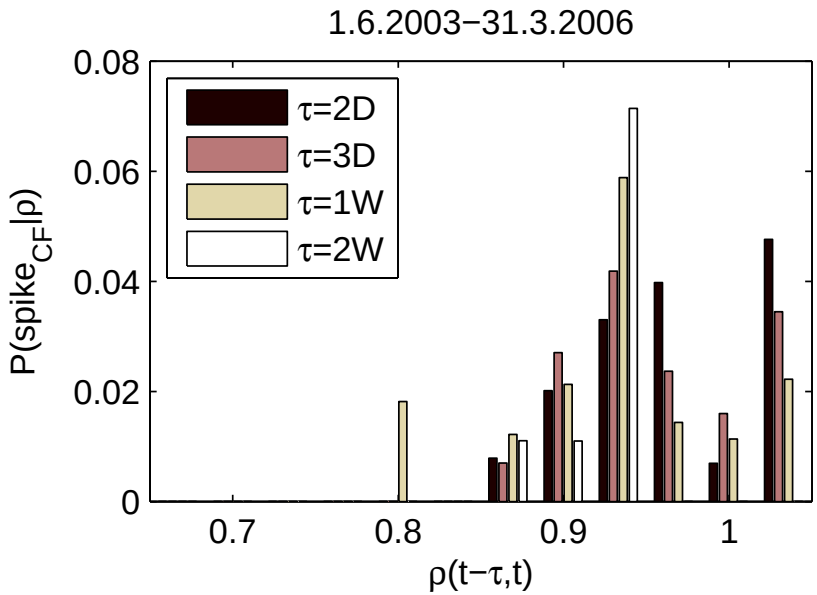






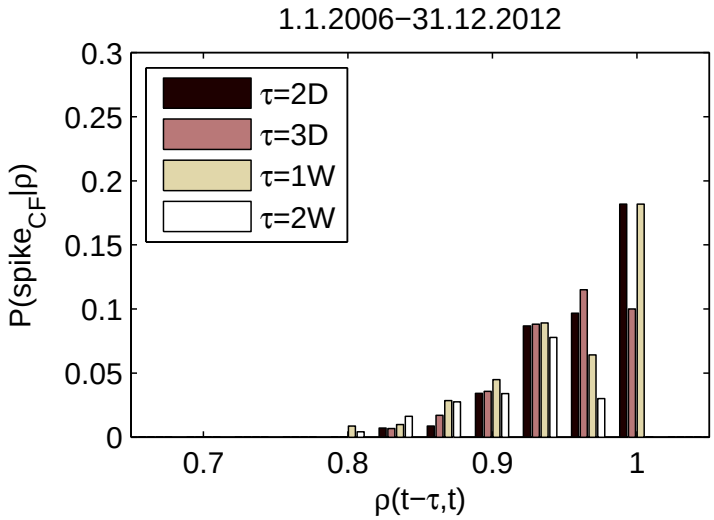
Number of spikes and spike probability

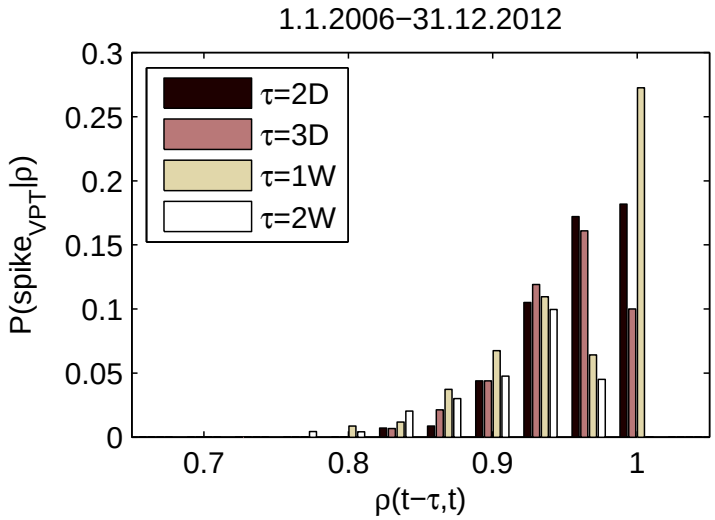


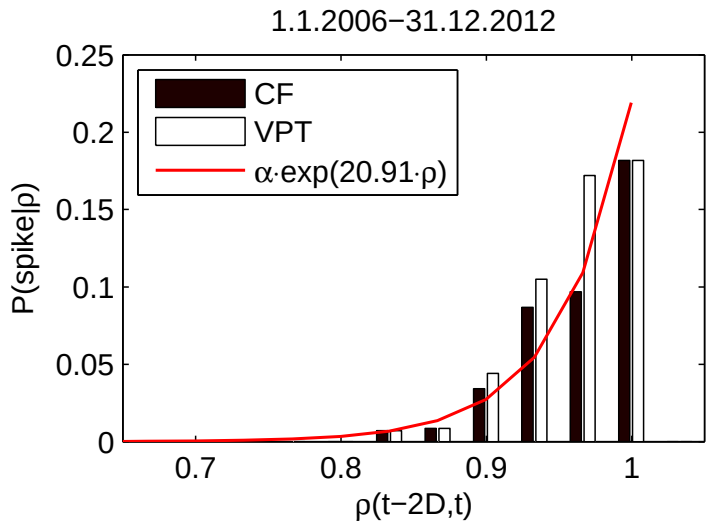


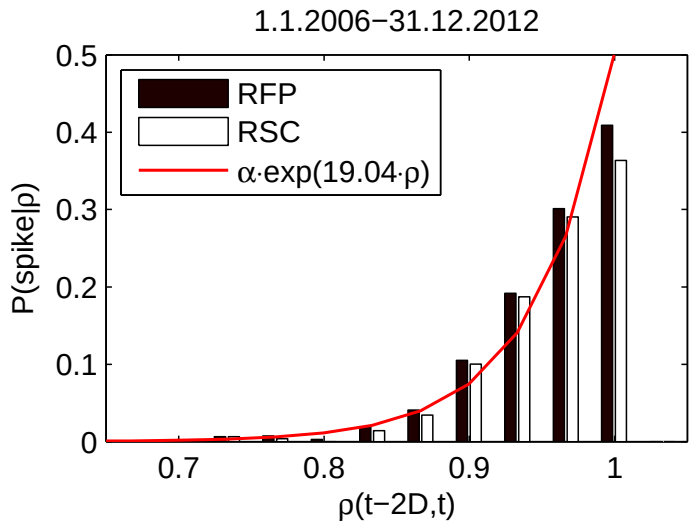
Anderson and Davison (2008): $\rho = 85\%$ is the 'industrial standard' warranting a safe functioning of the power system

Spike probability ... is roughly exponential









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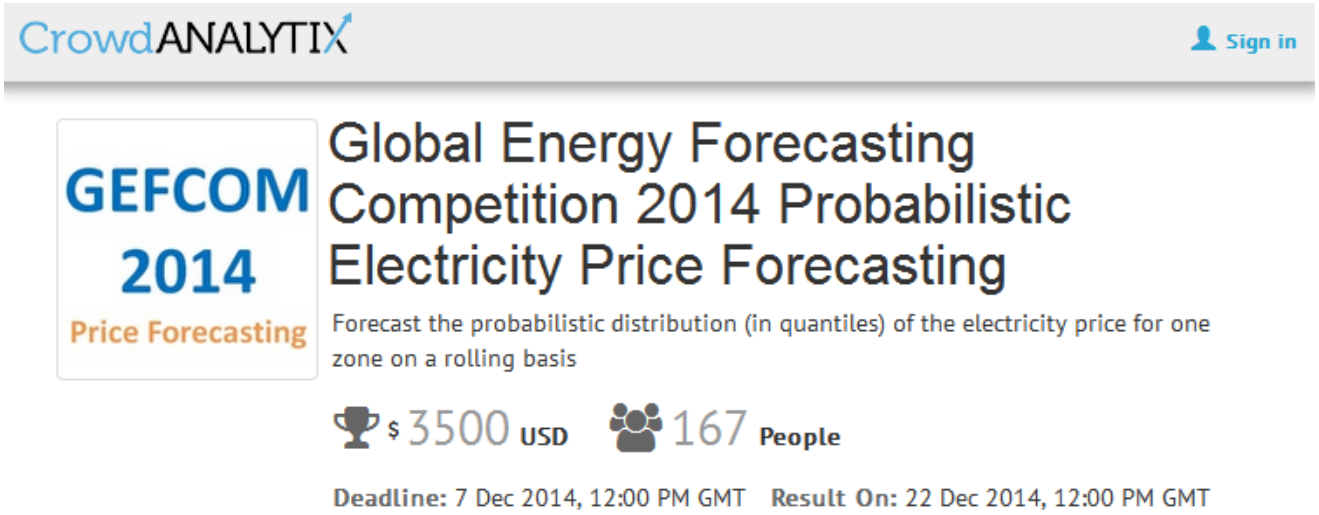
5. **The need for an EPF-Competition**
   - **A universal test ground**
   - **Guidelines for evaluating forecasts**

The need for an EPF-Competition

- Many of the published results seem to contradict each other
  - Misiorek et al. (2006) report a very poor forecasting performance of a MRS model, while Kosater and Mosler (2006) reach opposite conclusions for a similar MRS model but a different market and mid-term forecasting horizons
  - On the other hand, Heydari and Siddiqui (2010) find that a regime-switching model does not capture price behavior correctly in the mid-term
- Cross-category comparisons are even less conclusive and more biased
  - Typically advanced statistical techniques are compared with simple AI methods, see e.g. Conejo et al. (2005a), and vice versa, see e.g. Amjady (2006)

A universal test ground

- This calls for a comprehensive and thorough study involving
  1. the same datasets
  2. the same robust error evaluation procedures
  3. statistical testing and forecast evaluation
- GEFCom2014 included an EPF track this year:



Guidelines for evaluating forecasts

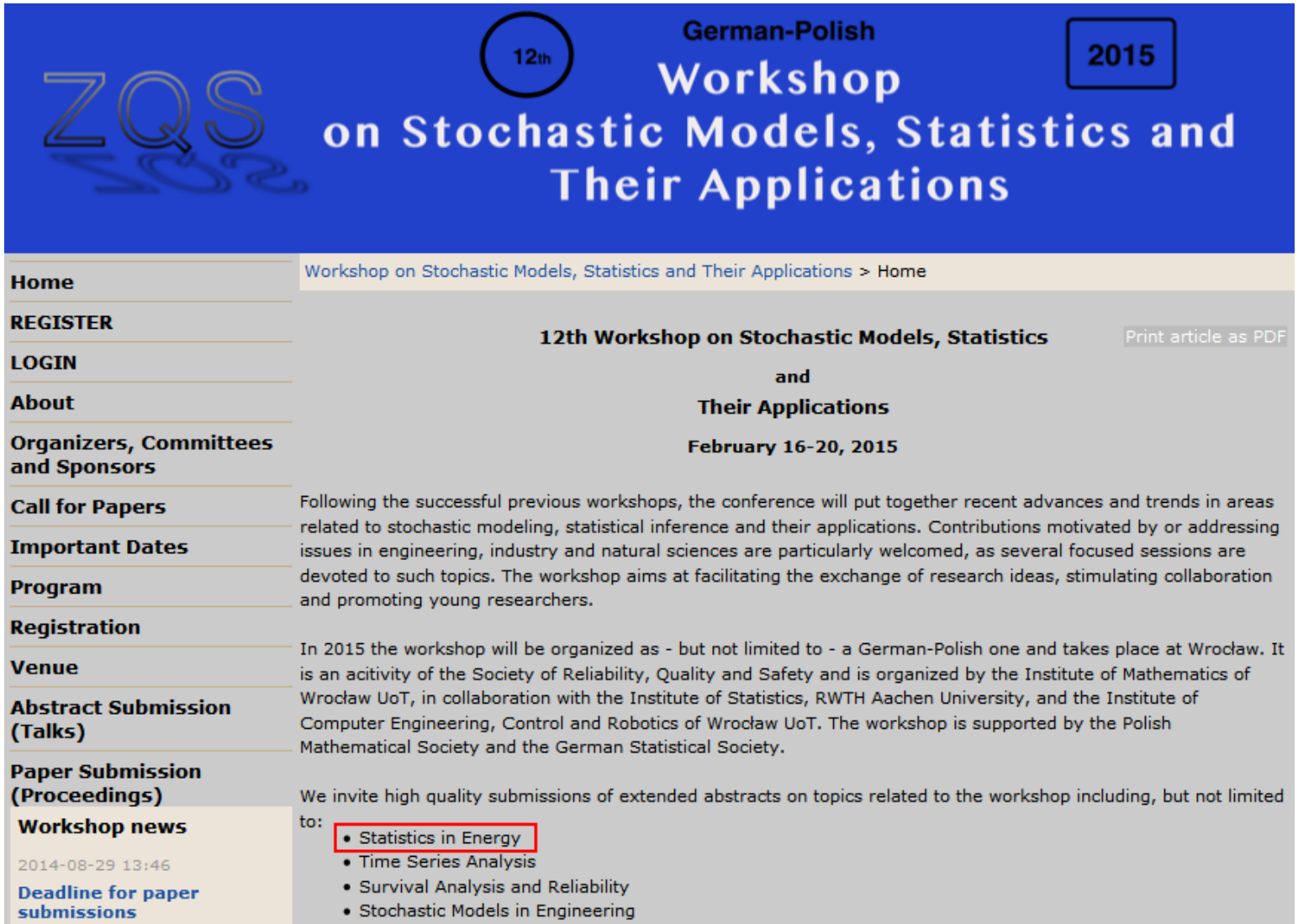
- A selection of the better performing measures for point forecasts
  - weighted-MAE, like the weekly-weighted WMAE
  - seasonal MASE (*Mean Absolute Scaled Error*)
  - RMSSE (*Root Mean Square Scaled Error*)

  should be used exclusively or jointly with the more popular ones (MAPE, RMSE), see e.g. Hyndman and Koehler (2006)
- For probabilistic forecasts
  - The *interval* or *Winkler score* can be used to evaluate PI and the *Continuous Ranked Probability Score* (CRPS) to evaluate density forecasts , see e.g. Gneiting and Raftery (2007), Maciejowska et al. (2014)

Guidelines for evaluating forecasts cont.

- Statistical tests for evaluating point forecasts
  - The Diebold and Mariano (1995) test for the significance of the difference in forecasting accuracy; for uses and abuses see Diebold (2013)
  - The *model confidence set* approach of Hansen et al. (2011)
  - The test of forecast encompassing, see Harvey et al. (1998)
- And probabilistic forecasts
  - The *conditional coverage* test of Christoffersen (1998); for extensions and alternatives see Berkowitz et al. (2011)
  - The Berkowitz (2001) approach to the evaluation of density forecasts (popular in VaR backtesting)

Thank you



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12th Workshop on Stochastic Models, Statistics and Their Applications

Print article as PDF

February 16-20, 2015

Following the successful previous workshops, the conference will put together recent advances and trends in areas related to stochastic modeling, statistical inference and their applications. Contributions motivated by or addressing issues in engineering, industry and natural sciences are particularly welcomed, as several focused sessions are devoted to such topics. The workshop aims at facilitating the exchange of research ideas, stimulating collaboration and promoting young researchers.

In 2015 the workshop will be organized as - but not limited to - a German-Polish one and takes place at Wrocław. It is an acitivity of the Society of Reliability, Quality and Safety and is organized by the Institute of Mathematics of Wrocław UoT, in collaboration with the Institute of Statistics, RWTH Aachen University, and the Institute of Computer Engineering, Control and Robotics of Wrocław UoT. The workshop is supported by the Polish Mathematical Society and the German Statistical Society.

We invite high quality submissions of extended abstracts on topics related to the workshop including, but not limited to:

- Statistics in Energy
- Time Series Analysis
- Survival Analysis and Reliability
- Stochastic Models in Engineering