Karlsruher Institut für Technologie

An Economic Analysis of the German Secondary Balancing Power Market

Strommarkttreffen, 22.01.2016 in Berlin (Acatech)

Fabian Ocker
E-Mail: Fabian.Ocker@kit.edu

Institute for Economics – Prof. Dr. Karl-Martin Ehrhart

Research Motivation

- Germany faces the „Energiewende“ with various implications
  - Variable Renewable Energy Soruces cover about 60% of energy supply in 2050 (Federal Ministry for Economic Affairs and Energy)
  - That is leading to a less predictable energy supply
  - Ancillary services, such as balancing power, become more important
  - Market mechanism: multi-attributive public procurement auctions

- Related research
  - Profit maximization in electrical (balancing) power auctions (Bushnell and Oren, 1994)
  - Scoring and pricing rules in energy markets (Chao and Wilson, 2002)
  - Discussion of pricing rules in the German balancing power markets (Müsgens, Ockenfels and Peek, 2014)
  - Renwable Energy Sources and balancing power markets (Hirth and Ziegenhagen, 2015)

Research questions & related own work

- **How is the German market for balancing power market designed?**
  - Ocker, F., Ehrhart, K.-M., Ott, M. (2015): *„An Economic Analysis of the German Secondary Balancing Power Market“*, Working Paper (under review).
- **How do suppliers behave within the current market design?**
  - Ocker, F., Ehrhart, K.-M. (2015)*: „The “German Paradox“ in the Balancing Power Markets“*, Working Paper (under review).
  - Belica, M., Ehrhart, K.-M., Ocker, F. (2016): *„Profits and Efficiency in the German Secondary Balancing Power Auction – A Game-Theoretical Analysis“*, Working Paper.
- **What alternative German market designs are discussed?**
  - Ocker, F., Belica, M., Ehrhart, K.-M. (2016): *„Die „richtige“ Preisregel für Auktionen – eine theoretische und empirische Untersuchung (inter-)nationaler Regelleistungs-märkte“*, 14. Symposium Energieinnovation Graz, 12.-14. February 2016.
- **How are other European balancing power markets designed?**
  - Ocker, F., Braun, S., Will, C. (2016): *„Design of European Balancing Power Markets“*, Working paper (under review).

Outline

- Basics of the current German Secondary balancing Power (SR) Market
- Theoretical Findings
- Empirical Findings
- International Balancing Power Markets

Basics of the current German SR-market (1/3)

- Net frequency needs to be constant (in Germany 50 Hz)
- In order to balance volatile energy production, an ancillary service for the German energy grid is needed: **balancing power** (reserve power)
  - Positive: energy is supplied to energy grid
  - Negative: energy is taken from energy grid
- Market mechanism used by transmission system operators (TSOs): public procurement auction (prequalification is required)
- Three different reserve power markets/qualities:
  Primary (PR), Secondary (SR) and Minute Reserve (MR)
- Two weekly time slots for SR: 8am-8pm (main period), else (sub-period)

Basics of the current German SR-market (2/3)

- Weekly repeated auction with nearly same suppliers (around 30)
- A complete bid consists of three components:
  power offer [MW], power bid [€/MW], energy bid [€/MWh]
- Activation strategy: merit-order of energy bids
- Scoring rule: only power bid, in increasing order until demand is met
- Pricing rule: Pay-as-bid (PaB) for both the power and energy bid
  - Federal Ministry for Economic Affairs and Energy (BMWi, 2016) & Müsgens, Ockenfels and Peek (2015):

    "*Changing the pricing rule (without changing the scoring rule) to uniform pricing (UP) will incentive suppliers to bid their true costs (incentive compatible) and market results will be more efficient*"

Basics of the current German SR-market (3/3)

- Two types of costs
  - Capacity costs – costs for keeping balancing power available
  - Calling costs – costs for providing balancing energy

- Positive/negative SR require different operation modes
  - Pos. SR: power plant running at/less than $P_{max} - q$
  - Neg. SR: power plant running at least at $P_{min} + q$

- Energy can be traded at alternative energy markets: if the variable costs *VC* of a power plant are less than relevant market price *w*, an operator participates at that energy market
  - Inframarginal power plant: $VC < w$ (opportunity costs!)
  - Extramarginal power plant: $VC > w$

Theoretical Findings – Decision-theoretic model (1/3)

- How should “rational“ bidders behave under different market designs?
- **I. Current market design** (PaB for power & energy bid)
  - **Power bid =** capacity costs – expected profits of the energy bid + “mark-up“
  - **Energy bid =** callings costs + “mark-up“
- **II. UP for power bid & PaB for energy bid**
  - **Power bid =** capacity costs – expected profits of the energy bid
  - **Energy bid =** callings costs + “mark-up“
- **III. PaB for power bid & UP for energy bid**
  - **Power bid =** capacity costs – expected profits of the energy bid + “mark-up“
  - **Energy bid <** callings costs
- **IV. UP for power & energy bid**
  - **Power bid =** capacity costs – expected profits of the energy bid
  - **Energy bid <** callings costs

Theoretical Findings – Decision-theoretic model (2/3)

- The current markt-design is not incentive compatible
  - Bidders exaggerate their costs to generatre profits (due to PaB)
  - Bidders include the expected profits of the energy bid into the power bid (scoring rule is not changed!)
- Changing the pricing rule to UP will not improve the incentive structure
  - Expected profits of the energy bid are still considered for the power bid
  - The “goods“ in the merit-order of the energy bids are not homogenous (the lower the position, the higher the probabilty for delivering balancing energy)
  - Bidders have incentives to be positioned at the front of the merit-order by reducing the energy bid below their calling costs
- General remarks on UP for the energy bid
  - What bid/price is determining the uniform price (last called energy bid)?
  - How many uniform prices will be introduced (one per week/day/hour)?
  - How to face “strategic bidding“?

Theoretical Findings – Game-theoretic model (3/3)

- There is an unique symmetric Bayes-Nash bidding equilibrium in both the current positive and negative SR-market (one shot-auction)

- In the equilibrium of the current market-design, the following hold
  - Profits at the SR-market are higher than at the spot-market
  - The higher the variable costs, the lower the profits at the SR-market
  - The higher the number of suppliers, the lower the profits at the SR-market
  - The auction outcome is efficient: suppliers with the lowest capacity costs will be selected for the SR-market and suppliers with the lowest calling costs will be used for providing balancing energy the most

- Assuming sufficient supply of „spinning reserve“, the positive and the negative markets differ substantially
  - Pos. Market: opportunity costs for not trading at another energy market
  - Neg. Market: no opportunity costs, but possible double compensation

Empirical findings – the "German Paradox" (1/7)

- The "German Paradox" in the balancing power markets:

  "*Despite the increasing energy supply of variable renewable energy sources, the demand for balancing power in Germany is declining*"
  (Hirth, L. and Ziegenhagen, I., 2015)

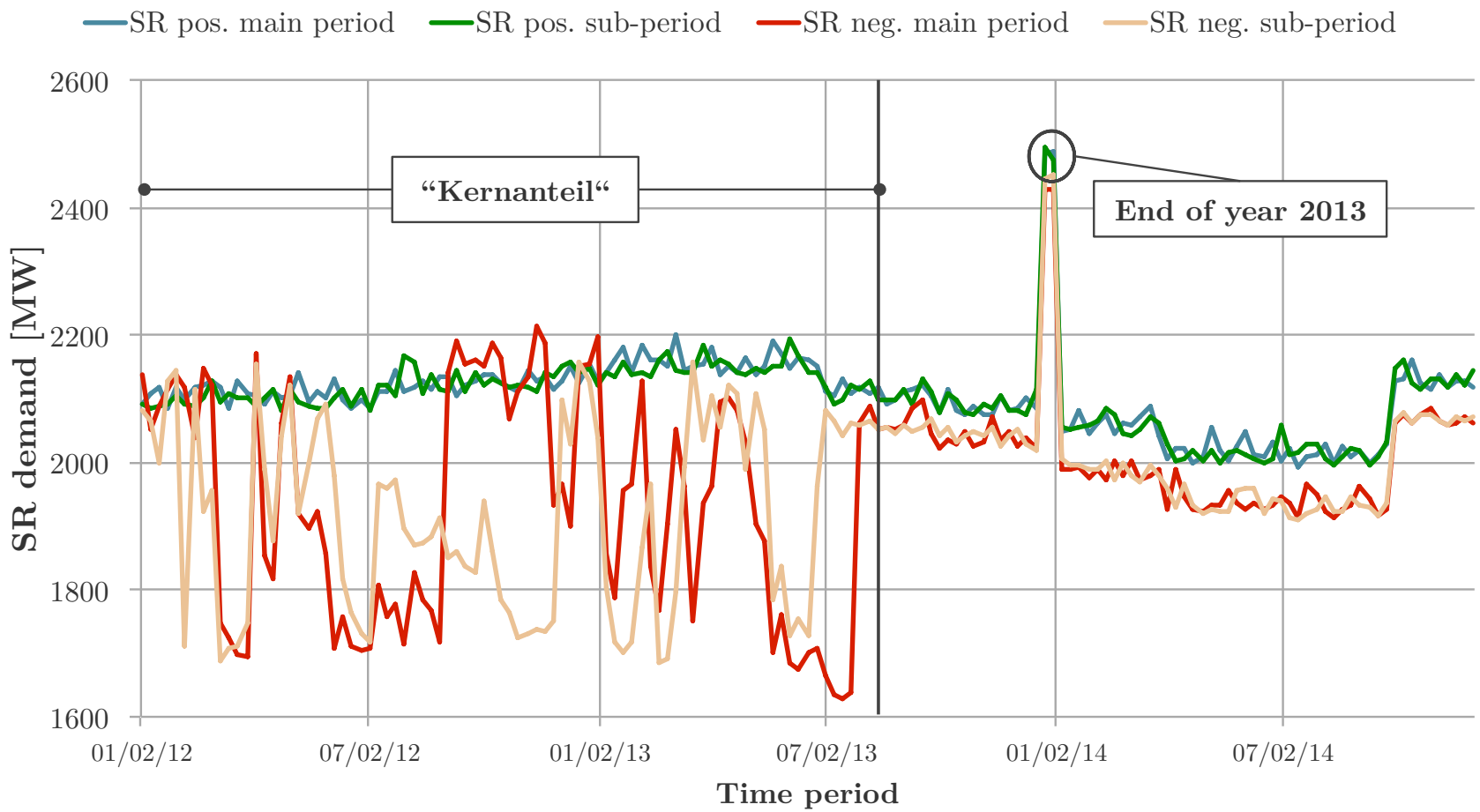
- Why is that?

- TSO cooperations lower balancing power demand in Germany
  - National: German TSOs introduced the "Netzregelverbund" in 2009
  - International: German TSOs joined the "International Grid Control Cooperation (IGCC)" in 2011

- Adaptations in the German energy markets were undertaken
  - Higher trading flexibility in the Intraday-market (15min since 09/2011)
  - Introduction of the 15min day-ahead market in 12/2014

Empirical findings – SR demand (2/7)

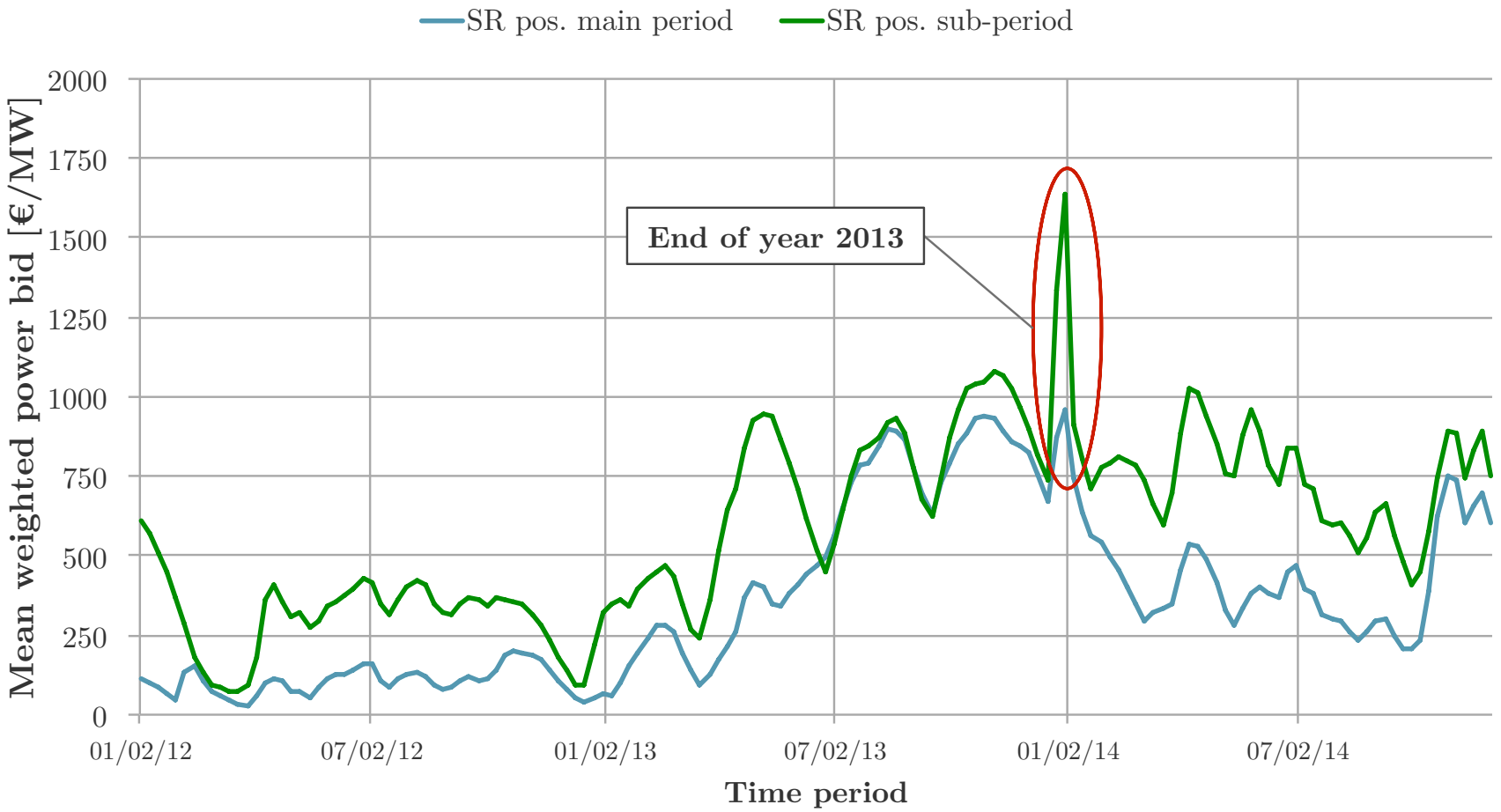
- Development of the SR demand
  (January 2012 - December 2014, 153 auctions)



Institute for Economics
Fabian Ocker

Empirical analysis – pos. SR power bids (3/7)

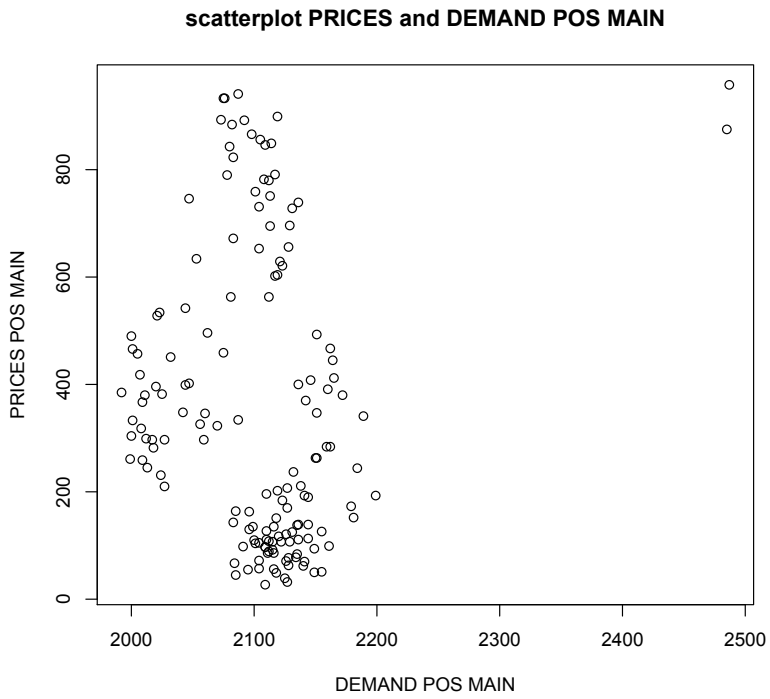
- Mean weighted power bid (published by TSOs)
  (January 2012 - December 2014, 153 auctions)

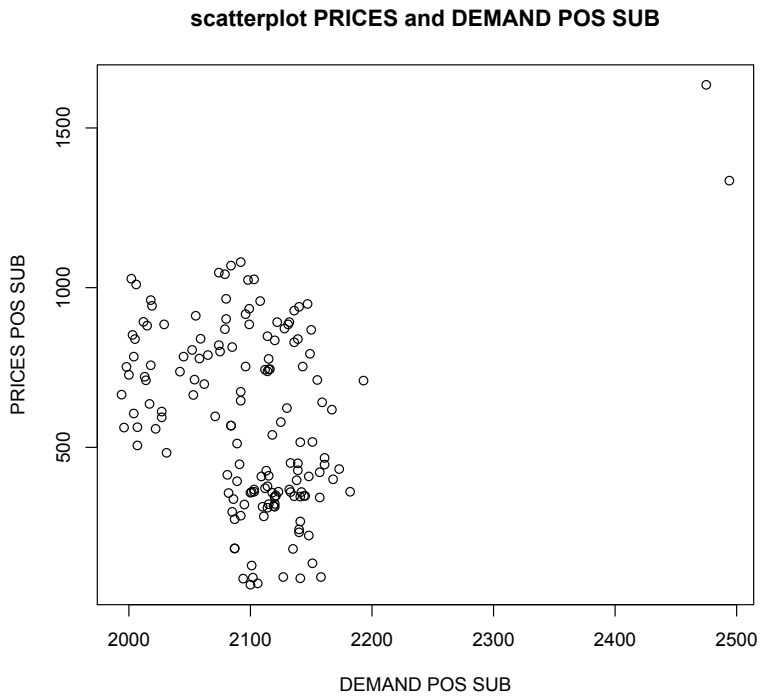


Institute for Economics
Fabian Ocker

Empirical analysis – SR demand and power bids (4/7)

- Scatter plots of pos. SR demand and SR prices (mean weighted power bids)
- Expected: “The higher the SR demand, the higher the SR prices”





Pos. SR main period: r_S = - 0,237

Pos. SR sub-period: r_S = - 0,299

→ No positive correlation for SR demand and prices found – why?

Empirical analysis – SR demand and power bids (5/7)

- Framework conditions were “stable” (supplier side, sport market price)
- Seperating the time period into two sub-periods:
  - Sub-period 1 (SP 1): January 2012 – June 2013
  - Sub-period 2 (SP 2): July 2013 – December 2014
- Then, significant positive-monotonic relationships are revealed:

Considered periods	r_S	⌀ Price	⌀ Demand
Main period: SP 1	+ 0,410 ***	170 €/MW	2129 MW
Main period: SP 2	+ 0,560 ***	561 €/MW	2077 MW
Sub-period: SP 1	+ 0,264 **	393 €/MW	2124 MW
Sub-period: SP 2	+ 0,210 *	808 €/MW	2077 MW

*** p-value < 0,001, ** p-value < 0,01, * p-value < 0,05

- **Hypothesis: coordination of the suppliers on a higher price level**

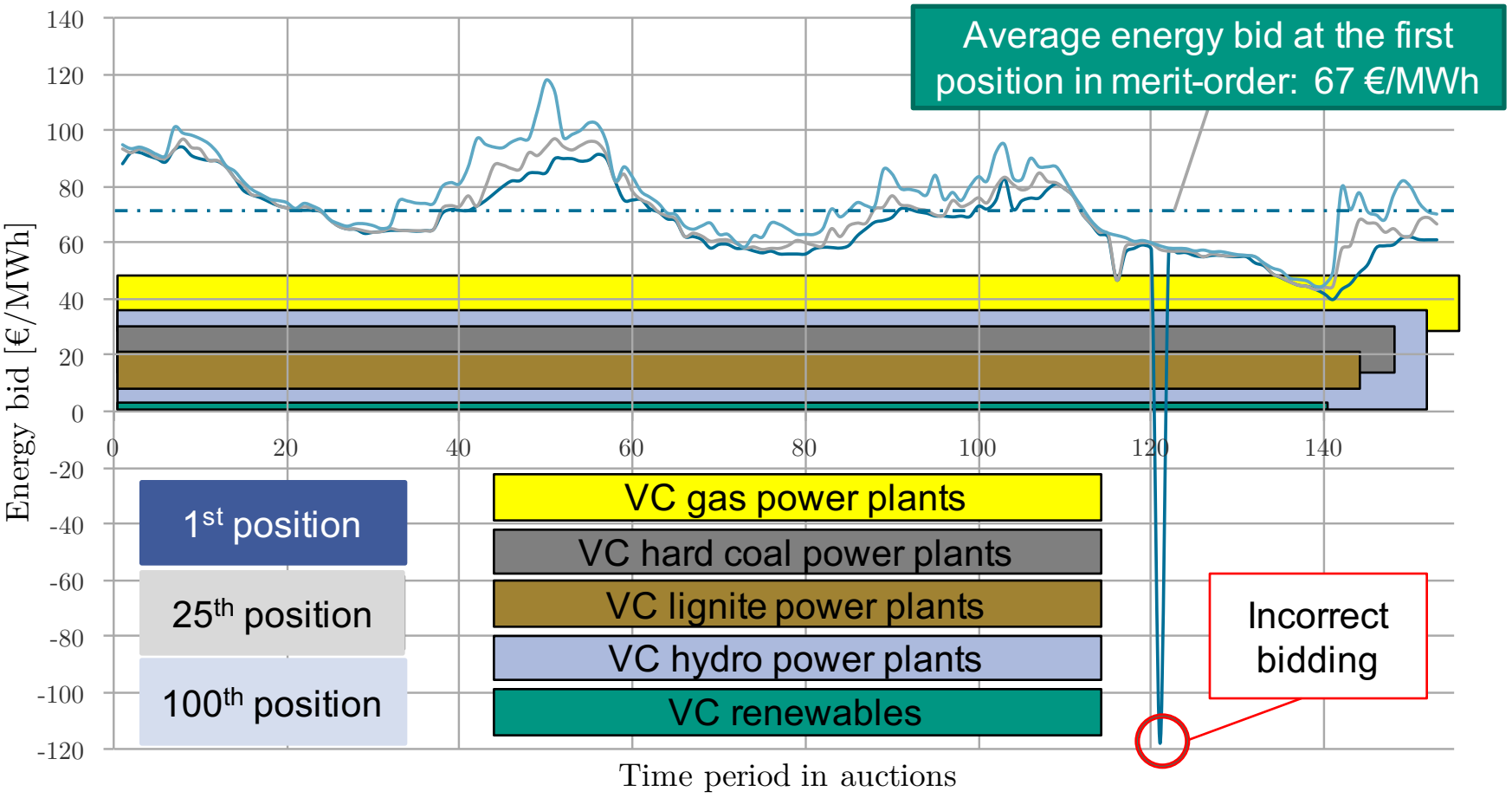
Empricial analysis – orientation of suppliers (6/7)

- SR prices are very complex/unsteady from suppliers' perspective
- How can suppliers cope with such a high degree of uncertainity?
- **Hypothesis: suppliers orientate towards former auction results**
- Durbin-Watson autocorrelationtest reveals significant results for the mean-weighted power bids in the positive SR-markets up to the fifth lag

→ suppliers orientate towards the last five auction results

Empirical analysis – SR energy bids (7/7)

- Positive SR-markt in the main period
  (January 2012 - December 2014, 153 auctions)



International Balancing Power Markets

- Empirical analysis of all 24 European countries that procure balancing power with public procurement auctions

- We find that …
  - 19 countries use the “three-quality” pattern (PR/SR/MR)
  - 23 countries generally distinguish positive from negative balancing power
  - the scoring rule (winner determination) is either based on the power & energy bid, only the power bid or by considering additional factors
  - different pricing rules are applied: 10 countries use UP, 12 countries use PaB, 2 countries use combinations of UP and PaB
  - countries with a high share of renewable energy sources use more short-term and flexible auction designs (duration, frequency, prequalification)
  - the transperancy of the European markets leaves room for improvement
  - there exist TSO cooperations in central and northern Europe

→ Still a long way to a common European Balancing Power Market!