TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Business and Economics, Chair of Energy Economics, Prof. Dr. Möst

A model-based market power analysis of the German market for Frequency Containment Reserve

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Samir Jeddi, 28th April 2018

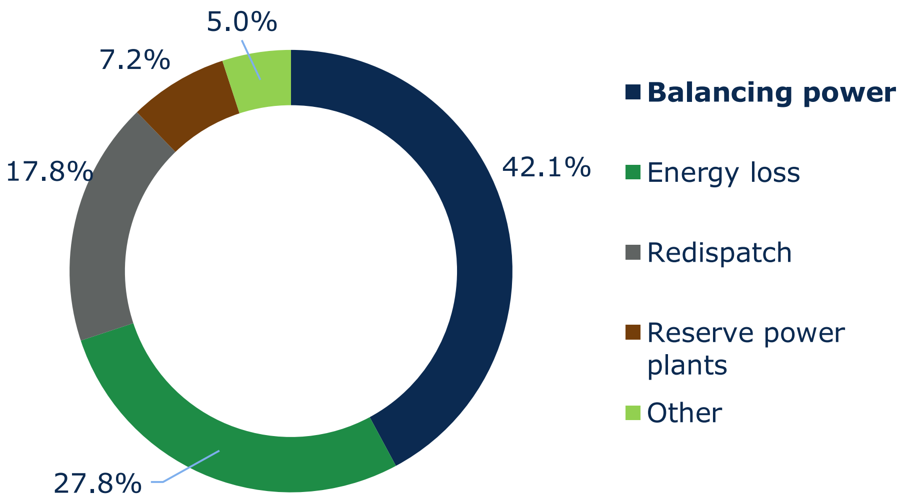
Agenda

1. Challenges for the German balancing power market
2. Methodology
    - Bi-level market models
    - Solution approach
3. Results
    - Historic market power analysis
    - Alternative market design
    - Future market behaviour
4. Conclusion

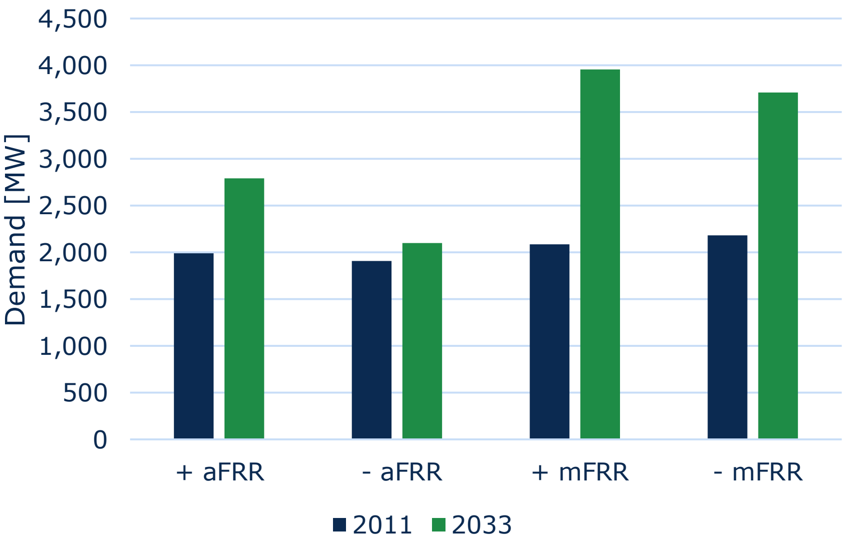
Challenges for the German balancing power market

Market development favours market power

Breakdown of costs for system services



Projection of the balancing power demand



	FCR	aFRR	mFRR
Cost [Mio. EUR]	103	228	106
Prequalified Suppliers	23	34	46

Source: Own Illustration based on BNetzA (2016), Dena (2014) und regelleistung.net (2017).

Challenges for the German balancing power market

Just a few model-based market power analysis in the literature

Econometric and theoretical analysis:

- Impact of the formation of the GCC
  Riedel und Weigt (2007), Müller und Rammerstorfer (2008)
- Correlation analysis between spot and balancing power markets
  Growitsch und Weber (2008), Haucap et al. (2012)
- Analysis of bidding behavior
  Heim und Götz (2013), Müsgens et al. (2014)
- Theoretical analysis of the pricing scheme
  Belica et al. (2016)

Market power indices:

Concentration ratio	CR_1	CR_3	CR_4	CR_5	HHI
Value	0.37	0.84	0.95	0.98	2,674
Critical value	(0.33)	(0.5)	(0.67)	(0.67)	(2,500)

Source: Own illustration based on Heim und Götz (2013).

Model-based market power analysis:

- Models based on decision theory
  Ocker et al. (2015)
- Market models
  Wieschhaus und Weigt (2008)
- Structural analysis of modelled market results
  Knaut et al. (2017)

Methodology

Bi-level market models simulate real market behaviour

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Optimization models: MPEC

Optimization problem Firm *j*

$$\max_{p_i, DV} \pi_j = \sum_{i \in \Omega_j}^{n} (\lambda - c_i) * g_i$$

$$s.t.$$

$$ULR_j$$

$$\min_{g_i} C_{SO} = \sum_{i=1}^{n} p_i * g_i$$

$$s.t.$$

$$\sum_{i=1}^{n} g_i - D = 0 \; : \; \lambda$$

Market clearing of the TSO

Equilibrium models: EPEC

Optimization problem Firm *1*

$$\max_{p_i, DV} \pi_1 = \sum_{i \in \Omega_1}^{n} (\lambda - c_i) * g_i$$

$$s.t.$$

$$ULR_1$$

Optimization problem Firm *j*

$$\max_{p_i, DV} \pi_j = \sum_{i \in \Omega_j}^{n} (\lambda - c_i) * g_i$$

$$s.t.$$

$$ULR_j$$

Optimization problem Firm *M*

$$\max_{p_i, DV} \pi_M = \sum_{i \in \Omega_M}^{n} (\lambda - c_i) * g_i$$

$$s.t.$$

$$ULR_M$$

$$\min_{g_i} C_{SO} = \sum_{i=1}^{n} p_i * g_i$$

$$s.t.$$

$$\sum_{i=1}^{n} g_i - D = 0 \; : \; \lambda$$

Market clearing of the TSO

Source: Own illustration based on Ventosa et al. (2005).

Methodology

Linearization is the preferred solution approach

Linearization:

- \+ Analytical
- \+ Identification of all equilibriums
- ~ Guarantee for optimality
- ~ Extensive analysis possible
- ~ Inclusion of a high number of variables

Diagonalization:

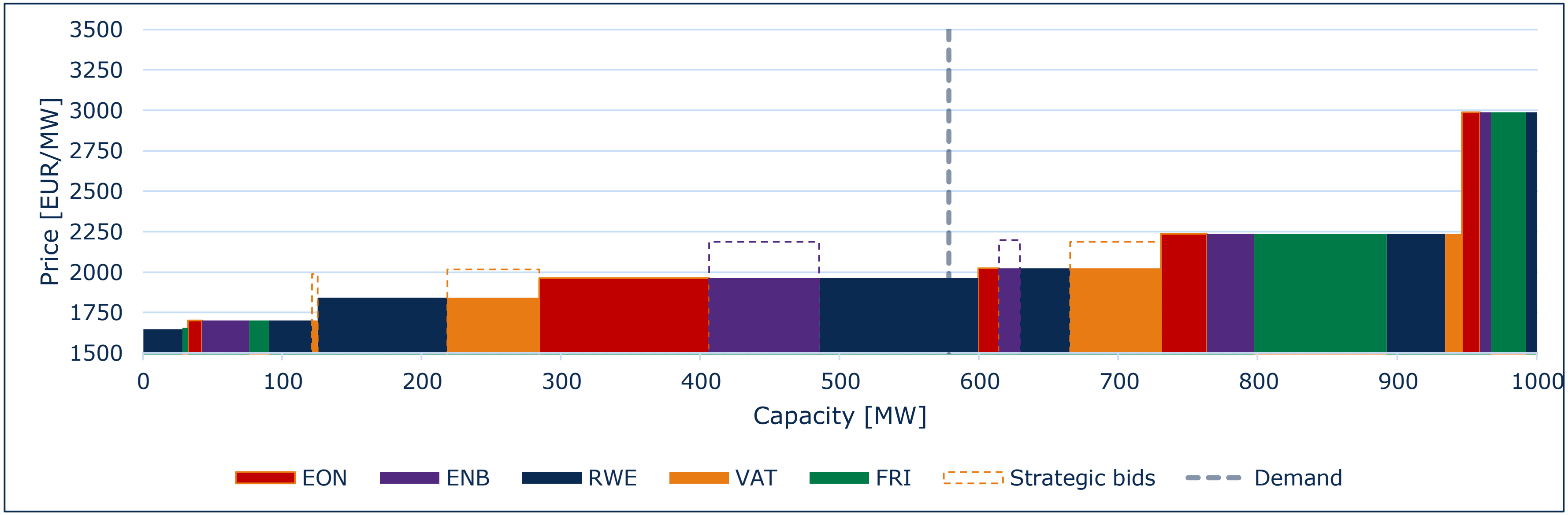
- ϟ Heuristic
- ϟ Convergence problems
- ϟ No guarantee for optimality
- ϟ No identification of all equilibriums

NLP-Formulation:

- \+ Differentiation of dual variables
- ϟ High number of variables
- ϟ Limited scope of analysis

Results

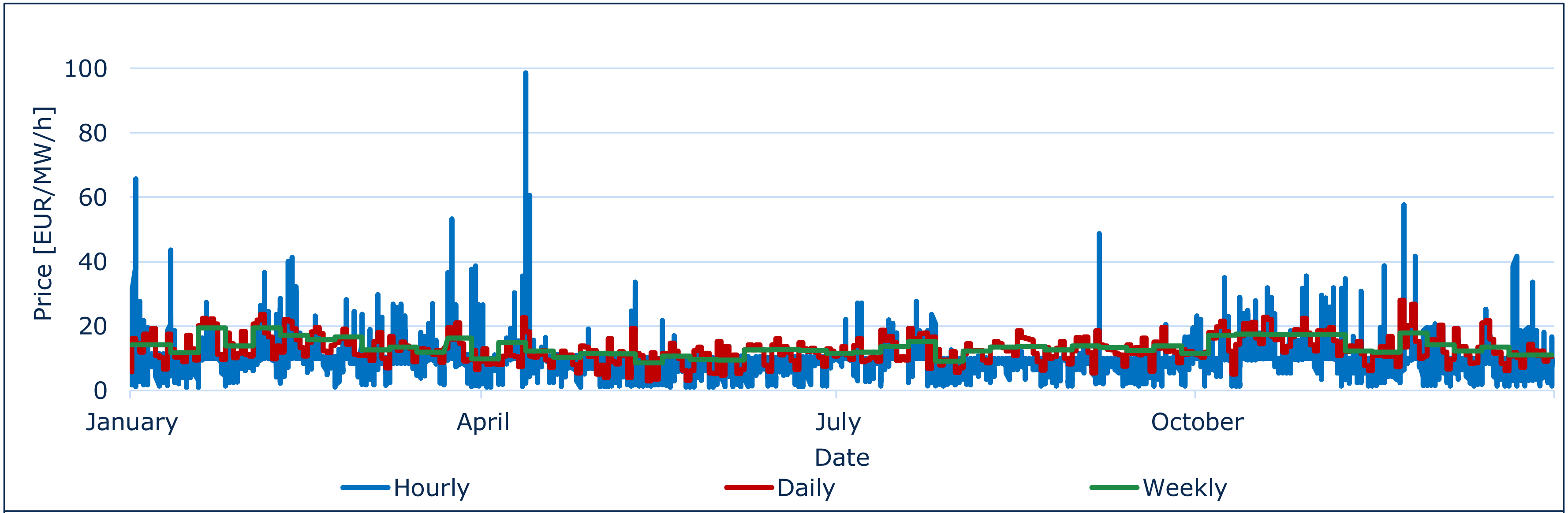
Individual suppliers can just moderately influence the market price

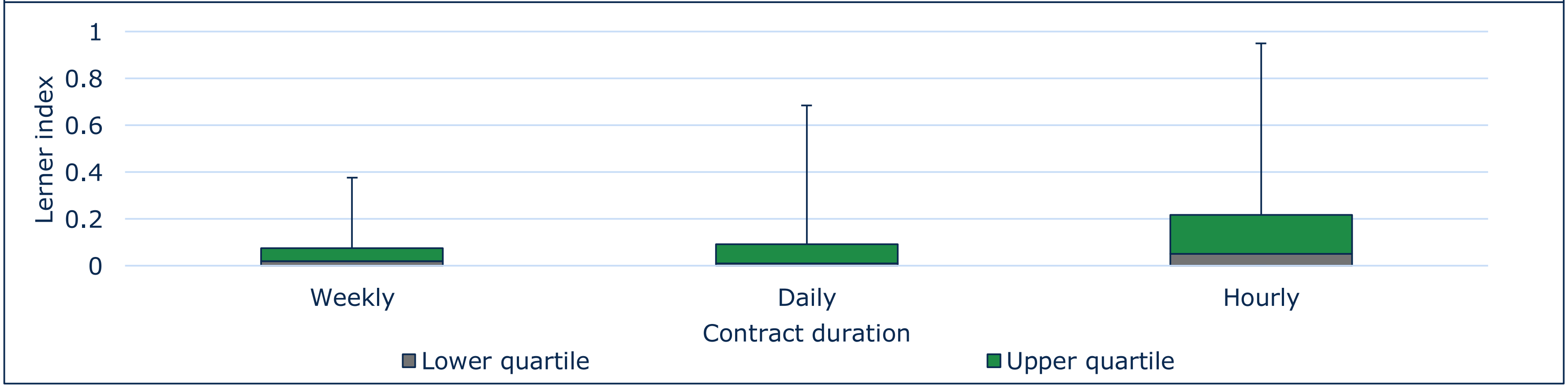


	EPEC	Competition	MPEC			
			EON	ENB	RWE	VAT
Average price [EUR/MW]	2,427	2,302	2,379	2,397	2,408	2,406
Average yearly Lerner index [%]	6.50	0.00	4.28	5.14	5.63	5.51

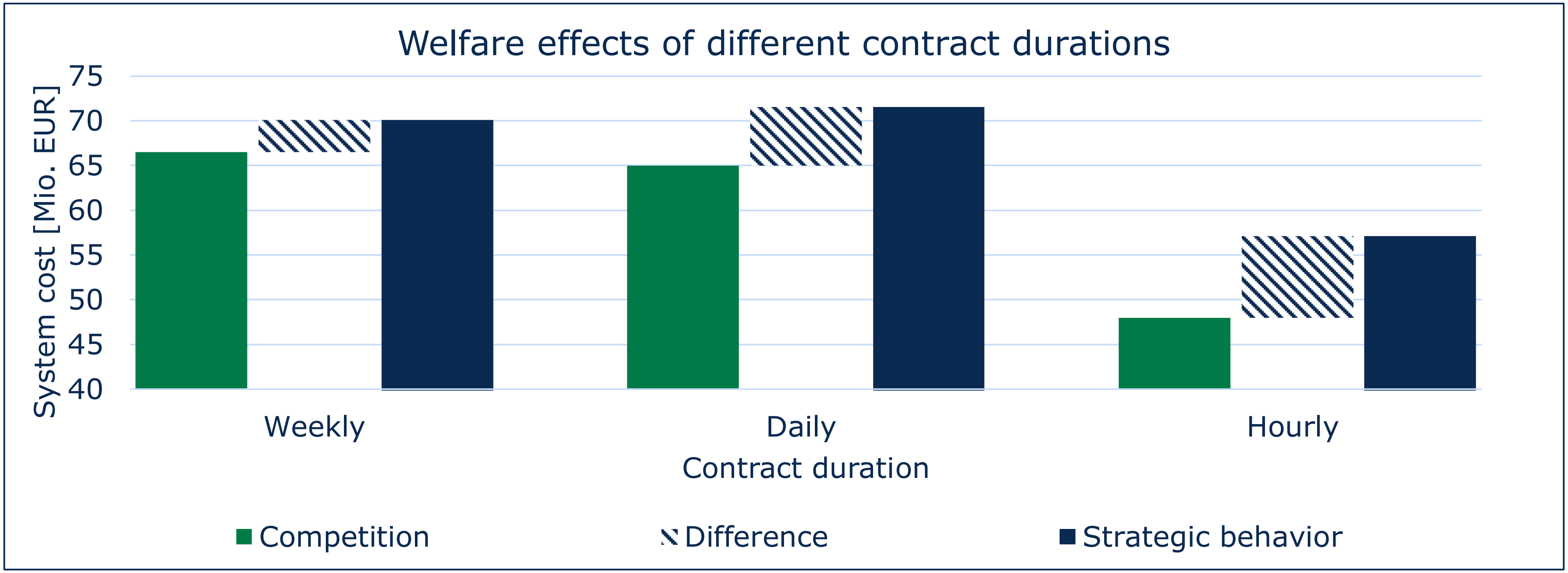
Results

Shorter contract durations increase the market power potential





Results
Shorter contract durations might lead to welfare losses



Results

Battery storages improve the market efficiency in 2025

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Scenario A (NEP 2015)
- Low market penetration of RES
- Constant demand
- Biggest share of conventional generation

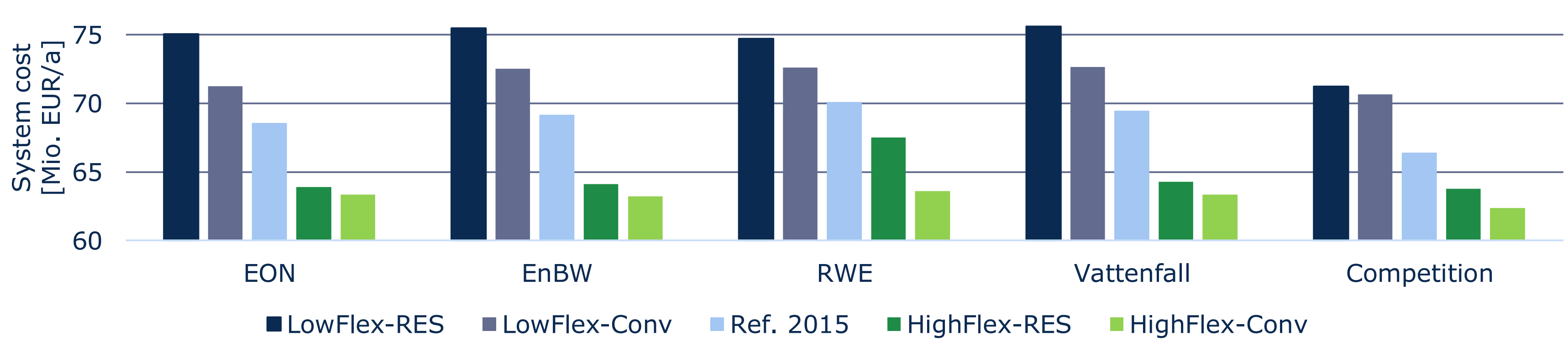
Low-Flex_Therm
- 300 MW battery storage

High-Flex_Therm
- 500 MW battery storage

Scenario C (NEP 2015)
- High market penetration of RES
- Demand reduction
- Lowest share of conventional generation

Low-Flex_EE
- 300 MW battery storage

High-Flex_EE
- 500 MW battery storage



Conclusion

☑ **Equilibrium model** with **discrete** supply function
☑ Solution by innovative combination of **linearization techniques**
☑ Model **validation**
☑ Analysis of **alternative market design** and **future market behaviour**

- Historic market results: Limited market power
- Shorter contract durations: Lower system costs and increased market power
- Battery storage investments: Reduction of market power potential with decentralized ownership, as well as decreasing system costs

☐ Further research on modelling EPECs in real markets
☐ Modelling the optimization problem under consideration of stochastic opportunity costs

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»Wissen schafft Brücken.«