Auction Design for a Strategic Reserve Market

Joint research with

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A changing environment

Towards low-carbon energy supply

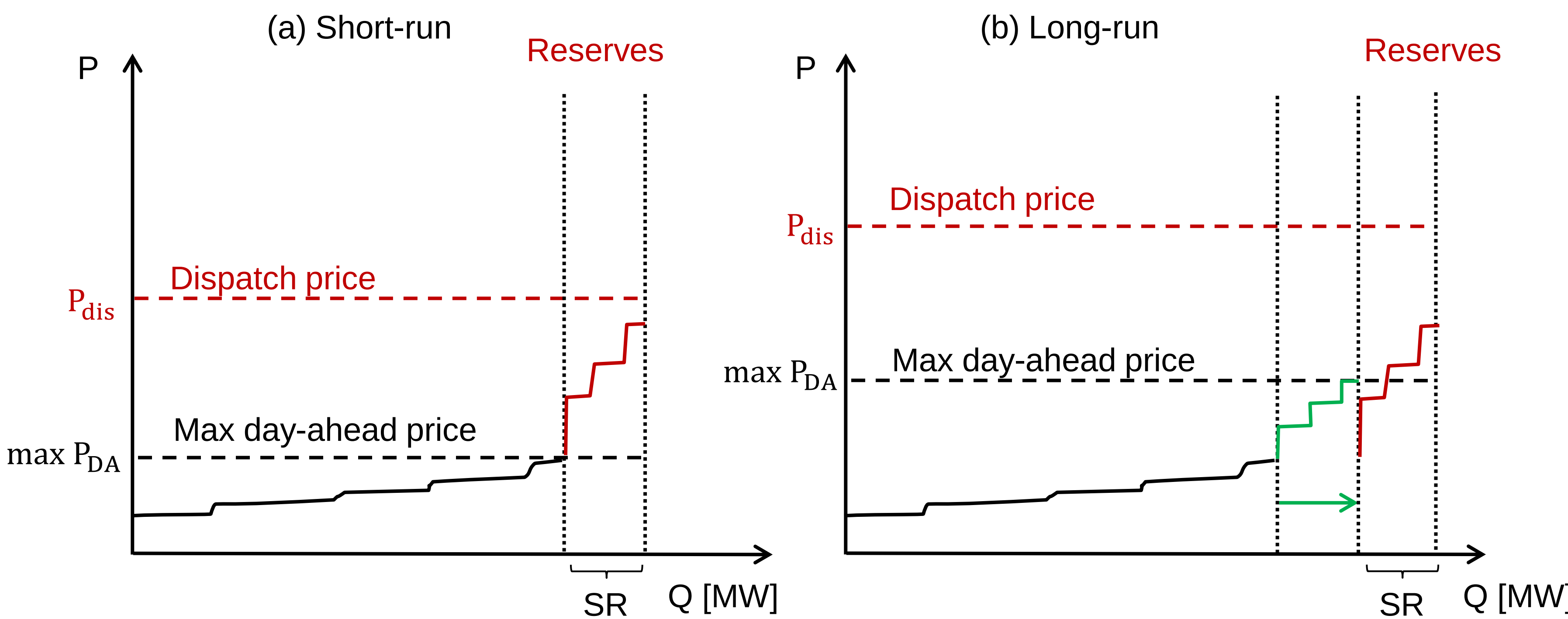
- Transformation towards large-scale integration of renewable energy sources (RES)
- Intermittent supply of RES with low marginal cost
  - Conventional generators needed as reserves in case of low wind and solar generation
  - “Missing money problem”: Does the market provide sufficient investment incentives?
- Traditional market design: *energy-only market*
  - Generators receive revenues for <u>*produced energy [€/MWh]*</u> and not for holding <u>*capacity reserves [€/MW]*</u>

► Is energy-based remuneration adequate for a world of *50+ percent RES*?

A Strategic Reserve market

The Swedish model as an example

- TSO acquires max. *2000 MW* of reserves (units with a utilization below 40 hours/year)
  - Gas, Oil (2011: 1309 MW)
  - Demand response. (2011: 583 MW)



Reserve dispatch price = Maximum day-ahead price (min. 800 €/MWh) + variable cost

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Auction design issues

Electricity markets and auction design in Germany

	Existing markets		Proposed reserve market
Type of market	**Spot market**	**Balancing market**	**Reserve market**
Bids	Energy bids	Capacity bid and Energy bid	Capacity bid and Energy bid
Pricing	Uniform pricing	Pay-as-bid pricing	Pay-as-bid pricing
Bidding rule	Simultaneous	Simultaneous	Simultaneous
Scoring rule	-	Sequential (e.g. in Germany)	Simultaneous or Sequential

Auction design issues

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An auction design model (work in progress)

- TSO as auctioneer aims to minimize reserve costs by selecting the cheapest units
- Generators bid a certain amount of capacity for a given time period
  - Capacity is withdrawn from the day-ahead market
  - The bids of each unit i consists of
    - A capacity bid b_i^K [€/MW]
    - An energy bid b_i^C [€/MWh]
  - Assuming a *first-price*, *pay-as-bid auction*, each bidder receives its own bids if selected for the reserve market.
  - Total profits:

$$\boxed{\pi_i = b_i^K + \rho_i(b_i^C) \cdot b_i^C}$$

with $0 \leq \rho_i \leq 1$ dispatch duration of unit i (dispatch function)

► How are winning bids selected?

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Scoring mechanisms

Scoring mechanism	Simultaneous scoring rule	Sequential scoring rule
Bidding	Simultaneous	Simultaneous
Scoring rule (Selection)	$S_i = b_i^K + \Omega_i b_i^C$	$S = b_i^K$
Energy demand (Dispatch)	$\rho(b_i^C)$	$\rho(b_i^C)$

Maximization problem of bidders:

Max $E(\pi_i) = P_i(S_i(.)) \cdot [b_i^K - k_i + \rho(b_i^C) \cdot (b_i^C - c_i)]$

Relative weights of bids in scoring rule

$$\frac{\frac{\partial S_i(b_i^C, b_i^K)}{\partial b_i^C}}{\frac{\partial S_i(b_i^C, b_i^K)}{\partial b_i^K}} = \rho(b_i^C) + (b_i^c - c_i)\frac{\partial \rho(b_i^C)}{\partial b_i^C}.$$

MRS of energy and capacity bids

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1. Simultaneous scoring rule

$$S = b_i^K + \Omega_i \cdot b_i^C$$

$$\underbrace{\frac{\frac{\partial S_i(\mathrm{b}_i^C, \mathrm{b}_i^K)}{\partial \mathrm{b}_i^C}}{\frac{\partial S_i(\mathrm{b}_i^C, \mathrm{b}_i^K)}{\partial \mathrm{b}_i^K}}}_{\Omega_i} = \rho\left(\mathrm{b}_i^C\right) + (\mathrm{b}_i^c - \mathrm{c}_i)\frac{\partial \rho\left(\mathrm{b}_i^C\right)}{\partial \mathrm{b}_i^C}.$$

Proposition 1: *Assuming that a simultaneous scoring rule of the form* $S_i = b_i^K + \Omega_i b_i^C$ *is implemented, where* $\boldsymbol{\Omega_i} = \boldsymbol{\rho_i}\ \forall i$ *(optimal scoring rule), bidders will bid their true marginal cost (*$b_i^C = c_i$*) on the energy market.*

Main result: **Truthful marginal bids**

Assumption: actual dispatch (ρ_i) for each bidder I is known *a priori* to the auctioneer as well as to bidders.

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2. Sequential scoring rule

$$S = b_i^K$$

$$\boxed{\frac{\frac{\partial S_i(\mathrm{b}_i^C, \mathrm{b}_i^K)}{\partial \mathrm{b}_i^C}}{\frac{\partial S_i(\mathrm{b}_i^C, \mathrm{b}_i^K)}{\partial \mathrm{b}_i^K}} = \rho(\mathrm{b}_i^C) + (\mathrm{b}_i^c - \mathrm{c}_i)\frac{\partial \rho(\mathrm{b}_i^C)}{\partial \mathrm{b}_i^C}.}$$

$$\underbrace{\qquad\qquad}_{0}$$

Proposition 2: *In case of a sequential scoring rule, where units are chosen on basis of their capacity bids only, bidders will choose a mark-up on their energy costs according to*

$$(b_i^c - c_i) = \frac{-\rho(b_i^C)}{\frac{\partial \rho(b_i^C)}{\partial b_i^C}} > 0$$

Main result: **Positive mark-up on energy bids**

(due to limited number of bidders at the „second stage“ (dispatch))

► Energy bid as „strategic variable“ (to make profits)

► Capacity bid as „residual variable“ (opens the door to the reserve market)

Conclusions: welfare effects

- Sequential scoring rule (like in balancing markets)
  - Leads to strategic energy bidding (positive energy mark-up)
- Simultaneous scoring rule
  - "Correct" scoring weights
    - Leads to truthful marginal bids
    - Efficient selection and dispatch
  - In case of prediction errors:
    - Risk of strategic behavior
    - Inefficient selection and dispatch
    - In case of doubt: higher capacity weight seems less harmful
      - Distortion in direction of peak capacities with lower fixed costs
- Risk effects
  - Higher share of capacity payment reduces dispatch risk for reserves
  - Risks depend on timeframe of the reserve auctions

Thank you for your attention !

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