Two Bidding Zones in the German Electricity Market - Distributional Effects of Regional Price Signals

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Bidding areas in Europe:

- Internal Energy Market: Implicit market coupling with NTC capacity
- Today only in markets with clear geographic borders (Nordpool/Italy)
- Discussion on bidding zones on European level (regulation on CACM)
- Implications of bidding zones: Affects on prices and rent distribution
  - Re-shaping of zones
  - NTC capacity
The case of Germany:

- Regional imbalances increasing (RES and coal plants in the north)
- Internal congestion: Redispatch up from 26mn ('09) to 165mn ('12)
- Neighbors: Transit flows and loop flows (north-south)
- No support for regional pricing in Germany
  - Other construction sites (capacity markets / feed-in tariffs / network, etc.)
  - Perception that split in prices zones is a “defeat” (for the “Energiewende”)
  - Grünbuch (BMWi): bidding zones only if not network investment
- Plan: network investment (takes time to realize)
Research question:

What are the benefits/issues of two bidding zones in Germany?

- System implications
- Zonal electricity prices
- Regional changes in stakeholder rents

Quantitative analysis for Germany (isolated):

- Dispatch
- Redispach model
Dispatch model:

Objective: minimizing generation costs

\[
\min_{g_{pt}, r_{nst}, p_{st}} \text{costs}^{sp} = \sum_{pt} (C_{pt} \times g_{pt})
\]

subject to: maximum generation by power plant block and renewable technology

\[
s. t. \quad g_{pt} \leq \bar{G}_{pt} \quad \forall p, t
\]
\[
r_{nst} \leq \bar{R}_{nst} \quad \forall n, s, t
\]

and the representation of pumped storage plants

\[
p_{slevel_{bt}} = 0.75\bar{p}_{s_{bt}} - \bar{p}_{s_{bt}} + p_{slevel_{b(t-1)}} \quad \forall b, t
\]
\[
\bar{p}_{s_{bt}} + \bar{p}_{s_{bt}} \leq \bar{PS}_{b} \quad \forall b, t
\]
\[
p_{slevel_{bt}} \leq \bar{LS}_{b} \quad \forall b, t
\]
(Zonal) balance and trade:

Uniform pricing energy balance

\[ \sum_p g_{pt} + \sum_n (\sum_s r_{nst} - Q_{nt} + PT_{nt}) + \sum_b (\overrightarrow{pS_{bt}} - \overrightarrow{pS_{bt}}) = 0 \quad \forall t \]

Zonal pricing energy balance

\[ \sum_p g_{pt} + \sum_n \left( \sum_s r_{nst} - Q_{nt} + PT_{nt} \right) + \sum_b (\overrightarrow{pS_{bt}} - \overrightarrow{pS_{bt}}) + \sum_y (z f_{zyt} - z f_{yzt}) = 0 \quad \forall z, t \]

Constraint on the trade capacity between the two zones

\[ z f_{zyt} < \text{NTC}_{zyt} \quad \forall z, y, t \]
Nodal pricing constraints:

Nodal pricing energy balance

\[ \sum_{p \in n} g_{pt} + \sum_{s} r_{nst} - Q_{nt} + P_{Tnt} + \sum_{b \in n} (\bar{p}_s - \bar{p}_{s_b}) + n_{nt} = 0 \quad \forall n, t \]

DC load flow constraints

\[ |p_{flt}| \leq \bar{P}_l \quad \forall l, t \]
\[ n_{nt} = \sum_{k} (\theta_{kt} \times B_{nk}) \quad \forall n, t \]
\[ p_{flt} = \sum_{n} (\theta_{nt} \times H_{ln}) \quad \forall l, t \]
\[ \theta_{n\_slackt} = 0 \quad \forall n, t \]
Redispatch model:

Objective: minimizing re-dispatch costs

\[ \min_{g^+, g^-} \text{costs}^{rd} = \sum_{pt} (g^+_{pt} \times C_{pt}) - \sum_{pt} (g^-_{pt} \times C_{pt}) \]

subject to re-dispatch constraints

\[ s.t. \quad g^+_{pt} \leq \bar{G}_{pt} - g^0_{pt} \quad \forall p, t \]
\[ g^-_{pt} \leq g^0_{pt} \quad \forall p, t \]
\[ r^-_{nst} \leq r^0_{nst} \quad \forall n, s, t \]

and the re-dispatch energy balance

\[ \sum_{p \in n} (g^0_{pt} + g^+_{pt} - g^-_{pt}) + \sum_s (r^0_{nst} - r^-_{nst}) - Q_{nt} + PT_{nt} + \sum_{b \in n} (\bar{p}s^0_{bt} - \bar{p}s^0_{bt}) + ni_{nt} = 0 \quad \forall n, t \]
Data and scenarios

Network data:
• 438 network nodes with supply and demand
• 709 individual transmission lines (220 / 380 kV)

Hourly data (8784 hours):
• Demand
• Renewable availability
• Fixed imports and exports to neighboring countries
Data and scenarios

Conventional capacity:
- About 600 power plant blocks
- Fuel
- Technology
- Efficiency
- Regional transport costs for hard coal

Renewable capacity (TSO data):
- Capacity aggregated by node
- Zero marginal generation costs
Definition of two bidding zones is arbitrary!

- Alternative of defining one high wind zone in the north
- There could be also more than two zones
- Zonal setting in this analysis sets the focus on scarcity in the south
Capacities in 2012 and scenario for 2015:

- North: + share of capacity with low variable costs (conventional and RES)
- South: - conventional capacity

<table>
<thead>
<tr>
<th>Technology</th>
<th>2012 North</th>
<th>2012 South</th>
<th>2015 North</th>
<th>2015 South</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear</td>
<td>4099</td>
<td>7969</td>
<td>-1275</td>
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<tr>
<td>Lignite</td>
<td>20350</td>
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<td>Hard coal</td>
<td>17580</td>
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<td>CCGT</td>
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<tr>
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<td>-206</td>
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<tr>
<td>Waste</td>
<td>1059</td>
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<td></td>
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<tr>
<td>Other</td>
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<td>147</td>
<td>-110</td>
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<tr>
<td>Pumped-hydro storage(^{13})</td>
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<td>Sum conventional</td>
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<td>Solar PV</td>
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<td>+4339</td>
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<tr>
<td>Wind onshore</td>
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<tr>
<td>Wind offshore</td>
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<tr>
<td>Sum renewable</td>
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<td>29391</td>
<td>+13231</td>
<td>+5169</td>
</tr>
<tr>
<td>Peak load in zones</td>
<td>54640</td>
<td>31390</td>
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</table>
Results according to level of „Net Transfer Capacity“ (NTC):

- With lower NTCs increasing intra- and counter-zonal re-dispatch
- Reduction stronger in 2015
- How to choose/calculate the NTC level: lowest overall redispatch at 8GW
- Price zones able to decrease north-south re-dispatch (35%)
Hourly trade flows (2015):

→ 2 TWh from north to south

Price differences (south-north)
Redispatch by network node and technology:

**Uniform price**

**Two zones**
Results

Changes in electricity prices and rents/costs/profits by stakeholder:

<table>
<thead>
<tr>
<th>[EUR/MWh]</th>
<th>Price</th>
<th>Consumer</th>
<th>Producer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nuclear</td>
<td>Lignite</td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td>-0.10</td>
<td>-0.10</td>
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<tr>
<td></td>
<td></td>
<td>+0.26</td>
<td>+0.30</td>
</tr>
<tr>
<td>2015</td>
<td>-0.46</td>
<td>+1.22</td>
<td>+1.41</td>
</tr>
</tbody>
</table>

- Consumers in south pay higher than average price markup (correlation load)
- Renewable output highest losses (north) / lowest gains (south)
- Highest gains per MWh for peak generation technologies
Conclusion

**Prices**
- Low average price difference / higher spread in certain hours
- Price increase in south higher than decrease in the north
- Regional signal for dispatch but sufficient for investments?

**Rents**
- Distributional effects:
  - Generation levels in the southern dispatch (coal 2-4% / gas 3-10%)
  - Stakeholders exposed to redistribution to different extend
  - Generators with high variable costs due better (than RES)
  - Total levels in redistribution: ↑ for lignite, hard coal, and nuclear
  - Collected congestion rent free for allocation (?)

**System**
- Two zones might be useful for increasing regional imbalance (2015)
- Challenge: Multiple regions with congestions / + network investment
- Question how to define stable bidding zones
Vielen Dank für Ihre Aufmerksamkeit.
Network flows (DCLF results):

- **peak load**
  - low res
- **winter night**
  - high wind
- **summer off-peak**
  - high PV