Political Shocks and Efficient Investment in Electricity Markets

by

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Our Paper …

- presents a detailed power market investment and dispatch model (LP) with consistent electricity price estimators
- illustrates the effects of political uncertainty
  - using the example of the change in profit contribution
  - for a specific CCGT-power plant
  - due to the political decisions in Germany with respect to nuclear power
Nuclear Phase-Out (June 2000)

- Decided by red-green coalition government in June 2000
- An average of 32 years of operation for nuclear power plants in Germany
Decided by conservative-liberal coalition government end of September 2010
- Prolongation of running times by 8 and 14 years respectively
Nuclear Phase-Out Nuclear Phase out (2011 June)

- Decided by conservative-liberal coalition government in June 2011
- Successive shutdown until 2022
The German Merit Order (without CHP and RES)
The German Merit Order (without CHP and RES)

- Merit Order (excluding nuclear power)
- Merit Order (including nuclear power)

Variable costs in €/MWh<sub>el</sub>

Net cumulated capacity in GW<sub>el</sub>

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In addition to the merit order, the model …

- … considers non-dispatchable generation (wind, solar, CHP, …)
- … includes endogenously capacity additions (and reductions)
- … includes endogenously international power exchange by modeling several regions simultaneously
- … includes endogenously dynamic effects (e.g. start-up costs, balancing power, pump storage, planned power plant revisions, …)
The Model

- Long-term investment and dispatch model
- Fundamental optimization model (LP)
- Objective: minimization of total system costs
- Resolution
  - 10 reference years
  - 4,380 periods per year
  - 10 model regions (Germany and neighboring countries)
  - up to 23 technologies per region
- Shadow prices (i.e. marginals of demand constraint) used as price estimators
min Z = \sum_y f_y^d(y) * 
    (\text{num\_years}(y) * 
     \begin{cases} 
     \sum_{p,t} \text{num\_hours} * f_p^d(p) * z^{\text{var}}(y,p,t) * G_{\text{PLAN}T}(y,p,t) \\
     + \sum_{p,t} f_p^d(p) * z_{\text{up}}(y,p,t) * C_{\text{UP}}(y,p,t) \\
     + \sum_{p,t} f_p^d(p) * z_{\text{down}}(y,p,t) * C_{\text{DOWN}}(y,p,t) \\
     + \sum_t z^{\text{fixed}}(t,y) * C_{\text{INST}}(y,t) \\
     + \sum_t s_{\text{invest}}^{\text{cost}}(y,t) * z_{\text{invest}}(t,y) * C_{\text{ADD}}(y,t) 
\end{cases})
European Electricity Market Model

Constraints (1)

- **Capacity** of a technology determined by commissioning and decommissioning
- Certain part of the capacity in **overhaul** over the course of a year
- **Capacity ready-to-operate** determined through startups and shutdowns and limited to the installed capacity minus the capacity in overhaul (startups and shutdowns linearized) and unexpected outages
- **Generation**
  - upwards limited by the capacity ready-to-operate
  - downwards limited by linearized minimum load requirements (defined as share of capacity ready-to-operate)
European Electricity Market Model

Constraints (2)

- **Generation** equals residual demand plus/minus international exchange plus electricity consumption from pump storage
- **Exchange** between countries limited by net transfer capacities
- Stored energy of (pump) storage plants determined by pumped and turbined energy amounts plus natural inflow
Results
System Marginal Costs of Demand

![Graph showing System Marginal Costs of Demand over years from 2012 to 2030. The graph includes three lines representing Atomic Consensus, Energy Concept, and Nuclear Phase-Out 2022.](image-url)
Results
Profit contribution for Trianel’s CCGT power plant

- CCGT project in Hamm-Uentrop with 800 MW installed net generating capacity
- commercial operation since end of 2007 (expecting atomic consensus, i.e. nuclear phase out)
Thank you very much! Questions?
Motivation
Political Uncertainty

- Changes in nuclear power policy affect the entire energy market
- Nuclear power
  - is a technology with low variable costs
  - covers base load (high full load hours)
- Shutting down nuclear power capacity
  - changes the merit order
  - increases electricity prices
Results

- Trianel CCGT
  - begin of operation at the end of 2007
  - expected time of operation 30 years (until 2037)
  - calculation horizon (2012-2037) - last 25 years of operation time

<table>
<thead>
<tr>
<th></th>
<th>Atomic Consensus</th>
<th>Energy Concept</th>
<th>Nuclear Phase-Out 2022</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue electricity generation (million €)</td>
<td>2,646</td>
<td>1,430</td>
<td>2,610</td>
</tr>
<tr>
<td>Variable production costs (million €)</td>
<td>-2,153</td>
<td>-1,136</td>
<td>-2,117</td>
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<tr>
<td>Startup and shutdown costs (million €)</td>
<td>-87</td>
<td>-66</td>
<td>-87</td>
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<tr>
<td>Fixed costs (million €)</td>
<td>-270</td>
<td>-270</td>
<td>-270</td>
</tr>
<tr>
<td>Net revenue (million €)</td>
<td>136</td>
<td>-42</td>
<td>136</td>
</tr>
</tbody>
</table>

⇒ Significant effect on the profitability of the CCGT
CO\textsubscript{2} Prices

![Graph showing CO\textsubscript{2} prices over years from 2010 to 2030 with different scenarios: Atomic Consensus, Energy Concept, and Nuclear Phase-Out 2022.]