Political Shocks and Efficient Investment in Electricity Markets

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• 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)

![Graph showing the Merit Order (including nuclear power)]

- Variable costs in €/MWh$_{el}$
- Net cumulated capacity in GW$_{el}$
The German Merit Order (without CHP and RES)

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

Variable costs in €/MWh el

Net cumulated capacity in GW el
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
European Electricity Market Model

Objective Function

\[ \min Z = \sum_y f_y^d (y) \times \]

\[ (\text{num\_years}(y) \times \]

\[ \text{variable costs} \quad \left\{ \begin{array}{l}
\sum_{p,t} \text{num\_hours} \times f_p^d (p) \times z^{\text{var}} (y, p, t) \times G_{\text{PLANT}} (y, p, t) \\
\sum_{p,t} f_p^d (p) \times z_{\text{up}} (y, p, t) \times C_{\text{UP}} (y, p, t) \\
\sum_{p,t} f_p^d (p) \times z_{\text{down}} (y, p, t) \times C_{\text{DOWN}} (y, p, t) \\
\sum_t z_{\text{fixed}} (t, y) \times C_{\text{INST}} (y, t) \\
\sum_t s_{\text{cost}}^{\text{invest}} (y, t) \times z_{\text{invest}} (t, y) \times C_{\text{ADD}} (y, t) 
\end{array} \right. \]
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: Atomic Consensus, Energy Concept, and Nuclear Phase-Out 2022. The costs are represented in €/MWh.](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>
</tr>
<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 with three lines representing different scenarios: Atomic Consensus, Energy Concept, and Nuclear Phase-Out 2022.](image)

Year

- 2010
- 2012
- 2014
- 2016
- 2018
- 2020
- 2022
- 2024
- 2026
- 2028
- 2030

EUA price (€/tCO\textsubscript{2})

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50

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