The Effect of Divestiture in the
German Electricity Market

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Agenda

1. Introduction
2. Model
3. Scenarios
4. Conclusion
The German Electricity Market

- Significant price increase since the start of liberalization
- Simultaneously fuel price increase and start of the EU emission trading

Source: EEX
The German Electricity Market

- Oligopolistic market with dominant Duopoly (Bundeskartellamt, 2006)
- The major 4 own about 85% of the available conventional power plant capacity

Competition Policy

Large array of instruments:
- Unbundling of dominant incumbents (horizontal/vertical)
- Price regulation, market monitoring
- Reducing market entrance barriers of new companies
- Efficient network management

Horizontal divestiture as a possible measurement to reduce market power potentials and increase welfare:
- Int. experience show the potential benefit (e.g. UK, splitting up of National Power and PowerGen)
- Ceteris paribus the increase of market participants leads to a higher competitive pressure
- Problem: divestiture represent a “hard” measurement
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Oligopoly Models:
Cournot and Supply Function Equilibrium (SFE)

Two major modeling trends:

Cournot-Models: easy to calculate, allows technical restrictions, criticized for giving implausible outcomes
(eg. Ellersdorfer, 2005; Willems, 2002; Neuhoff et al., 2005; Bushnell et al., 1999)

SFE-Modelle: complex, simplifications necessary, considered to represent electricity markets in a realistic way
(eg. Green and Newbery, 1992; Baldick and Hogan, 2002; Holmberg, 2007; Anderson and Hu, 2008)

To calibrate the models the contract position $f_i$ is varied:
- A firm which sells contracts is more aggressive in the spot market
- Without contracts, modeled prices are typically too high in Cournot model
(Bushnell et al., 2008)
Model of Spot Market Competition
(Willems et al., 2009)

- Cournot: Firms set output assuming that the output of other players remains fixed
  
  With:
  - markup $P - c_i$
  - production $q_i$
  - demand slope $\gamma$
  - contract $f_i$

- SFE: Firms bid supply functions assuming that the supply function of the other players remains fixed
  
  With:
  - markup $P - c_i$
  - production $q_i$
  - demand slope $\gamma$
  - contract $f_i$
  - slope of supply function $\beta_i$
Calibration

• Both models are calibrated to the 2006 market data
• Only the peak period is considered
• Monthly fuel prices and import elasticities
• Hourly load values and market prices

→ Optimal contract cover for Cournot and SFE model obtained
  Cournot: 37%  SFE: 18%
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Scenarios

• The calibrated reference pre-divestiture situation (base case)

2 divestiture cases:

• 6 firm case: E.ON and RWE are spitted up symmetrically, the emerging 2 new firms are sold to single strategic players respectively → 6 strategic players in the market with a lower average market share

• 4 firm case: E.ON and RWE are spitted up symmetrically, the emerging 2 new firms are sold to fringe firms → 4 strategic players in the market with a lower average market share
Supply Results

Cournot

SFE

- Both divestiture cases show a shift of the supply curve towards the marginal cost curve
- SFE bid curve shows a steeper increase in peak quantities
## Price and Welfare Outcomes

<table>
<thead>
<tr>
<th></th>
<th>Pre-Divestiture</th>
<th></th>
<th>6 Firm Case</th>
<th></th>
<th>4 Firm Case</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cournot</td>
<td>SFE</td>
<td>Cournot</td>
<td>SFE</td>
<td>Cournot</td>
<td>SFE</td>
</tr>
<tr>
<td>Peak Preis [€/MWh]</td>
<td>63.6</td>
<td>62.9</td>
<td>-8.3</td>
<td>-9.8</td>
<td>-16.1</td>
<td>-16.9</td>
</tr>
<tr>
<td>Wohlfahrt [Mrd. €/a]</td>
<td>44.67</td>
<td>44.75</td>
<td>+1.51</td>
<td>+1.80</td>
<td>+2.87</td>
<td>+2.96</td>
</tr>
<tr>
<td>Konsumentenrente [Mrd. €/a]</td>
<td>37.79</td>
<td>37.98</td>
<td>+2.78</td>
<td>+3.29</td>
<td>+5.45</td>
<td>+5.55</td>
</tr>
<tr>
<td>Produzentenrente [Mrd. €/a]</td>
<td>6.88</td>
<td>6.77</td>
<td>-1.26</td>
<td>-1.49</td>
<td>-2.57</td>
<td>-2.60</td>
</tr>
</tbody>
</table>

- Significant welfare increase and price decrease in both divestiture cases
- Both models produce similar outcomes → stable results
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Conclusion

• Apply a Cournot and SFE model to two divestiture cases in Germany
• An increase of consumer surplus of more than 5 bn € per year, and a peak price reduction of more than 16 €/MWh can be achieved
• Divested assets should not be sold to strategic players
• Whether divestiture is the best fitted instrument for that task is not answered → comparison with other measurements like the increase in cross-border transmission capacity and the further integration of congestion management schemes
• The translation of the result to other markets is not advisable
Thank you for your attention,
Questions?

Hannes Weigt
Chair of Energy Economics and Public Sector Management
BackUp
Cournot versus Supply Functions:

What does the data tell us?

Bert Willems, Ina Rumiantseva and Hannes Weigt

Chair of Energy Economics and Public Sector Management, Dresden University of Technology
Tilburg Law and Economics Center, TILEC, Tilburg University
Energy Institute, K.U. Leuven

Conference on "The Economics of Energy Markets"
June 20-21, 2008, Toulouse, France
Agenda

- Introduction
  - Cournot and SFE model formulation
  - Application to Germany
  - Results
  - Conclusion
  - Literature
Introduction

• Liberalization of electricity markets increases the need for market modeling
• Important to obtain robust results from oligopolistic models
• Two basic modeling trends:
  - Cournot models (easy to calculate, criticized for giving implausible outcomes)
  - Supply Function equilibria (complex, considered to represent electricity markets in a realistic way)

• Aim of our study:
  • Compare the classic Cournot approach with SFE modeling to determine which is more suited to model strategic behavior
Oligopolistic models in Electricity Sector

• Both SFE and Cournot models have been used for electricity markets

• Cournot models (vertical bid-function)
  - Extensively used, existence results, performant solvers (PATH)
  - *Smeers, Hobbs, Hogan, Shmuel, Willems*…
  - A lot of technical restrictions can be included
  - Unrealistic results, if not calibrated (too high prices)

• Supply function models (smooth bid-function)
  - *Green, Newbery, Evans, Holmberg, Anderson*…
  - Supposed to present competition better
  - Did not really break through as practical modeling tool
Which models perform better?

• Until now, no comparisons have been made between SFE and Cournot models because:
  - SFE-models were not available for asymmetric players
  - Cournot-models gave unrealistic results (too high prices due to large demand inelasticity)

• This papers solves this problem by
  - Using the latest modeling technique to calculate SFEs
  - Adjust for import and fringe elasticities and contract positions

• It enables us…
  …to compare both models for identical assumptions with respect to market structure, generation capacity, and demand structure
  …to test which model “calibrates” best to real world data
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Model of Spot Market Competition

- Model of spot market competition with forward sales
- Demand for electricity is stochastic ($\varepsilon$) and time depend ($t$)
- Firms simultaneously submit a bid function to exchange
  = willingness to supply energy
- Market clearing determines equilibrium production and price
- Firm $i$’s spot market profit, given past forward sales $f_i$

With:
- price $p$
- production cost $c_i(.)$
- production $q_{ii}$
- contract $f_i$

- Contracts $f_i$ are not observed: used as a calibration parameter
Model of Spot Market Competition

- Type of bid functions depends on the model
  - Cournot: Firm $i$ observes demand shock and can make different bid every hour
    \[ b_i = q_i^e \]
  - SFE model: Firm $i$ bids a supply function (fixed for whole sample period)
    \[ b_i = q_i^{s} \]

- Often it is claimed that the last strategy is more realistic… ,
- … but a priori this is unclear.
Model of Spot Market Competition

• Cournot: Firms set output assuming that the output of other players remains fixed

With:
- markup $P - c_i'$
- production $q_i$
- demand slope $\gamma$
- contract $f_i$

• SFE: Firms bid supply functions assuming that the supply function of the other players remains fixed

With:
- markup $P - c_i'$
- production $q_i$
- demand slope $\gamma$
- contract $f_i$
- slope of supply function $\beta_i$

• Impact of contracts $f_i$
  - A firm which sells contracts is more aggressive in the spot market
  - Without contracts, modeled prices are typically too high in Cournot model
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Model adjustments

• Benchmark:
  • German market in Jan. and Feb. 2006
  • Spot price of EEX, Demand data of UCTE

• Supply:
  • Four strategic players and a competitive fringe
  • Marginal generation costs based on large plant database
    - Efficiency levels (heat rates), availability
    - Fuel prices
    - Emission allowance prices
  • Each firm is represented by a smoothed marginal cost function
Model adjustments continued

- Demand:
  - Demand ‘elasticity’ in Germany
  - Based on
  - ‘Elasticity’ of import: 2SLS Regression

\[
\frac{\hat{q}_{it}}{p_{it}} - \frac{\hat{q}_{jt}}{p_{jt}} = \gamma
\]

- ‘Elasticity’ of Fringe Production

\[
\frac{\hat{q}_{it}^{(1)}}{p_{it}} - \frac{\hat{q}_{jt}}{p_{jt}} = \gamma
\]

With:
- Price in Germany \( p_{it} \)
- Price in other regions \( p_{jt} \)
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Unique Cournot outcome and bundle of SFE outcomes

Price, MC

Data: Jan – Feb 2006

Total Thermal Production
Calibration of contract coverage

• Each firm has contract cover proportional to installed capacity
  
• Calibration by a non-linear least squares regression:
  
• Goodness of fit of regression:

  • R-squared
    - Which proportion of the variation in observed prices is explained by the model
  • Standard deviation of error
    - How large is the unexplained part in the model

With:
- observed prices $P_{obs}$
- predicted prices
- contract coverage $\Phi$
Results of calibration

- Both models can be adjusted equally well to the observations

<table>
<thead>
<tr>
<th></th>
<th>Contract Cover</th>
<th>Std Dev Error</th>
<th>R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cournot</td>
<td>49.8 ± 0.5 %</td>
<td>9.41</td>
<td>0.85</td>
</tr>
<tr>
<td>SFE</td>
<td>27.4 ± 1.3 %</td>
<td>9.31</td>
<td>0.85</td>
</tr>
</tbody>
</table>

• Coverage depends on model
• SFE is less sensitive to coverage

n=1361
Robustness Tests: Start Up and Capacity constraints

- Both models neglect start-up and capacity constraints.

- **Solution:** Add linear regressor

\[ q^{\text{MC}} = \alpha \cdot q^{\text{SFE}} + \beta \]

- **MC best approximation:** based upon dispatch model of German market

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<th>Std Dev Error</th>
<th>R2</th>
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</thead>
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<tr>
<td>Cournot</td>
<td>50.4 ± 0.6%</td>
<td>9.39</td>
<td>0.85</td>
</tr>
<tr>
<td>SFE</td>
<td>25.5 ± 1.8%</td>
<td>9.26</td>
<td>0.85</td>
</tr>
</tbody>
</table>

- $\tau$ is relatively small
- Results do not significantly change
Robustness Tests: Sub-periods

• Changing model specification
  - Different contract coverage during peak and off-peak periods
  - Vary marginal generation costs on monthly basis
  - Different import elasticities for peak and off-peak periods in each month respectively

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<th>Contract Cover</th>
<th>Std Dev Error</th>
<th>R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cournot Peak</td>
<td>46.4 ± 0.9%</td>
<td>11.26</td>
<td>0.77</td>
</tr>
<tr>
<td>Cournot Off-Peak</td>
<td>56.8 ± 1.7%</td>
<td>5.53</td>
<td>0.84</td>
</tr>
<tr>
<td>SFE Peak</td>
<td>23.0 ± 1.5 %</td>
<td>10.18</td>
<td>0.81</td>
</tr>
<tr>
<td>SFE Off-Peak</td>
<td>41.9 ± 8.3%</td>
<td>6.03</td>
<td>0.81</td>
</tr>
</tbody>
</table>

• Counter intuitive: higher contract coverage during off-peak
  - Supply curve closer to marginal costs
  - More competitive in base load
  - Misspecification in marginal cost?
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Conclusions

• Comparison of classical Cournot model with the more complex SFE approach using the observed market outcomes as benchmark

• Both models can be adjusted to represent observed market outcomes:
  - The Cournot approach fits best assuming a relatively high level of contract coverage
  - The SFE model fits best when firms do only have a medium level of coverage

• Using the R-squared coefficient as a measure both models perform equally well once calibrated

• → Cournot models should be the preferred when electricity market characteristics must be modelled in technical detail (e.g. study of market rules or congestion allocation mechanisms)

• → SFE is less sensitive to calibration which is important for long-term simulations when contract positions are endogenous (e.g. in merger studies)
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References (Selected)

• Anderson E, Hu X. Finding supply function equilibria with asymmetric firms. Mimeo; Australian Graduate School of Management; 2005.
• Delgado J., Coalition-proof supply function equilibria under capacity constraints. Economic Theory 2006, 29, 219-229
• Evans J, Green R: Why did British electricity prices fall after 1998? Economic and Social Research Council project; University of Surrey and University of Birmingham; 2005.
• Wächter A, Biegler L. On the implementation of a primal-dual interior point filter line search algorithm for large-scale nonlinear programming, Mathematical Programming 2006; 106; 25-57.
Main Ingredients of model

• Model of spot market competition

• Firms have an existing net contract position before they bid into the spot market = Calibration parameter

• Firms simultaneously submit a bid function into the power exchange
  - Type bid function depends on model

• The power market clears demand and supply
  - Equilibrium price and quantities are established

• Nash Equilibrium = F (Contract positions)

• Calibration of model

• The calibration parameters are adjusted to reflect market data
Cournot models

• Firms set output assuming that the output of other players remains fixed:

\[
\begin{align*}
\text{With:} \\
\text{markup } P - c_i' \\
\text{market share } s_i \\
\text{demand elasticity } e
\end{align*}
\]

• For realistic elasticity & low number of players:
  - Prices are too high
  - Quantity are too low

• Conclusion: Standard Cournot model is not appropriate for electricity markets

• Solution: Cournot equilibrium with contracting
  - A firm which has sold contracts will become more aggressive in the spot market

\[
\begin{align*}
\text{With:} \\
\text{markup } P - c_i' \\
\text{production } q_i \\
\text{inverse demand slope } \gamma \\
\text{contract } f_i
\end{align*}
\]
Supply Function Equilibria

• Firms bid supply functions assuming that the supply function of the other players remains fixed:

With:
- markup $P - c'_i$
- production $q_i$
- inverse demand slope $\gamma$
- contract $f_i$
- slope of supply function $\beta_i$

• Results are typically a range of feasible equilibrium supply functions (Equilibrium selection needed)

• Solution depends on contracts signed + slope demand function