Electricity Wholesale Market Prices in Europe: Convergence?

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Agenda

1) Introduction
2) Data
3) Methodology
4) Results
5) Conclusion
Introduction

Regulation 1228/2003/EC does not specify a preferable „market based congestion management method“

Cross-border capacity auctions became standard in Central Europe

Why is this interesting:

Durable inefficient auction outcomes lead to inefficient trade flows and thus to welfare losses due to an international scheduling that is based on wrong price signals
What will we do?

Test whether there is a single European wholesale electricity market
Test whether electricity wholesale prices are converging
Test whether cross-border capacity auction prices can explain the persistency of price differentials
Data

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European mean electricity price as well as regional deviations
Jan05 - Jul06 (€/MWh)

APX – Amsterdam Power Exchange
EEX – European Energy Exchange
EXAA - Energy Exchange Austria
DKE – East Danish price area
DKW – West Danish price area
SWE – Swedish price area
PNX – Powernext
PPX – Polish Power Exchange
UKPX – UK Power Exchange
OMEL - Operador del Mercado Ibérico de Energía
OTE – Czech Market Operator

=> There is no single European electricity market, but is there convergence?
Convergence of European electricity markets?

Correlation of the 3rd and 13th hour wholesale spot prices with their first (X-axis) and second (Y-axis) PC

The significant increase of $\tau_1$ from the early to the more recent period implies, that some series approached the common European pattern.

$\Rightarrow$ There is convergence towards a single European electricity market, but price differentials persist. Why?
Congestion is a justifyable reason for cross-border price differentials.
Methodology

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Testing strategy

- Test for convergence and integration taking into account congestion and the limited foresight of traders
- Calculate the predictable arbitrage opportunities (price differential in the profitable direction minus capacity auction price)
- Test whether these increased/decreased significantly over time
Time Varying Coefficient model

\[ \gamma_{\text{net},t}^{i,j} = \alpha_t + \varepsilon_t \]

\[ \alpha_t = \beta \alpha_{t-1} + \nu_t \]

where \( \varepsilon_t \sim N(0, \sigma_\varepsilon^2) \) and \( \nu_t \sim N(0, \sigma_\nu^2) \) are white noise processes,

\[ \gamma_{\text{net},t}^{i,j} = \begin{cases} 
\log(p_t^i - c_t^{j \rightarrow i}) - \log(p_t^j) & \text{if } p_t^i > p_t^j \\
\log(p_t^i) - \log(p_t^j - c_t^{i \rightarrow j}) & \text{if } p_t^i < p_t^j
\end{cases} \]

is the observed importing (neg) or exporting (pos) arbitrage potential in \( t \) and \( \alpha_t \) is the expected arbitrage potential in \( t \).
Testing for Convergence

We estimate $\hat{\alpha}_t$ using the Kalman Filter and Smoother (see Hamilton 1994).

To test for convergence we estimate $\hat{\alpha}_t^2 = \delta_1 + \delta_2 t + \xi_t$.

Convergence toward full integration is assumed if the null hypotheses $\hat{\delta}_1 \leq 0$ and $\hat{\delta}_2 \geq 0$ can both be rejected.

Test statistics are calculated using bootstrapping as $\xi_t$ is not normally distributed.
Results

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Some Examples of $\hat{\alpha}_t$

Some markets are highly integrated (EEX-PNX), at others the capacity auction explain a significant fraction of the price differential (EEX-OTE), at most the net price differential remains significant (EEX-PPX).
Daily implicit auctions provide significant unused arbitrage potentials

Number of hours of the day in which neighboring markets significantly (5%) converged/diverged when correcting for hourly congestion charges (net)

<table>
<thead>
<tr>
<th>Load period</th>
<th>PPX-OTE</th>
<th>EEX-OTE</th>
<th>EEX-PPX</th>
<th>EEX-PNX</th>
<th>EEX-APX</th>
<th>EEX-DKE</th>
<th>EEX-DKW</th>
<th>PNX-OME</th>
<th>Σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>Convergence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>61</td>
</tr>
<tr>
<td>Σ = 105</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>44</td>
</tr>
<tr>
<td>Divergence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Σ = 28</td>
<td></td>
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<td></td>
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<td></td>
<td>20</td>
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</tbody>
</table>

⇒ Few markets (12/192) were integrated
⇒ Most (105/192) converged
⇒ But some (28/192) even diverged
⇒ The remaining (47/192) showed no significant behaviour
⇒ Only 61% of the series where integrated or converged significantly, despite correcting for congestion and imperfect foresight
Conclusion

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Conclusion

This paper provided empirical evidence that a single market for electricity in continental Europe had not been attained by mid-2006.

The use of PCA revealed that in June 2004-July 2006, 48% of the peak and 37% of the off-peak price variances were not explained by the first principal component.

We showed that national electricity price differences significantly diminished over time for some market pairs.

We found that 59% of the studied hourly pairs of national wholesale electricity prices in 2002-2006 converged. This increased market integration was mainly an off-peak phenomenon. While 64% of the converging series were in off-peak, 75% of the diverging series were in peak.
Conclusion

We found that more than 93% of the studied market pairs featured significant predictable arbitrage opportunities but that 39% of them were not converging toward arbitrage freeness.

We suggest that future research should include identifying the reasons for the inefficiencies of explicit auctions, such as risk premiums for traders and the exercise of market power. We believe, too, that EU policy makers should be made aware of these and other potential obstacles to the gradual realization of a common wholesale market for electricity.
Appendix

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6) Appendix
Selected References


Cross-border congestion management method in the sample period (1/2002-8/2006)

<table>
<thead>
<tr>
<th></th>
<th>DKW</th>
<th>SWE</th>
<th>EEX</th>
<th>UKPX</th>
<th>OMEL</th>
<th>APX</th>
<th>PPX</th>
<th>EXAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>DKE</td>
<td>IA</td>
<td>IA</td>
<td>&lt;2005 EA &gt;2005 IA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DKW</td>
<td></td>
<td>IA</td>
<td>EA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PNX</td>
<td></td>
<td></td>
<td>&lt;2005 NMB &gt;2006 EA</td>
<td>EA (only base)</td>
<td>&lt;2005 NMB &gt;2006 EA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EEX</td>
<td></td>
<td>AL (Merchant line)</td>
<td></td>
<td></td>
<td>EA</td>
<td>&lt;2005 EA* &gt;2005 CEA</td>
<td>NMB (no congestion)</td>
<td></td>
</tr>
</tbody>
</table>

EA: Explicit Auction; EA*: Explicit Auction without day-ahead auctions; AL: Access Limitation; CEA: Coordinated Explicit Auction (Poland; Czech Republic; Germany); IA: Implicit Auction; NMB: Non-market based (e.g. pro rata; priority list); The table roughly summarizes ETSO (2004, pp. 5-7) and ETSO (2006, pp. 7-10) where more detailed information can be found.
## Timing of cross border auctions and spot markets

<table>
<thead>
<tr>
<th>Available capacity known to market participants</th>
<th>Cross Border Auctions</th>
<th>Power Exchanges</th>
</tr>
</thead>
<tbody>
<tr>
<td>EON-TenneT (EEX-APX)</td>
<td>EON-ELTRA (EEX-DKW)</td>
<td>APX (NordPool)</td>
</tr>
<tr>
<td>Bid for 100 MW at 5€</td>
<td>8:30</td>
<td>9:00</td>
</tr>
<tr>
<td>9:00 End of bidding</td>
<td>9:00</td>
<td>9:30</td>
</tr>
<tr>
<td>Publication of Results</td>
<td>9:30</td>
<td>10:00</td>
</tr>
</tbody>
</table>

- **EEX-APX**: Cross Border Auctions
- **EEX-DKW**: Cross Border Auctions
- **NordPool**: Power Exchanges
- **EEX**: Power Exchanges