Integration of European Electricity Markets: Evidence from Spot Prices

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Research Question

- EU: Promotion of internal energy market → integration efforts!
- **How well integrated are European electricity markets?**
- **Why market integration is important?**
  - Supply security – enhanced balancing of supply
  - Reduces need for reserve capacity
  - Better integration of intermittent renewables
  - Increases welfare (and consumer surplus) through allocative efficiency
  - Induces competition
  - Limits market power (strategic withholding of capacity)
  - Mitigation of uncertainty (better investment signals?)
  - Reduction of spot prices (on average, but winners & losers)
How to Integrate Markets?

- **Investment in cross-border capacities**
- **Reduction of (intra-market) transmission bottlenecks (e.g. DE)**
- **Market coupling**: efficient auctioning of capacity
  - **Explicit auctions**: Power and interconnector capacity are auctioned separately. Consequences: coordination failures and strategic withholding of interconnection capacity
  - **Implicit auctions**: Power and interconnector capacity are auctioned simultaneously (and synchronization of market rules, e.g. PX closing hours). Electricity flows always from the low price area towards the high price area. The congestion revenue calculated on the basis of price differential is the “true” congestion revenue.
Price Convergence

- Market integration is a prerequisite for price convergence
  - Market coupling
  - Uncongested interconnection capacity
    - Unconstrained electricity trade: Law of One Price holds (!)

- Integration of European electricity markets

- On average lower prices, but...
  - ... Prices in high-price market decrease
  - ... Prices in low-price market increase

- Creates winners and losers!
  - Thus, practical implementation of market integration cumbersome

The dynamics of electricity prices change (e.g. variance)
1) Autarky: $P_A < P_B$
Scenario 2: Limited Interconnection Capacity

1) Autarky: $P_A < P_B$

2) Constrained trade: $P_A < P_{A,\text{CapLim}} < P_{B,\text{CapLim}} < P_B$

Consumers: $-A+C+D$, Producers: $+A+B-C$, Welfare: $+B+D$
With unconstrained interconnections, consumers in the higher price zone would gain more in terms of consumer surplus than what other consumers in the lower price zone would lose

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Keppler et al. (2016, p. 4)
Day-ahead spot prices (€/MWh)

- Changing supply structures (e.g. more RES) lead to drop in spot prices
- Some markets seem better integrated (DE, FR, DKe) than others (IT)

Low degree of integration (?)
1. Before introduction of market coupling, capacities were frequently congested (in both directions).
2. Market coupling led to a vast reduction in capacity bottlenecks.
3. Over time, congestion has been increasing between GER and FRA, mainly due to production from volatile renewables.

**Direction of congested hours: DE and selected neighbors**

<table>
<thead>
<tr>
<th>Direction</th>
<th>Market Coupling</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015Q1,2</th>
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<tbody>
<tr>
<td>DE---&gt;FR</td>
<td></td>
<td>90.4%</td>
<td>10.8%</td>
<td>30.4%</td>
<td>41.9%</td>
<td>31.7%</td>
<td>66.7%</td>
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<tr>
<td>FR---&gt;DE</td>
<td></td>
<td>84.6%</td>
<td>27.0%</td>
<td>6.9%</td>
<td>11.5%</td>
<td>17.3%</td>
<td>6.5%</td>
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<tr>
<td>Total</td>
<td>09.11.2010</td>
<td>91.5%</td>
<td>37.8%</td>
<td>37.3%</td>
<td>53.4%</td>
<td>49.1%</td>
<td>73.3%</td>
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</table>
Method: 1. Cointegration

\[ P_{A,t} = \alpha + \beta P_{B,t} + Z_t : \]

- \( \alpha \) ... systematic difference (transport costs, institutional differences)
- \( \beta \) ... long-run equilibrium relation between \( P_A \) and \( P_B \)

1. **Perfect integration:**
   \( \alpha = 0, \ \beta = 1, \text{if export < capacity and market coupling = 1} \)

2. **Divergence:**
   \( \alpha > 0, \ \beta \neq 1, \text{if export = capacity and/or market coupling = 0} \)

\[ P_{A,t} = \alpha + \beta P_{B,t} + \gamma C B C_{AB,t} + \delta P_{B,t} C B C_{AB,t} + \epsilon C B C_{BA,t} + \zeta P_{B,t} C B C_{BA,t} + Z_t \begin{cases} \text{if } MC_{AB,t} = 1 \\ \text{if } MC_{AB,t} = 0 \end{cases} \]

\( \rightarrow \) Controlling for CBC and MC should indicate perfect integration \( (\alpha = 0, \ \beta = 1) \)
Method: 2. Error Correction Model

\[ P_{A,t} = \alpha + \beta P_{B,t} + Z_t \]

\( \hat{Z} \) ... Error term: deviations from long-run relation

1. Unrestricted model: \( \Delta P_{A,t} = \theta + \vartheta \Delta P_{A,t-24} + \eta \hat{Z}_{t-24} + \mu' X + \epsilon_t \)

\( \eta \) ... speed of adjustment from price shock in t-24 back to long-run cointegrating relationship

2. Restricted model: \( \Delta P_{A,t} = \theta + \vartheta \Delta P_{A,t-24} + \eta (P_{B,t-24} - P_{A,t-24}) + \mu' X + \epsilon_t \)

\( \eta \) ... speed of adjustment from price shock in t-24 back to uniform prices (i.e. \( \beta = 1 \))

\( \Delta \) represents difference (e.g. \( \Delta P_{A,t} = P_{A,t} - P_{A,t-24} \)),

\( X \) = structural variables: # congested hours, solar & wind forecasts, price of gas, seasonality (day of week, months, years, holidays)

(!) Estimation only possible during market frictions (i.e. \( P_{A,t-24} \neq P_{B,t-24} \))

\( \rightarrow \) Otherwise: no errors (i.e. instantaneous adjustment)
**Data & Add-Ons to Existing Literature**

- Hourly data, 2010/Q1–2015/Q2
- 25 electricity markets: SK, CZ, EST, LT, LV, FIN, NO1, NO2, NO3, NO4, NO5, ES, PT, SE1, SE2, SE3, SE4, DKW, DKE, IT, HU, SL, CH, FR, DE
- We discuss lag structure (1h, 24h – demand and supply stickiness)
- Inclusion of congestion & market coupling
- Direction of congestion (without MC, interconnectors may be congested in both directions)
- No congestion & market coupling: prices converge instantaneously
- How efficiently do markets work when congestion is present?
Adjacent market pairs have high degree of integration
Over time, integration increases, then decreases
  - Investment in interconnector capacity (+),
  - Market coupling (+),
  - Increasing production from volatile renewables (-)
  - Other confounding factors (+/-)
Average $\beta$ coefficients of DE and other markets subject to forecasted renewables production in DE
### 1st stage estimates before and after market coupling

<table>
<thead>
<tr>
<th>Market</th>
<th>Intro. MC</th>
<th>Before MC</th>
<th>After MC</th>
<th>Notes</th>
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<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>α</td>
<td>β</td>
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<tr>
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<td>SE4</td>
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<tr>
<td>ES</td>
<td>FR</td>
<td>13.05.2014</td>
<td>21.96</td>
<td>0.41</td>
</tr>
</tbody>
</table>

Notes: * insignificant coefficient (below the 10% significance level). “Intro. MC” stands for the date of the introduction of market coupling.

- With MC and no congestion $\rightarrow a=0 \& \beta=1$, perfect integration
- No MC and no congestion $\rightarrow a\neq 0 \& \beta\neq 1$ (possible outcome).
1. **Unconstrained model**: $ETC_{t-1,DE-FR} \approx -0.31$ meaning that 31% of a price shock is absorbed in one day back to the (imperfect) long-run cointegrating relationship.

2. **Constrained model**: $ETC_{t-1,DE-FR} \approx -0.11$ meaning that 11% of a price shock is absorbed in one day back to uniform prices.
Discussion & Conclusions (1)

• **Market integration necessitates**
  - Reduction of transmission bottlenecks, interconnection capacity, market coupling

• **Fully integrated electricity markets:**
  - Optimization of social welfare, but also welfare redistribution (!)
  - Practical implementation tough
  - Market integration reduces need for reserve capacity

• **Evidence that EU market integration rose until mid of 2012, then declined**
  - On average, $\beta = 0.81$ for adjacent markets; $\beta = 0.40$ for non-adjacent markets
  - $\rightarrow$ Some markets tend to be better integrated than others
**Discussion & Conclusions (2)**

- **Efficiency of integration is modest**
  - EU averages: unconstrained model: $\bar{\eta} = -0.28$, constrained model: $\bar{\eta} = -0.23$
  - Market coupling seems to be an important tool for capacity allocation
  - Large potential for improvements from additional capacity investments and further promotion of market coupling

- **Is perfect integration (i.e. one single price) desirable?**
  - Can costly investments in additional interconnection capacity and in market coupling offset welfare benefits? (static vs dynamic effects)
  - Desirable to foster market integration *up to some degree* (?) → attain a great deal of associated positive effects but avoid the enormous investment costs of inducing perfect market integration
  - Caution: With increased market integration, unilateral policies may have (positive/negative) **externalities** on other markets
    - Calls for better **internalization of externalities** through intl. coordination
    - E.g. GER: increasing production of RES / nuclear phase-out
Thank you!