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

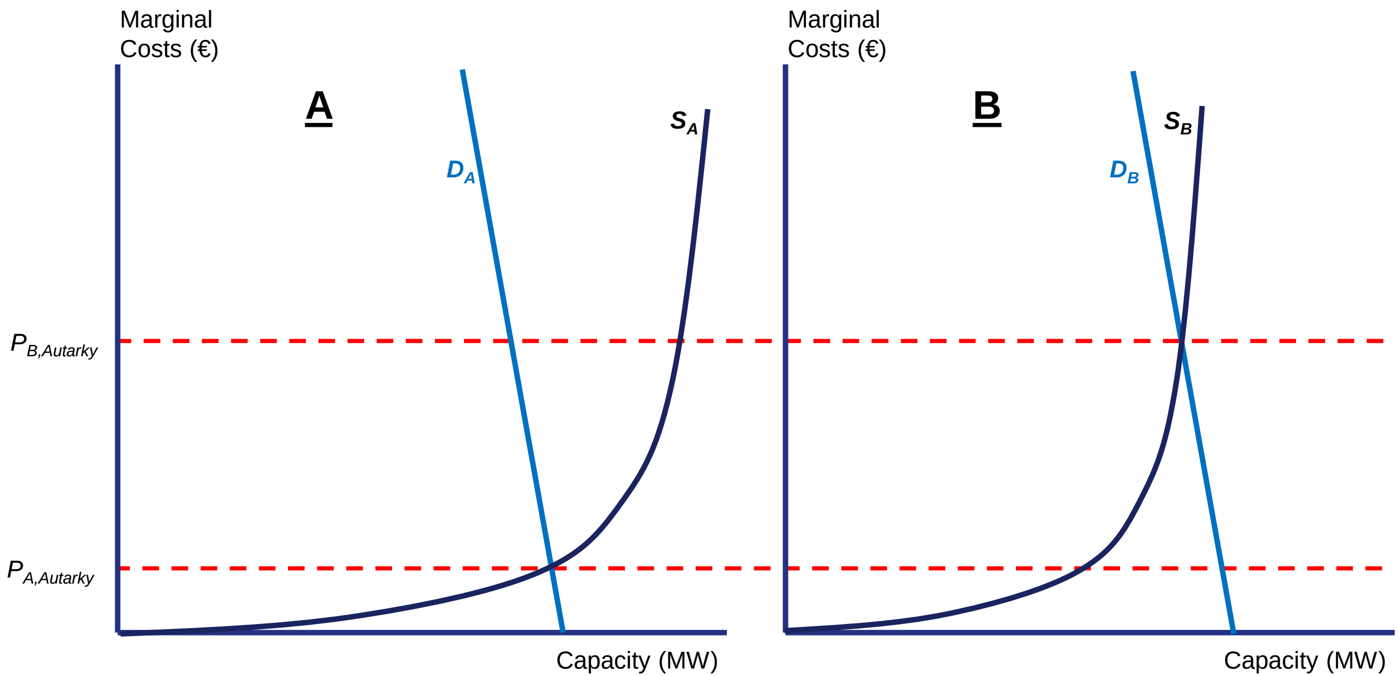
- Market integration is a prerequisite for price convergence
  - Market coupling
  - Uncongested interconnection capacity
    - → Unconstrained electricity trade: Law of One Price holds (!)
- Integration of European electricity markets
- On average lower prices, but...

  ... Prices in high-price market decrease

  ... Prices in low-price market increase

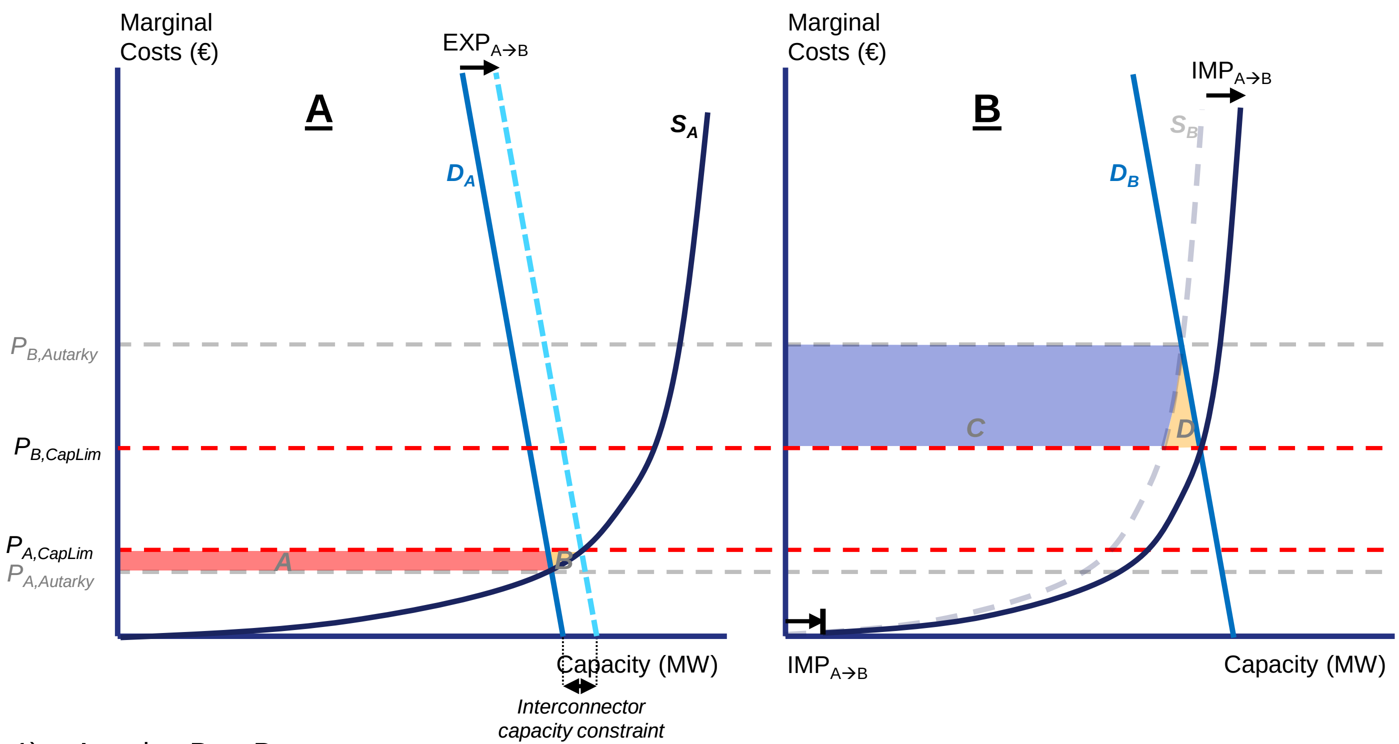
  The dynamics of electricity prices change (e.g. variance)
- ***Creates winners and losers!***
  - Thus, practical implementation of market integration cumbersome

Scenario 1: Autarky



1) Autarky: $P_A < P_B$

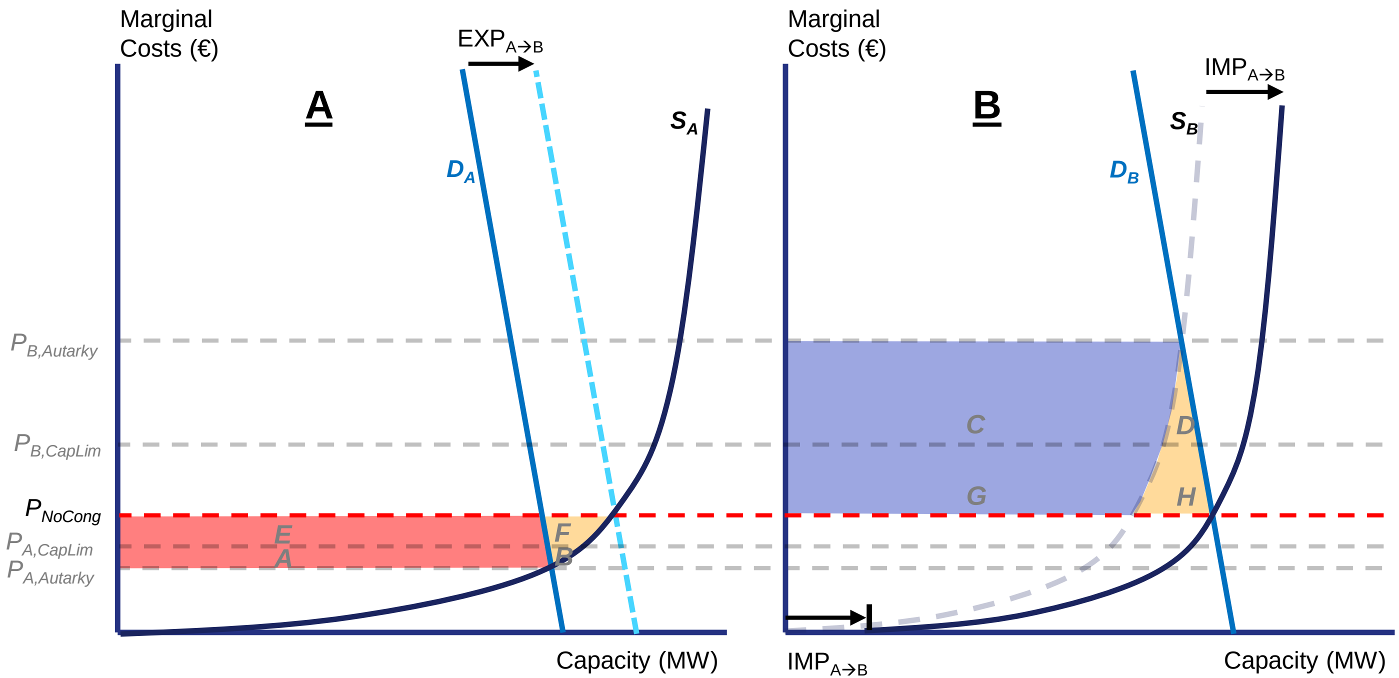
Scenario 2: Limited Interconnection Capacity



1) Autarky: $\boldsymbol{P_A} < \boldsymbol{P_B}$

2) Constrained trade: $P_A < \boldsymbol{P_{A,CapLim}} < \boldsymbol{P_{B,CapLim}} < P_B$
Consumers: −A+C+D, Producers: +A+B−C, Welfare: +B+D

Scenario 3: Full Market Integration



1) Autarky: $\boldsymbol{P_A} < \boldsymbol{P_B}$

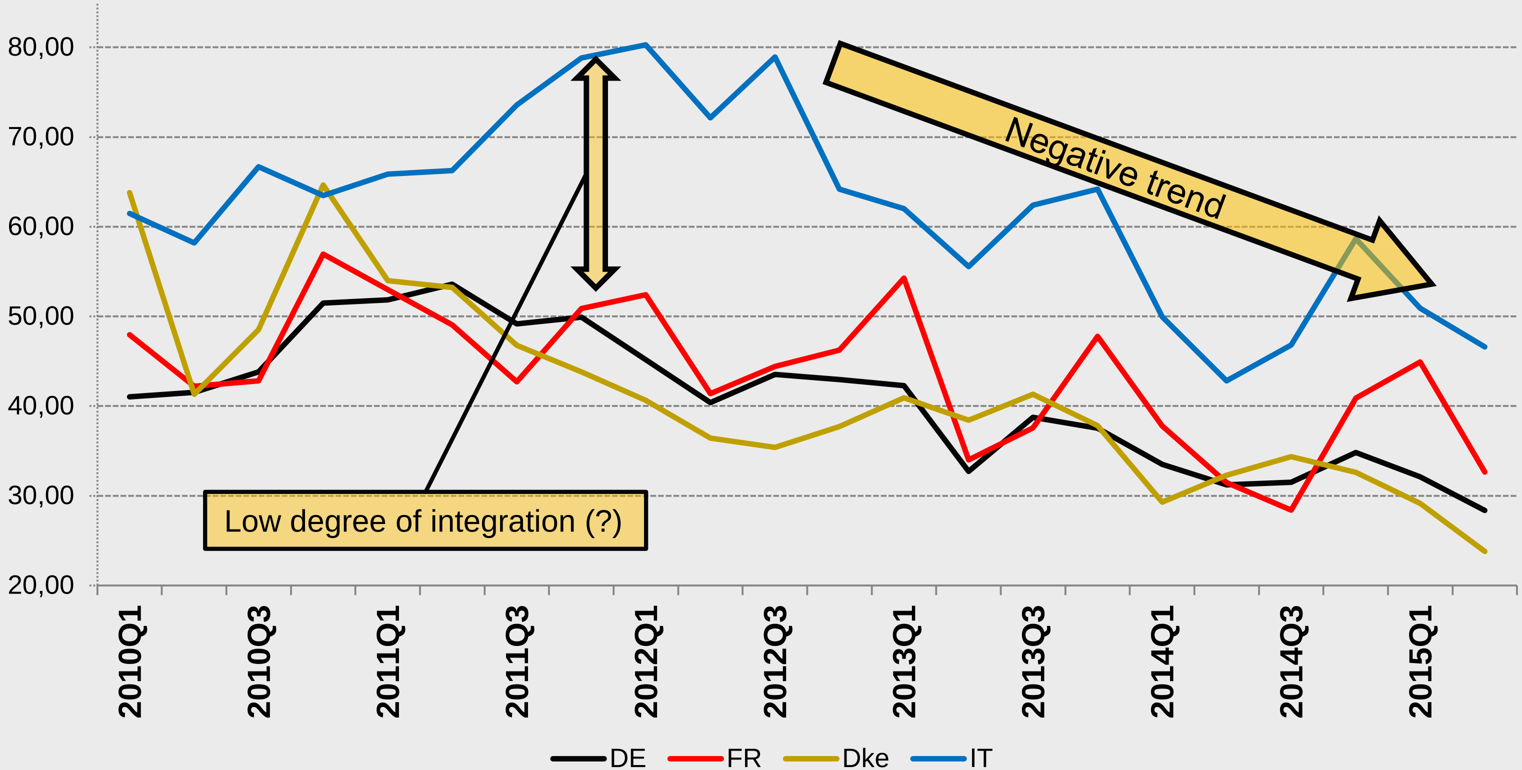
2) Constrained trade: $P_A < \boldsymbol{P_{A,CapLim}} < \boldsymbol{P_{B,CapLim}} < P_B$
Consumers: −A+C+D, Producers: +A+B−C, Welfare: +B+D

3) Unconstrained trade: $P_A < P_{A,CapLim} < \boldsymbol{P_{NoCong}} < P_{B,CapLim} < P_B$
Consumers: −A+C+D−E+G+H, Producers: +A+B−C+E+F−G, Welfare: +B+D+F+H

“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”

— 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)

Congestion & Market Coupling

Direction of congested hours: DE and selected neighbors

Direction	Market Coupling	2010	2011	2012	2013	2014	2015Q1,2
DE-->FR		90.4%	10.8%	30.4%	41.9%	31.7%	66.7%
FR-->DE		84.6%	27.0%	6.9%	11.5%	17.3%	6.5%
Total	09.11.2010	91.5%	37.8%	37.3%	53.4%	49.1%	73.3%

1. 2. 3.

Introduction Market Coupling

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

Method: 1. Cointegration

$$\boldsymbol{P_{A,t} = \alpha + \beta P_{B,t} + Z_t}:$$

α...systematic difference (transport costs, institutional differences)
β...long-run equilibrium relation between P_A and P_B

1. **Perfect integration:**
   $\alpha = 0,\ \beta = 1$***, if export < capacity and market coupling = 1***

2. **Divergence:**
   $\alpha > 0,\ \beta \neq 1$***, if export = capacity and/or market coupling = 0***

$$\boldsymbol{P_{A,t} = \alpha + \beta P_{B,t} + \gamma CBC_{AB,t} + \delta P_{B,t} CBC_{AB,t} + \epsilon CBC_{BA,t} + \zeta P_{B,t} CBC_{BA,t} + Z_t \begin{cases} if\ MC_{AB,t} = 1 \\ if\ MC_{AB,t} = 0 \end{cases}}$$

→ 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: $\Delta P_{A,t} = \theta + \vartheta \Delta P_{A,t-24} + \eta \hat{Z}_{t-24} + \mu' X + \varepsilon_t$

η ... speed of adjustment from price shock in t-24 back to long-rung cointegrating relationship

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

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

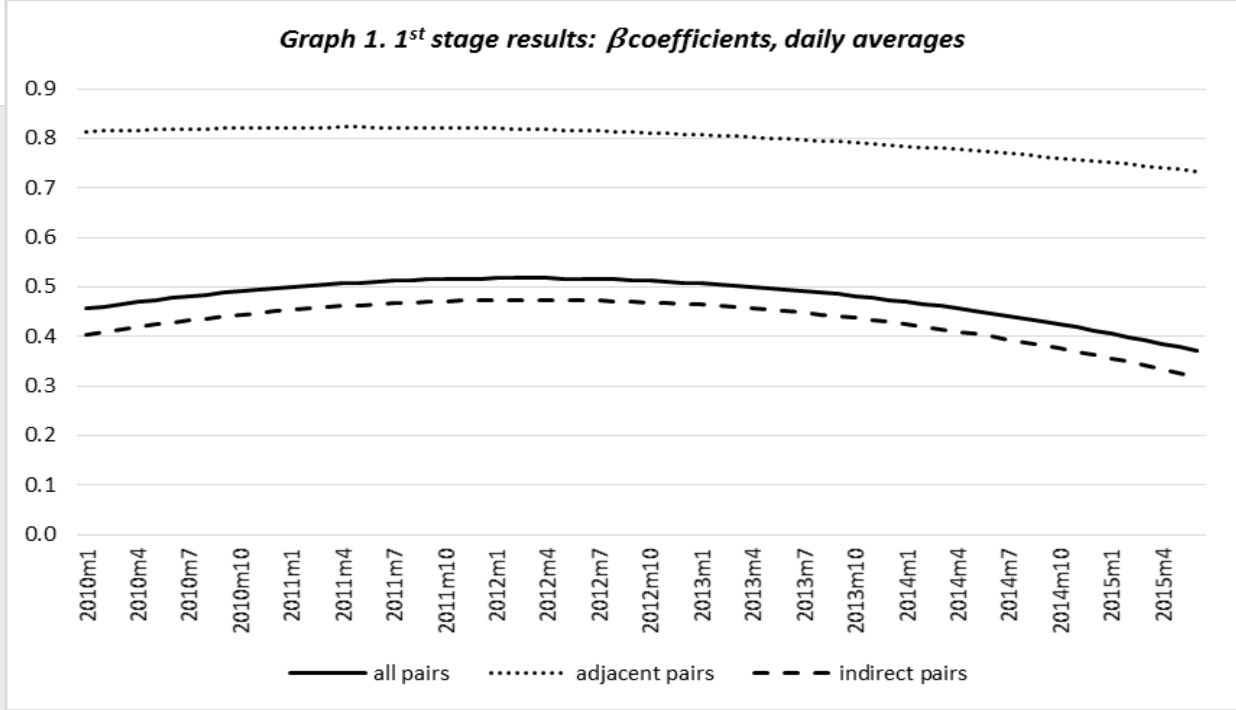
Δ represents difference (e.g. $\Delta \mathrm{P}_{\mathrm{A,t}} = \mathrm{P}_{\mathrm{A,t}} - \mathrm{P}_{\mathrm{A,t-24}}$),

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. $\mathrm{P}_{\mathrm{A,t-24}} \neq \mathrm{P}_{\mathrm{B,t-24}}$)
→ Otherwise: no errors (i.e. instantaneous adjustment)

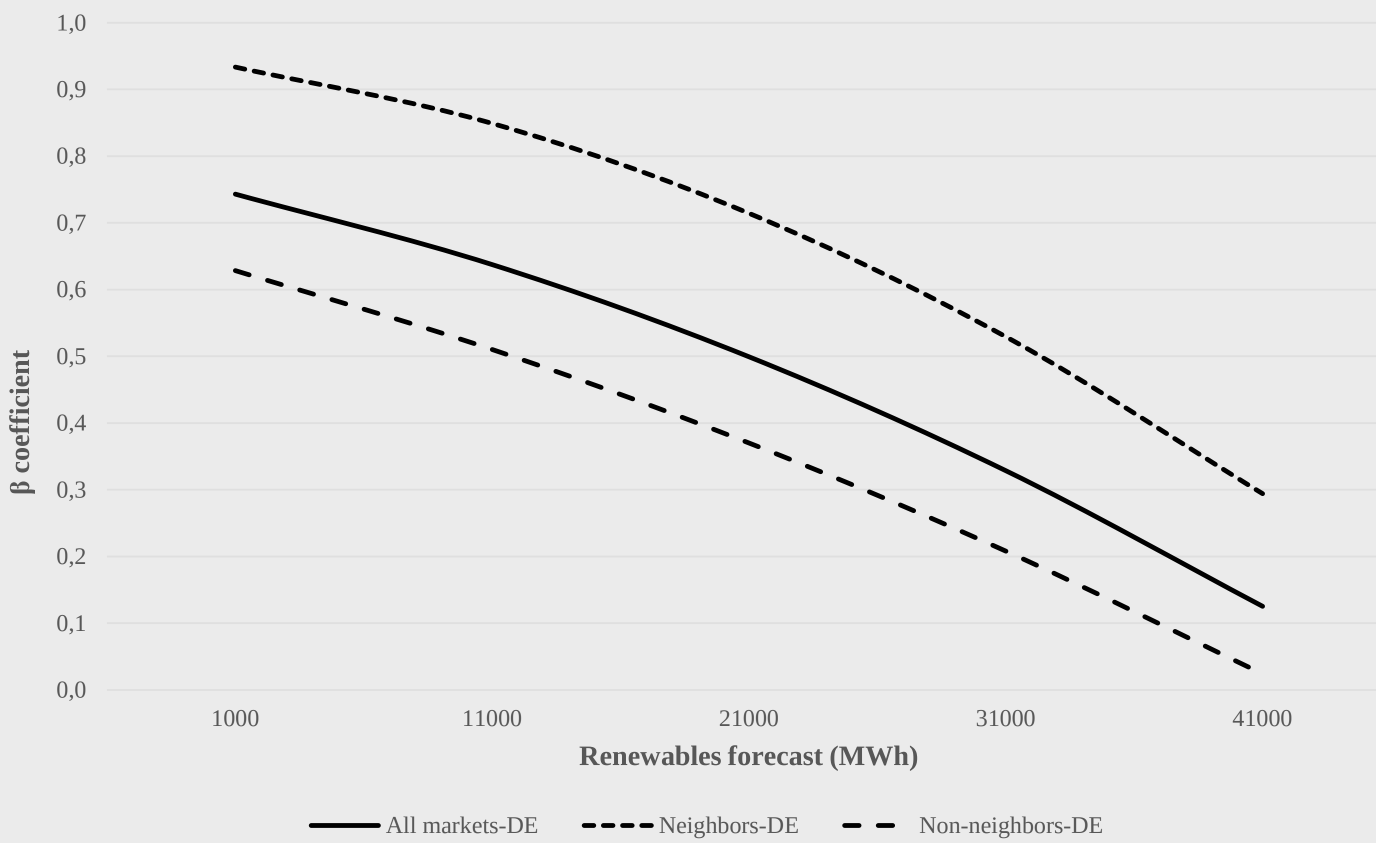
Data & Add-Ons to Existing Literature

- 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 d?o markets work when congestion is present?



- Adjacent market pairs have high degree of integration
- Over time, inegration increases, then decreases
    - Investment in interconnector capacity (+),
    - Market coupling (+),
    - Increasing production from volatile renewables (-)
    - Other confounding factors (+/-)

Average β coefficients of DE and other markets subject to forecasted renewables production in DE



1st stage estimates before and after market coupling

Market			Before MC							After MC					
A	B	Intro. MC	α	β	$C_{A\to B}$	$C_{B\to A}$	$P_B * C_{A\to B}$	$P_B * C_{B\to A}$		α	β	$C_{A\to B}$	$C_{B\to A}$	$P_B * C_{A\to B}$	$P_B * C_{B\to A}$
DE	*FR*	10.11.2011	0.64	0.89	4.68	8.46	-0.19	-0.05[a]		0.00[a]	1.00	1.61	16.70	-0.29	-0.25
DE	*IT*	24.02.2015	11.79	0.47	-3.47	1.91	0.04	-0.04		0.00[a]	1.00	-1.54[a]	16.03	-0.37	-0.29
DE	*DKE*	05.02.2014	1.79	0.96	11.95	15.21	-0.47	-0.14		0.00[a]	1.00	-4.38	12.35	-0.12	-0.15
DE	*DKW*	05.02.2014	-0.08[a]	1.00	-7.72	20.00	-0.03	-0.25		0.00[a]	1.00	-1.86	13.85	-0.19	-0.19
DE	*SE4*	05.02.2014	2.38	0.95	5.72	24.32	-0.38	-0.34		0.00[a]	1.00	-6.75	12.84	-0.05	-0.16
FR	*DE*	10.11.2011	11.18	0.85	-14.53	5.33	0.13[a]	0.03[a]		0.00[a]	1.00	-7.50	18.46	-0.04	-0.16
FR	*IT*	24.02.2015	10.43	0.56	2.49	-3.32	-0.11	0.25		0.00[a]	1.00	1.54[a]	25.89	-0.36	-0.40
FR	*ES*	13.05.2014	21.07	0.55	-18.65	12.72	0.15	-0.02		0.00[a]	1.00	-7.67	21.47	-0.22	-0.29
SL	*IT*	01.01.2011	7.49	0.87	0.05	-0.55	-0.29	0.14		0.00[a]	1.00	-2.98	21.44	-0.31	-0.31
IT	*DE*	24.02.2015	28.87	0.92	2.64	-0.74	-0.04	-0.08		0.00[a]	1.00	-9.93	32.59	-0.01[a]	-0.46
IT	*FR*	24.02.2015	28.84	0.74	-11.73	5.00	0.06	-0.03		0.00[a]	1.00	-7.21	31.87	-0.13	-0.48
IT	*SL*	01.01.2011	0.48	1.00	-4.65	28.85	-0.08	-0.24		0.00[a]	1.00	-7.02	31.85	-0.11	-0.46
DKE	*DE*	05.02.2014	0.45[a]	0.98	1.69	11.64	-0.21	0.01[a]		0.00[a]	1.00	-0.37	20.68	-0.58	-0.58
DKW	*DE*	05.02.2014	1.84	0.96	2.95	17.53	-0.25	-0.27		0.00[a]	1.00	5.67	15.79	-0.39	-0.39
SE4	*DE*	05.02.2014	1.56	0.94	6.17	19.56	-0.33	-0.14		0.00[a]	1.00	7.11	21.94	-0.40	-0.63
ES	*FR*	13.05.2014	21.96	0.41	-15.42	4.45	0.11	0.21		0.00[a]	1.00	-7.56	32.97	-0.07	-0.42

Notes: [a] *insignificant coefficient (below the 10% significance level). "Intro. MC" stands for the date of the introduction of market coupling.*

- With MC and no congestion → *α=0* & *β=1*, perfect integration
- No MC and no congestion → *α≠0 & β≠1 (possible outcome).*

Table 8. ECM before and after market coupling

Market			ECM (i) unconstrained				ECM (ii) constrained				Obs.		
A	B	β	η		η_{MC}		η		η_{MC}		$P_A \neq P_B$	Total	%
DE	FR	0.74	-0.31	***	-0.41	***	-0.11	***	-0.24	***	24541	48137	51.0
DE	IT	0.49	-0.35	***	-0.30		-0.11	***	-0.16	*	45823	48149	95.2
DE	DKE	0.63	-0.26	***	-0.33	***	-0.10	***	-0.23	***	31218	48114	64.9
DE	DKW	0.89	-0.30	***	-0.29		-0.25	***	-0.24		28835	48144	59.9
DE	SE4	0.52	-0.36	***	-0.39	***	-0.15	***	-0.26	***	37672	48117	78.3
FR	IT	0.50	-0.29	***	-0.45	***	-0.11	***	-0.25	***	45622	48154	94.7
SL	IT	0.65	-0.32	***	-0.55	***	-0.18	***	-0.42	***	36426	45048	80.9
HU	SK	0.92	-0.49	***	-0.61	***	-0.47	***	-0.58	***	23312	39404	59.2
IT	DE	0.81	-0.32	***	-0.39		-0.27	***	-0.32		45847	48149	95.2
IT	FR	0.67	-0.35	***	-0.34		-0.27	***	-0.22		45646	48154	94.8
IT	SL	0.73	-0.32	***	-0.33		-0.25	***	-0.21		36449	45048	80.9
DKW	DE	0.74	-0.29	***	-0.40	***	-0.16	***	-0.25	***	28840	48144	59.9
SE4	DE	0.61	-0.16	***	-0.18		-0.10	***	-0.08	*	37638	48117	78.2
ES	FR	0.34	-0.38	***	-0.44	***	-0.21	***	-0.29	***	44543	48154	92.5
SK	CZ	1.01	-0.92	***	-0.75	***	-0.92	***	-0.75	***	897	39408	2.3
Average:			-0.36		-0.41		-0.24		-0.30				

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
  - → 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!

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