

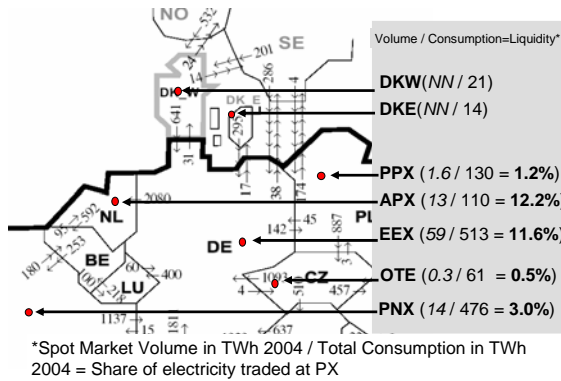
# Convergence of Wholesale Electricity Prices in Europe

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## Motivation

In the process of liberalization power exchanges developed in numerous European countries. Most of them are characterized by low liquidity.

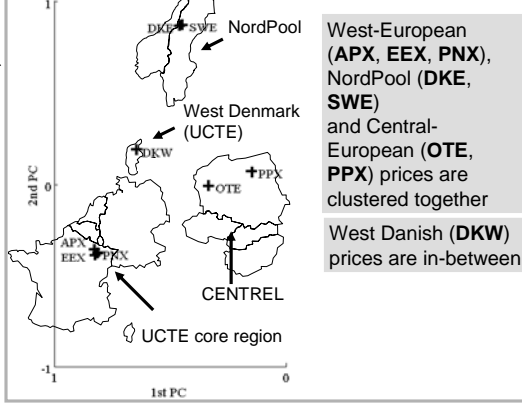
Power Exchanges in Central Europe



## Prices Interact

European wholesale prices interact due to shared fundamentals and cross border trade. However no Single Market has yet arisen.

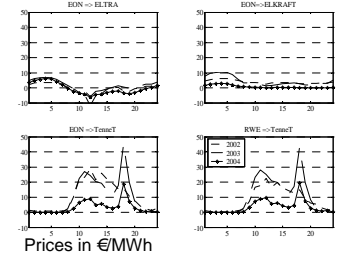
Correlation of wholesale spot prices with their first and second common component



## Cross-Border Capacity Auctions

European cross-border transmission lines are often congested. Capacities are mainly allocated via explicit auctions.

Results of Daily Transmission Auctions



## Issues

For the spot market, day ahead capacity allocation is most important. In this context explicit auctions feature various undesirable characteristics: they add uncertainty to international electricity traders and reduce available capacities significantly. Consequently **arbitrage opportunities can often not be fully exploited**. The purpose of my work is to test whether despite these shortcomings the auction results improved their ability to deduce the economically correct scarcity rents over time.

## Estimation

A time varying coefficient framework is used to test the development of this relation over time.

$$y_t = \alpha_t \cdot x_t + \epsilon_t$$

$$\alpha_t = \alpha_{t-1} + u_t$$

$$y_t = p_{i,t}$$

$$x_t = p_{j,t} + \text{transm}_{i \rightarrow j,t} - \text{transm}_{j \rightarrow i,t}$$

$$i, j = \text{APX, EEX, DKE, DKW}$$

$$\epsilon_t \sim N(0, \sigma_\epsilon^2)$$

$$u_t \sim N(0, \sigma_u^2)$$

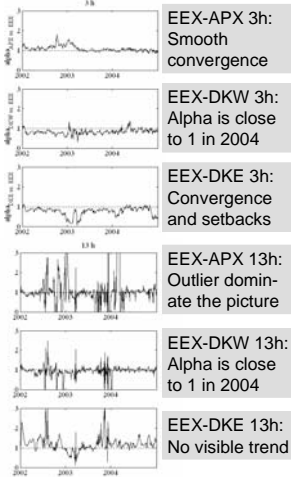
## Law of one Price

Arbitrage freeness would induce that the capacity auction results equal the price differences between the connected markets

$$p_{EEX,t} + \text{transm}_{EEX \rightarrow APX,t} = p_{APX,t} + \text{transm}_{APX \rightarrow EEX,t}$$

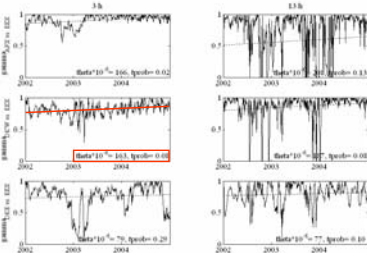
## Provisional Results

The time variant coefficients ( $\alpha_t$ ) show that auction results at some borders (DKW-EEX, APX-EEX) were converging towards arbitrage freeness, whereas at others (DKE-EEX) they were not.



## The Indicator

To assess the significance of convergence a proximity indice ( $\gamma_t$ ) and a convergence indicator ( $\theta$ ) are calculated



## Results

**DKW-EEX:** significant convergence in peak and off-peak.  
**APX-EEX:** Convergence towards arbitrage-freeness in off-peak. No significant convergence in peak due to outliers.  
**DKE-EEX:** No significant convergence in peak and off-peak.

	EON - TenneT (EEX-APX)			EON - ELTRA (EEX-DKE)			EON - Elkraft (EEX-DKW)		
	tprob	theta 10%	incpt	tprob	theta 10%	incpt	tprob	theta 10%	incpt
1h	0.06	0.09	0.90	0.21	0.10	0.81	0.09	0.10	0.86
3h	0.02	0.17	0.85	0.29	0.08	0.73	0.08	0.16	0.76
5h	0.03	0.18	0.83	0.36	0.00	0.74	0.13	0.13	0.76
7h	0.01	0.19	0.81	0.19	0.11	0.83	0.07	0.14	0.85
9h	0.10	0.20	0.74	0.18	0.02	0.83	0.09	0.12	0.84
11h	0.31	-1.24	-0.90	0.19	0.02	0.8	0.08	0.21	0.78
13h	0.13	0.21	0.91	0.10	0.08	0.77	0.08	0.19	0.80
15h	0.26	0.18	0.30	0.15	0.04	0.82	0.11	0.11	0.84
17h	0.25	-6.48	-7.12	0.20	0.04	0.85	0.06	0.13	0.87
19h	0.74	-5.88	-0.19	0.18	0.03	0.84	0.08	0.15	0.84
21h	0.07	0.13	0.85	0.17	0.08	0.83	0.09	0.10	0.89
23h	0.03	0.14	0.88	0.13	0.13	0.84	0.06	0.15	0.86

**Explicit auctions partly improved but generally remained inefficient.**

**Selected References:** Boisseleau, François, 2004. The role of power exchanges for the creation of a single European electricity market: market design and market regulation. Delft University Press.  
 Armstrong, Margaret and Gallil, Alain, 2005. Are day-ahead prices for electricity converging in continental Europe? An exploratory data approach. CERNA Working Paper.  
 Bower, John, 2002. Seeking the Single European Electricity Market: Evidence from an Empirical Analysis of Wholesale Market Prices. Economics Working Paper Archive at WUSTL.