Aalto University
School of Science

Impact of renewable energy on electricity prices – comparative analysis of Denmark and Germany

Tuomas Rintamäki

25 March 2013

Instructor: PhD Afzal Siddiqui, University College London

Supervisor: Professor Ahti Salo

Systeemianalyysin laboratorio

Agenda

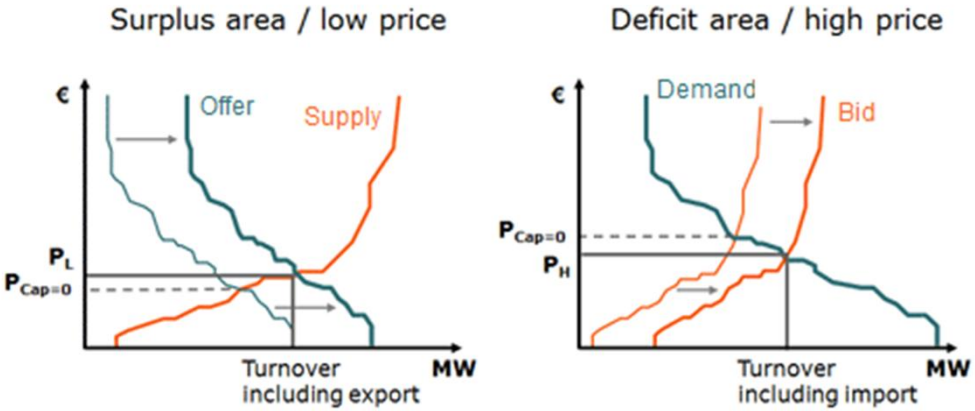
1. Recap on energy markets and renewables
2. Research objectives
3. Data
4. Methodology
5. Results
6. Conclusions
7. References

Recap on energy markets and renewables

- "**20-20-20**" targets for 2020

Country	2008 (%)	2009 (%)	2010 (%)	2020 (%)
Denmark	26.7	27.49	33.11	51.9
Germany	14.63	16.2	16.9	38.6

- **System price** (Nord Pool) and **ELIX** (EEX) are the equilibrium prices of aggregated supply and demand curves without transmission constraints
- **Area prices** are usually more relevant



P_L and P_H → Prices for each area when full utilization of trading capacity

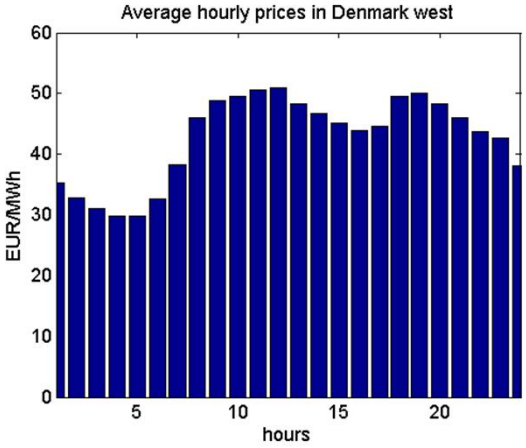
$P_{Cap=0}$ → Price in area with isolated price calculation.

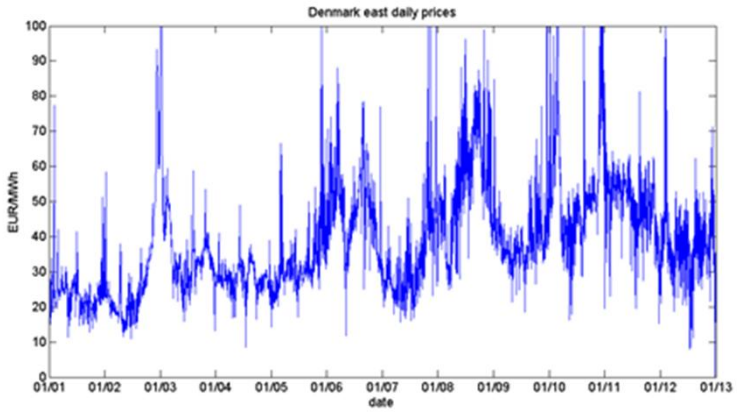
Research objectives

- Estimate the impacts of intermittent renewable electricity production on **electricity price levels** and **volatility**
- Assess if there is a difference in **short-term** and **long-term** impacts
- Explain the reasons for the results

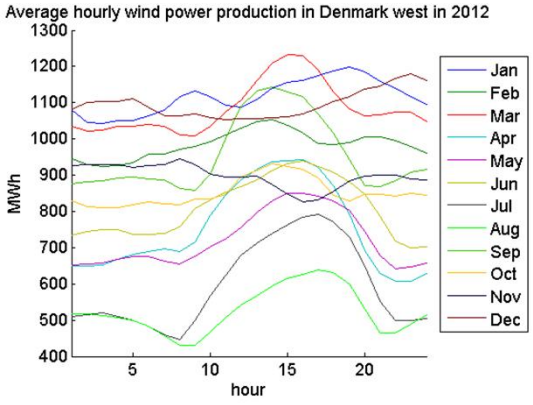
Data – Denmark

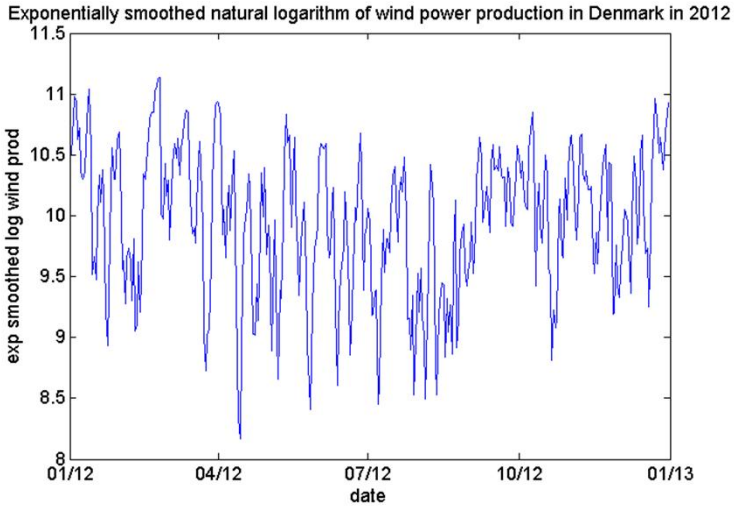
- Hourly prices reflect demand patterns
- Long-term price levels depend on macroeconomics, **hydro power availability**, fuel prices etc.





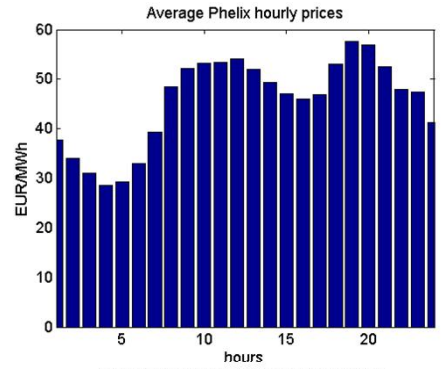
- Danish wind power has an output peak in peak hours (08-19)
- Long-term wind output is not stable

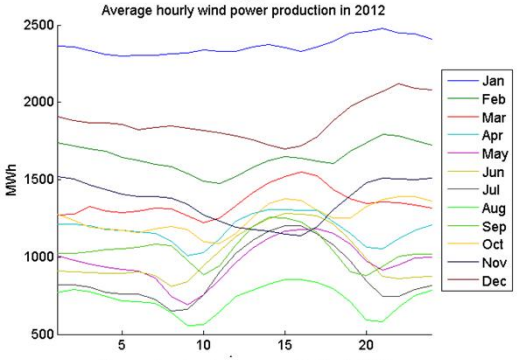


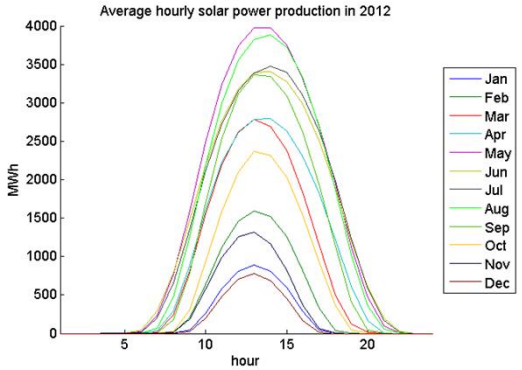


Data – Germany

- Hourly German prices are a bit higher than Danish prices
- Intraday wind output curve is rather flat
- Solar power production is stable







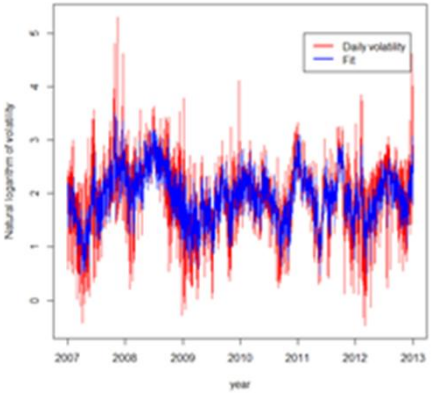
Methodology

- I use the same methodology as Mauritzen [1]
- Daily price volatility data is modeled as a SARMA process
- Weekly price volatility data is modeled as an ARIMA process
- In both cases, the best specification for the volatility is found by looking at ACF and PACF plots. The specification is validated by checking that the coefficients are statistically significant and by testing the model residuals with a Ljung-Box test
- Wind and solar power processes are **exogenous variables**
- Hence, the coefficients for wind and solar power show their impact on the price volatility
- Moreover, by splitting the data to **blocks**, I am able to explain the reasons for the impacts

Results – Denmark

- The best intraday model is SARMA(2,1)(1,2)$_7$ with an AR(1) for wind power as an external regressor

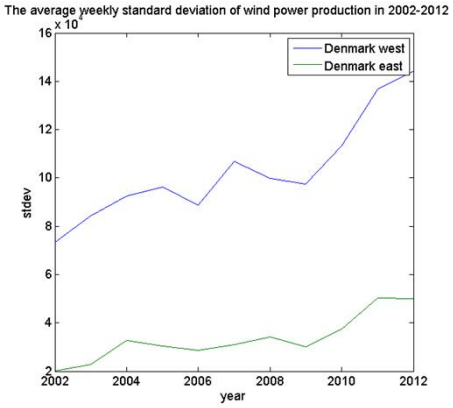
Coefficient	Denmark east	Denmark west
DE – wind$_t$	-0.0759	
DW – wind$_t$		-0.0751



- The best weekly model is ARIMA(1,1,0) with an exogenous wind power term

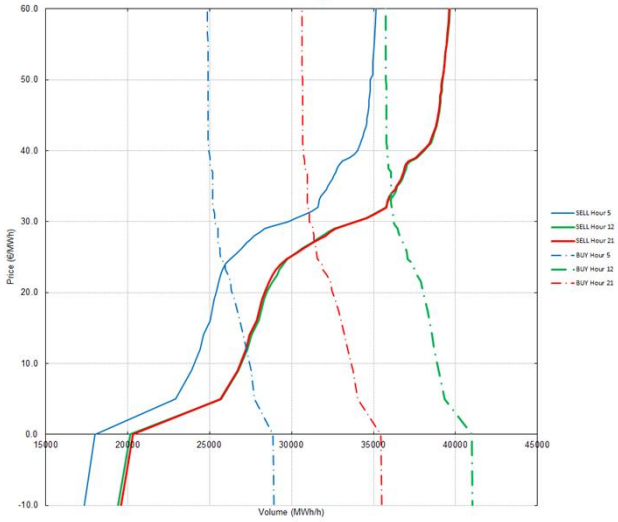
Coefficient	DE	DE	DW	DW
DE – wind$_t$	0.0521			
DE – wind$_t$ - std		0.0647		
DW – wind$_t$			0.1123	
DW – wind$_t$ - std				0.1001

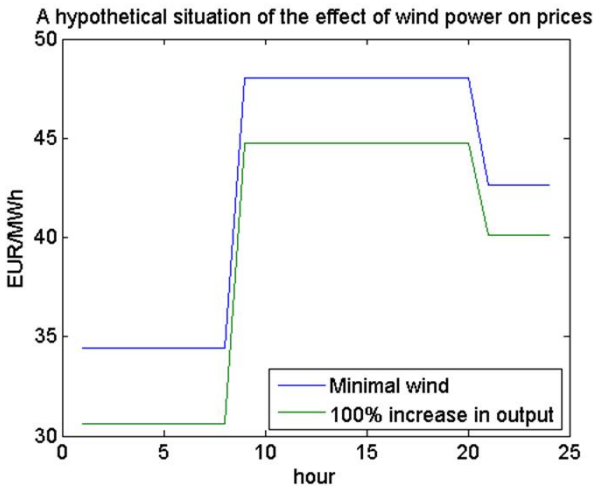
Red values: not significant, otherwise significant at 5% level



Results – division of Danish intraday data into blocks

Coefficient	Peak	Off-peak1	Off-peak 2
DE – $wind_t$	-0.0413	-0.0557	-0.0287
DW – $wind_t$	-0.0681	-0.1112	-0.0597



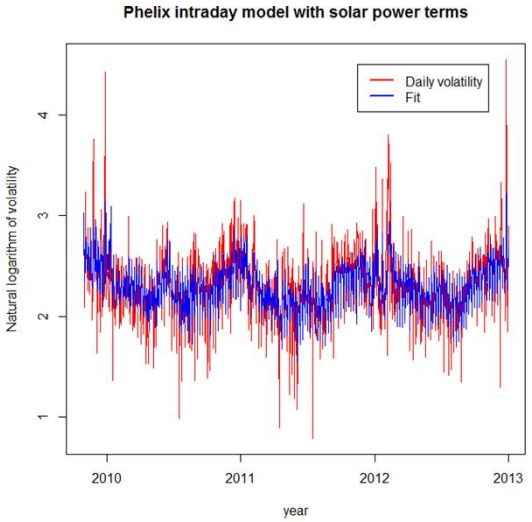


- Wind power has different impacts on different blocks
- Coefficients for the first off-peak are largest. The distribution of daily wind power affects the daily volatility

Results – Intraday model for Germany

- The best model for Germany is SARMA(2,1)(1,1)$_7$ with an AR(1) for wind, solar and combined output as an external regressor

Coefficient	Phelix (wind)	Phelix (solar)	Phelix (res)
DE – wind$_t$	0.0426		
DE – solar$_t$		-0.0369	
DW – res$_t$			0.0468



- Wind power increases daily volatility whereas more stable solar power decreases volatility. Combined output is driven by wind power

Results – Weekly model for Germany

Coefficient	wind	wind	solar	solar	res	res
DE – $wind_t$	0.1664					
DE – $wind_t$ - std		0.1520				
DE – $solar_t$			-0.1835			
DE – $solar_t$ - std				-0.0350		
DE – res_t					0.1708	
DE – res_t - std						0.1742

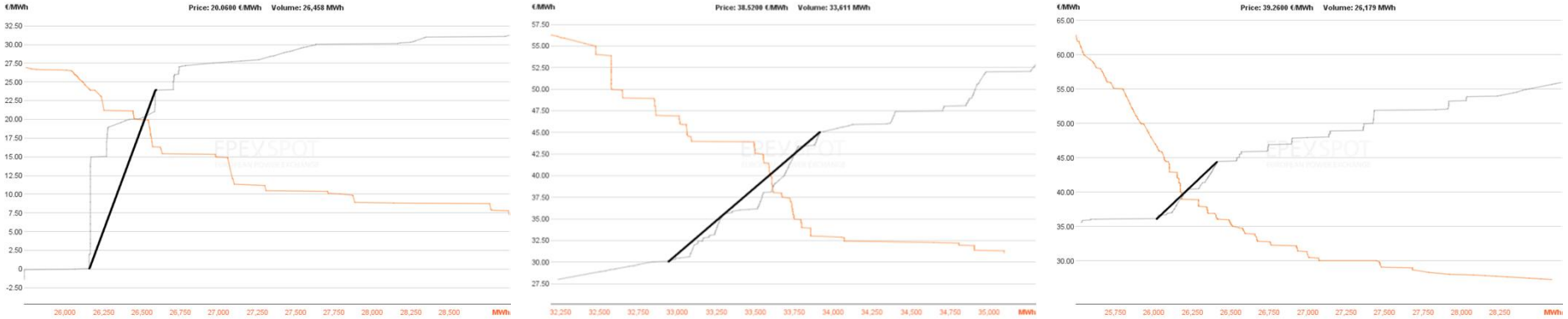
Red values: not significant, otherwise significant at 5% level

- Wind power and combined output increases the weekly volatility of prices
- No effect from solar power

Results – division of German intraday data into blocks

Coefficient	Peak	Off-peak1	Off-peak 2
DE - $wind_t$	-0.0979	-0.2468	-0.1107

Off-peak 1 | Peak | Off-peak 2



Grey curve: supply, orange: demand

- Average slopes on 5 February 2013: 0.055 EUR/MWh, 0.015 EUR/MWh, 0.0275 EUR/MWh

Conclusions

1. Danish wind power decreases daily Danish price volatility
2. Denmark west wind power increases the weekly volatility of Denmark west prices
3. German solar power decreases daily German price volatility. Solar power output is stable and more predictable than wind power
4. German wind power increases daily German price volatility. The German wind power curve is flat
5. German wind power increases the weekly volatility of German prices

References

1. Mauritzen J. *What happens when it's Windy in Denmark? An Empirical Analysis of Wind Power on Price Volatility in the Nordic Electricity Market.* Norwegian school of economics and business administration; 2010.
2. Ketterer J. C., *The Impact of Wind Power Generation on the Electricity Price in Germany.* Ifo Institute, Leibniz Institute for Economic Research at the University of Munich; October 2012.
3. Jónsson T., Pinson P., Madsen H. *On the market impact of wind energy forecasts.* Technical University of Denmark; 2009.