The Effect of Intermittent Renewables on the Electricity Price

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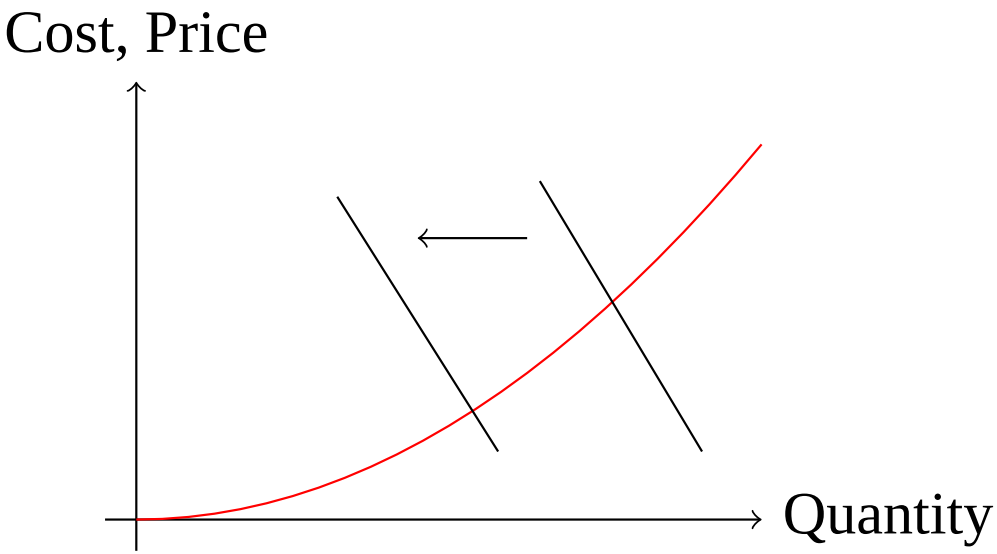
Agenda

Merit Order Effect

$$\text{Residual Demand} = \text{Demand} - \text{Renewables}$$



- Marginal cost of renewables 0
- Static model of competition (no inter-temporal choices)
- $\Rightarrow$ Residual demand consideration is equivalent to supply shift

Merit Order Effect (cont'd)

- Production from renewables ↑, Average prices ↓ [see, e.g., Sensfuß et al., 2008, Green and Vasilakos, 2010, Jacobsen and Zvingilaite, 2010, Woo et al., 2011]
- Might only be true in *short run*!
  - Production portfolio may change
  - Merit order may change (interchange of coal and gas due to CO_2 prices) which would change the supply curve and could offset the price-reducing effects, [see, e.g., Wozabal et al., 2013]

WHAT ABOUT PRICE VARIANCE?

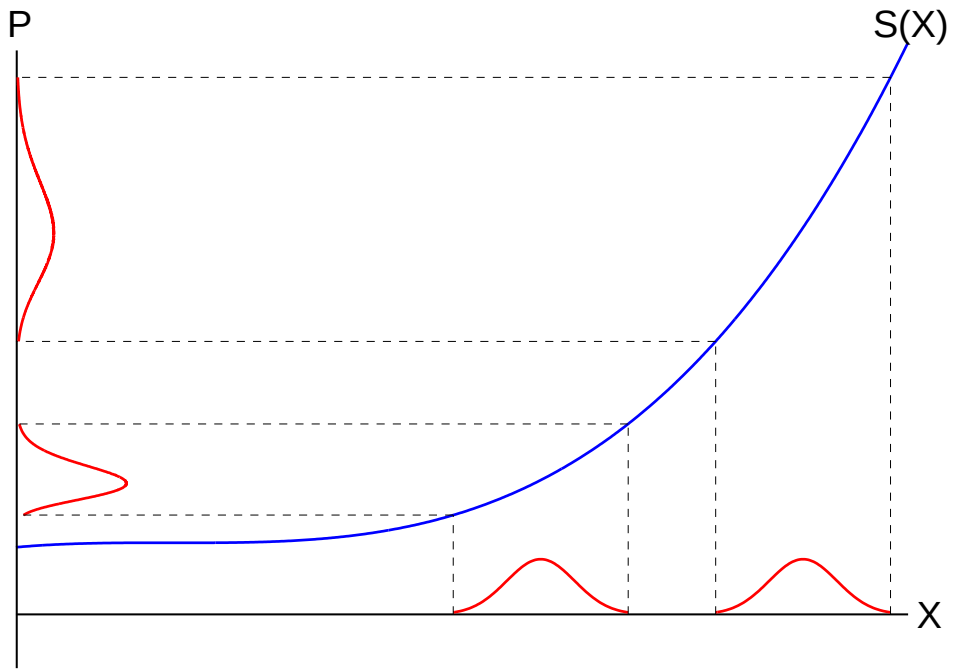
- Very often it is claimed that *price volatility* increases because of the intermittent nature of renewables [see, e.g., Green and Vasilakos, 2010, Jacobsen and Zvingilaite, 2010, Jónsson et al., 2010, Chao, 2011, Milstein and Tishler, 2011, Woo et al., 2011, Ketterer, 2012]
- Price volatility is vague: range of prices, more price peaks (pos/neg) or peaks are more extreme.
- Often no explicit distinction between *short-run* and *long-run effects*.

WHY IS THIS INTERESTING?

Short-run intra-day *price variance* is interesting for

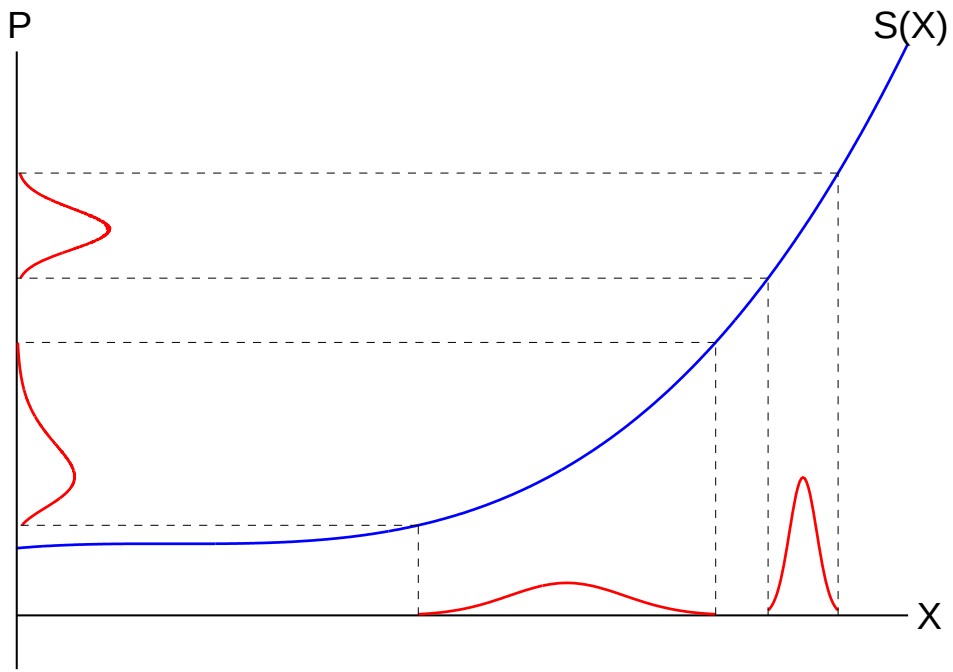
- Hydro pump storage plants, as they exploit price differences
- Investments in smart grids, to motivate smoothing of demand and lowering of peak prices.

CONVEX SUPPLY CURVE



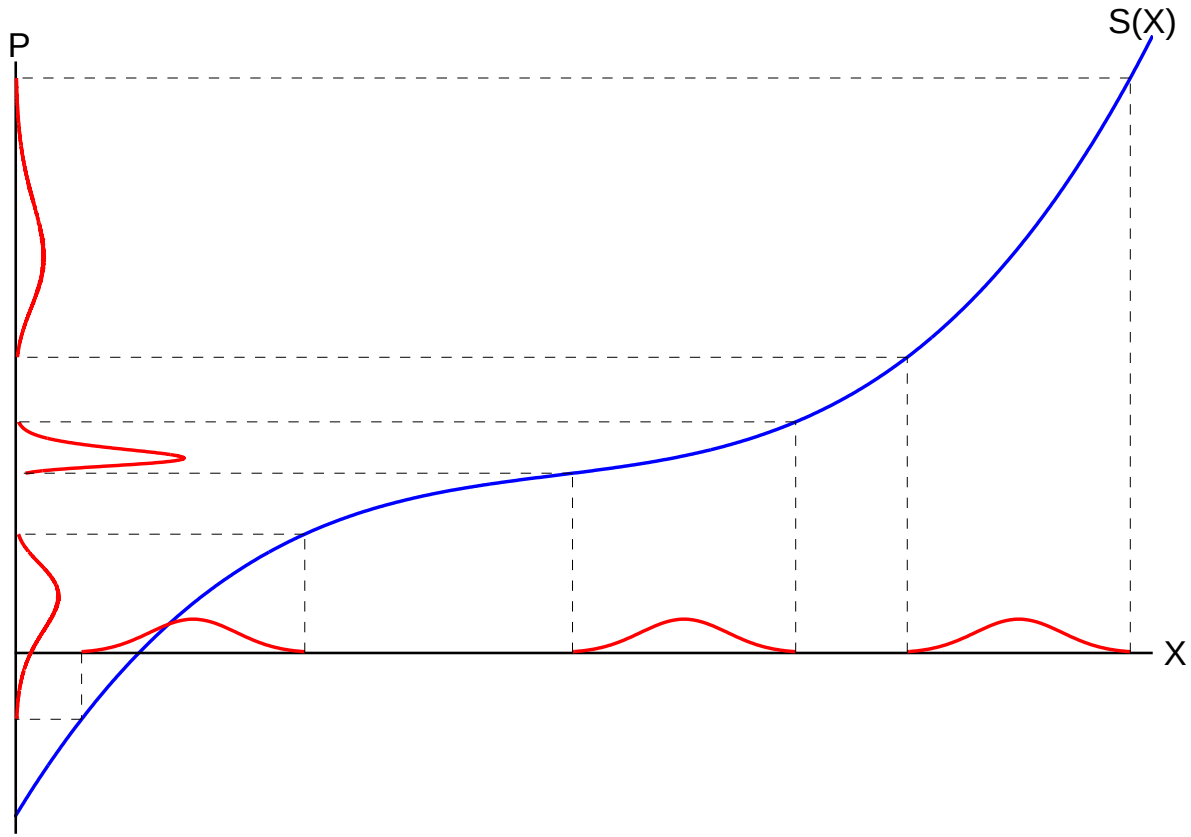
- Unchanged shape of residual demand distribution
- Price variance decrease

Convex supply curve (cont'd)



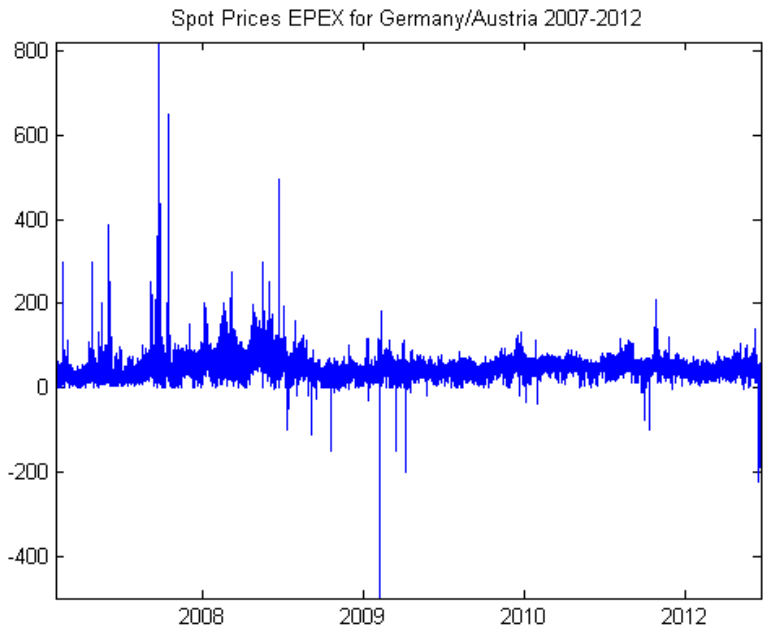
- Increased share of intermittent production broadens the shape of the residual demand distribution
- Price variance could increase
- Effect of intermittent production depends on
  - Shape of the residual demand distribution
  - Slope of the supply function

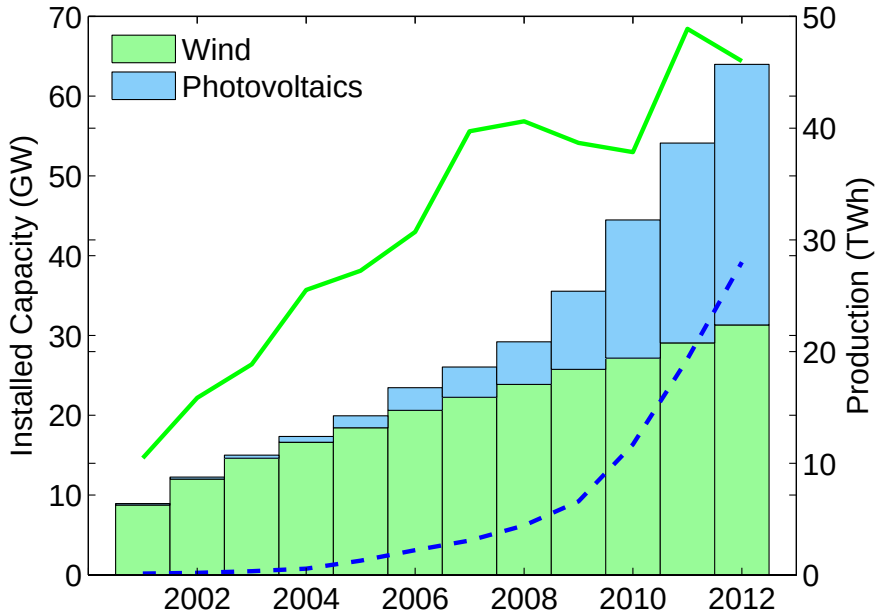
Inverse S-shaped supply curve



PRICES AT EPEX (GERMAN/AUSTRIAN WHOLESALE MARKET)

Did renewables increase price volatility? Naive approach:





EMPIRICAL QUANTIFICATION

Regression models to study the influence of

- the shape of the supply function
- the distribution of the residual demand

on

- *intra-day* price variance

in

- the German/Austrian day-ahead market of electricity for the years 2007–2012

Germany ideal showcase because of

- considerable investments in intermittent renewables (wind, photovoltaics) in the last years

Data

Variable	Description	Source
Price	Hourly day-ahead spot price for DE/AT	EPEX [2013]
Demand	Hourly load for DE/AT	ENTSO-E [2013]
Wind	Hourly day-ahead wind forecast for DE/AT	TSOs [2013]
Photovoltaic (PV)	Hourly day-ahead PV forecast for DE	TSOs [2013]
Temperature	Daily temperature index	Mathematica
Oil	Daily Europe Brent Spot Price FOB	EIA [2013]
Daylight minutes	Daily daylight minutes	

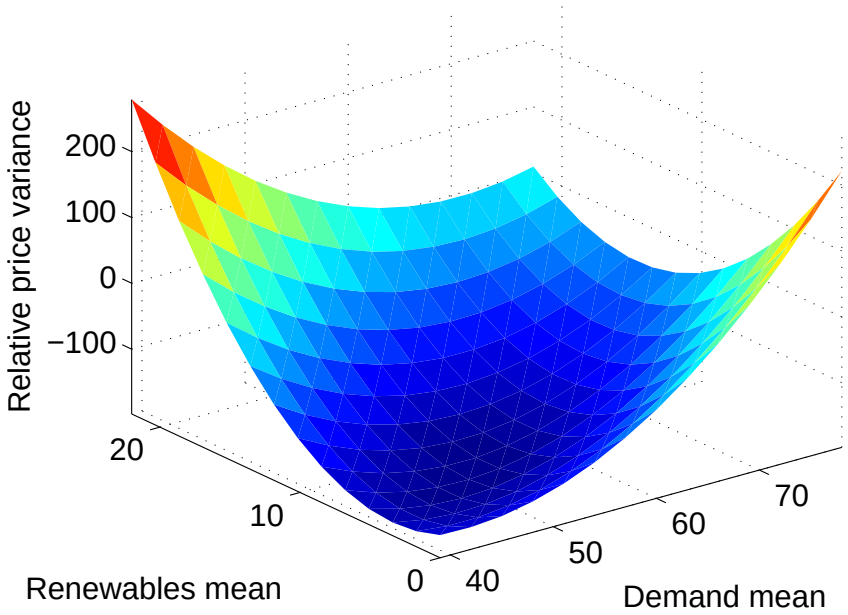
Models

	(1)	(2)	(3)
Intercept	1,013.20 (0.002)	314.79 (0.490)	214.97 (0.589)
RD Mean	−44.75 (0.000)		
(RD Mean)^2	0.47 (0.000)		
D Mean		−23.33 (0.110)	−23.45 (0.071)
(D Mean)^2		0.28 (0.034)	0.28 (0.017)
Ren Mean		20.94 (0.122)	
(Ren Mean)^2		1.31 (0.000)	
(Ren Mean) * (D Mean)		−0.76 (0.004)	
Wind Mean			35.50 (0.008)
(Wind Mean)^2			0.68 (0.004)
Solar Mean			−47.10 (0.071)
(Solar Mean)^2			11.81 (0.000)
(Wind Mean) * (D Mean)			−0.86 (0.001)
(Solar Mean) * (D Mean)			−1.43 (0.013)
(Solar Mean) * (Wind Mean)			1.92 (0.058)
RD Var	1.84 (0.000)		
D Var		1.42 (0.000)	1.33 (0.000)
Ren Var		1.29 (0.064)	3.41 (0.002)
D, Ren Cov		−6.79 (0.000)	−3.87 (0.000)
Daylight Mean	-0.06 (0.607)	0.05 (0.673)	0.07 (0.459)
Temp Mean	3.42 (0.062)	3.32 (0.042)	3.38 (0.019)
Oil P Mean	−1.13 (0.332)	−0.85 (0.367)	−0.05 (0.955)
Oil P 3M Mean	2.32 (0.047)	3.21 (0.001)	3.66 (0.000)
Adjusted R^2	0.25	0.32	0.39
N	2,188	2,188	2,188

Shape of distribution approximated by its variance

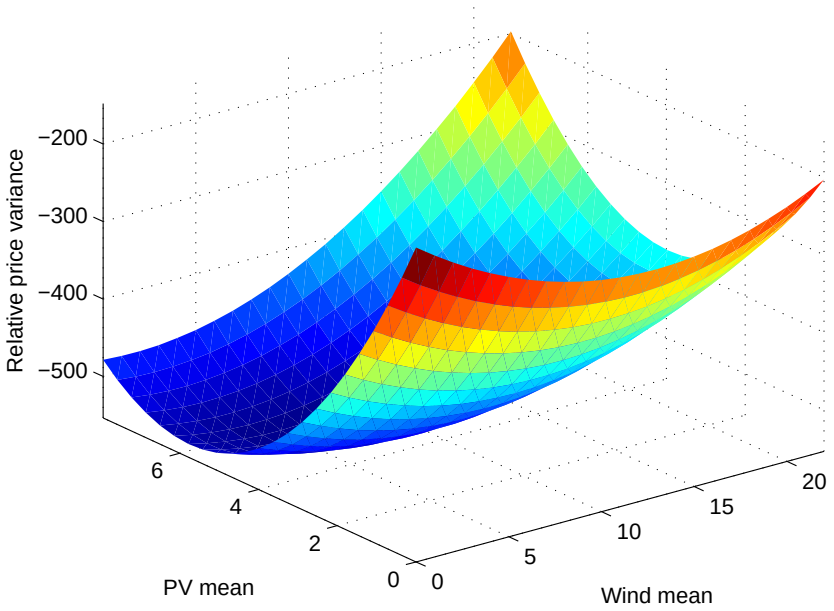
Squared demand to allow for inverse S-shaped supply

Effects (Model 2)



- High demand, high price variance
- Except low demand high infeed of renewables (neg. prices)

Effects (Model 3)



- Relative price variance evaluated at 62 GW demand
- High correlation between demand and Solar infeed (sharp decrease of variance)

Policy Implications and Conclusion

- Spot price variance depends on amount and type
  - Higher correlation (photovoltaics) with stochastic demand the higher the variance dampening effect
  - In markets with inverse S-shaped supply functions
    - first GW of intermittent renewables let price variance decrease
    - larger increase may lead to an increased price variance (concave part of merit order)
- Lower price variance, lower incentives to invest in demand side response technologies and storage facilities

THANK YOU FOR YOUR ATTENTION!

REFERENCES

Hung-po Chao. Efficient pricing and investment in electricity markets with intermittent resources. *Energy Policy*, 39(7): 3945–3953, 2011. doi: 10.1016/j.enpol.2011.01.010.

EIA. U. S. Energy Information Administration. Online, 2013. Available: http://www.eia.gov.

ENTSO-E. European Network of Transmission System Operators for Electricity. Online, 2013. Available: http://www.entsoe.eu, http://www.entsoe.net.

EPEX. European Power Exchange. Online, 2013. Available: http://www.epexspot.com.

Richard Green and Nicholas Vasilakos. Market behaviour with large amounts of intermittent generation. *Energy Policy*, 38(7): 3211–3220, 2010. doi: 10.1016/j.enpol.2009.07.038.

Henrik Klinge Jacobsen and Erika Zvingilaite. Reducing the market impact of large shares of intermittent energy in Denmark. *Energy Policy*, 38(7):3403–3413, 2010. doi: 10.1016/j.enpol.2010.02.014.

Tryggvi Jónsson, Pierre Pinson, and Henrik Madsen. On the market impact of wind energy forecasts. *Energy Economics*, 32: 313–320, 2010. doi: 10.1016/j.eneco.2009.10.018.

Janina C. Ketterer. The Impact of Wind Power Generation on the Electricity Price in Germany. Ifo Working Paper Series 143, Ifo Institute for Economic Research at the University of Munich, 2012.

Irena Milstein and Asher Tishler. Intermittently renewable energy, optimal capacity mix and prices in a deregulated electricity market. *Energy Policy*, 39(7):3922–3927, 2011. doi: 10.1016/j.enpol.2010.11.008.

Frank Sensfuß, Mario Ragwitz, and Massimo Genoese. The merit-order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in germany. *Energy Policy*, 36:3086–3094, 2008.

TSOs. German TSOs: Amprion, 50 Hertz, TenneT, and TransnetBW; Austrian TSO: APG. Online, 2013. Available: http://www.amprion.net, www.50hertz.com, http://www.tennettso.de, www.transnetbw.de, âwww.apg.at.

C.K. Woo, I. Horowitz, J. Moore, and A. Pacheco. The impact of wind generation on the electricity spot-market price level and variance: The texas experience. *Energy Policy*, 39(7):3939–3944, 2011. doi: 10.1016/j.enpol.2011.03.084.

David Wozabal, Christoph Graf, and David Hirschmann. Renewable Energy and its Impact on Power Markets. In Kovacevic, Pflug, and Vespucci, editors, *Handbook of Risk Management for Energy Production and Trading*, International Series in Operations Research and Management Science, pages 283â–311. Springer, 2013.