Renewable Risk and Its Impact on Market Prices: The German Case

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Motivation

- Increase of renewable capacity has many facets
  - Merit-order effect (Ketterer, 2014)
  - Firm behavior with diversified portfolios (Acemoglu et al., 2017)
  - Balancing of forecast errors (Kiesel & Paraschiv, 2017)
- Two-stage market setup
  - Large share of electricity is sold day-ahead
  - Only forecasts for renewable generation available at this point
- **Do renewable firms react to risk in weather predictions?**

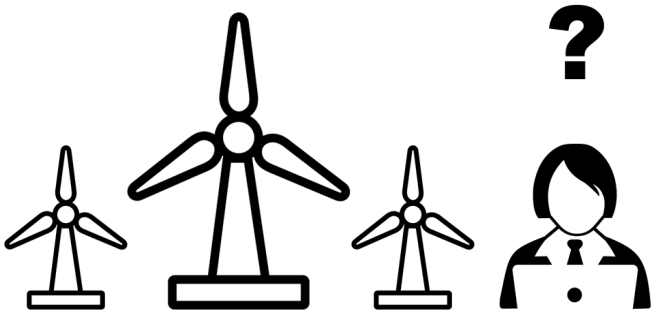
Incentive to withhold capacity

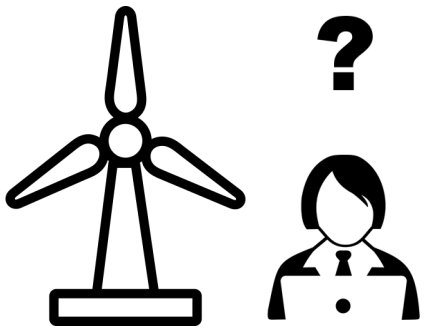
- Consider a risk-averse firm with renewable capacity in a competitive market
- Reacts to both individual output risk and aggregate price risk (Bessembinder & Lemmon, 2002)
- Hedge against price risk by reducing output at the day-ahead stage
- Withholding of renewable electricity will increase the day-ahead price via the merit-order effect
  - Day-ahead price will contain a risk premium

- Renewable firms in Germany are exposed to the market price via the market premium model
  - 95% (25%) of total wind (solar) electricity produced in 2018 (Fraunhofer, 2019)

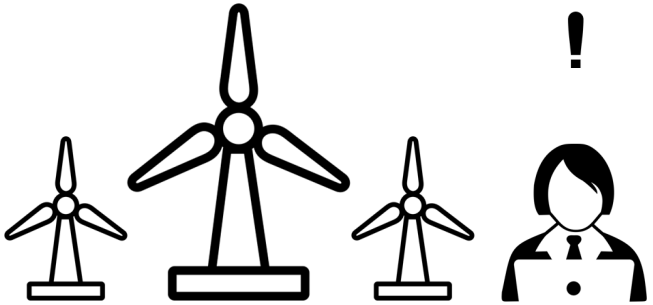
Price impact of output risk

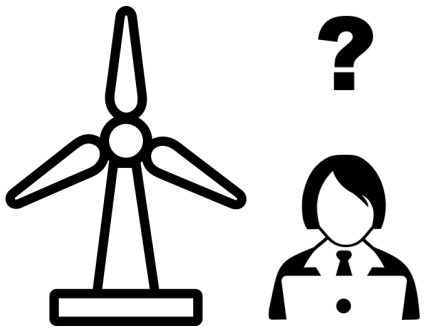
High price impact





Low price impact



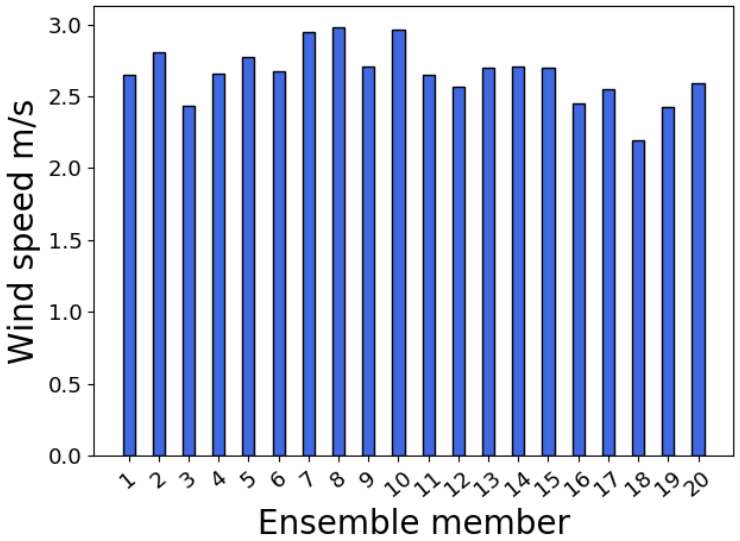


The data

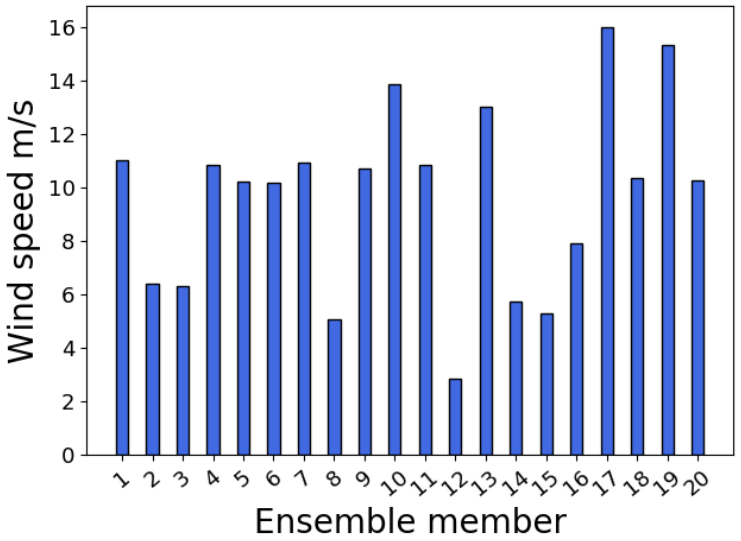
- Hourly data for Germany, 2015 - 2018
- Day-ahead and intraday price
- Forecasted and realized renewable production and demand
- Projected wind speed and solar radiation
- Measure for risk derived from meteorological model (COSMO-DE-EPS)

How to measure forecast risk?

- COSMO-DE-EPS is an ensemble model
- 20 different predictions for every point in time
- Example for wind in region 23:



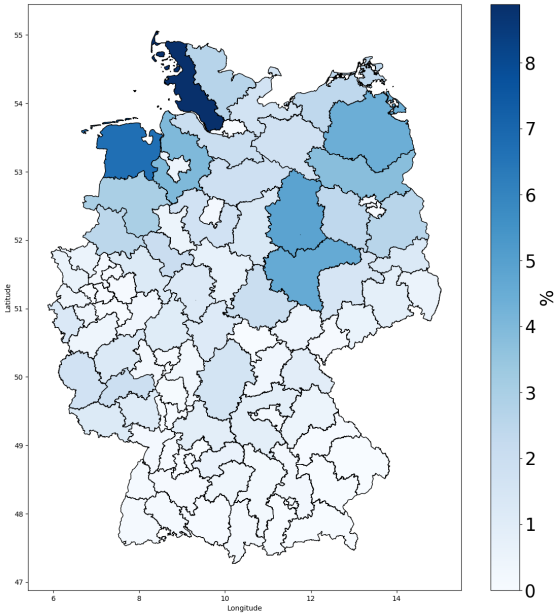
Lower risk: 30.8.2016, 4am-5am



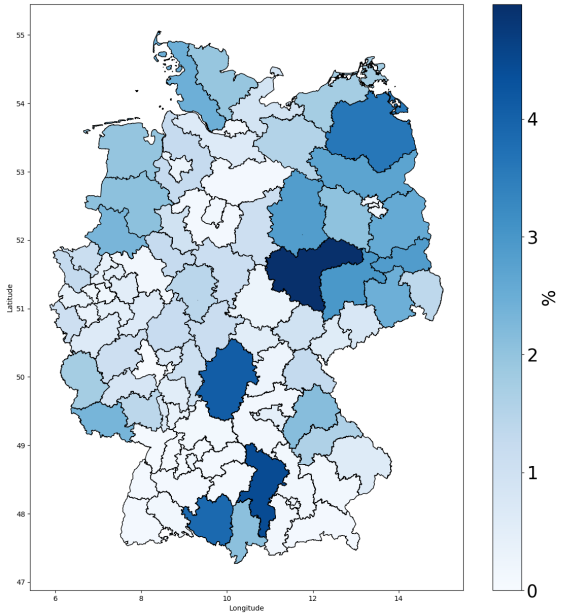
Higher risk: 18.1.2018, 11pm-12am

Regional information

- 95 regions allow for cluster identification



Wind capacity shares

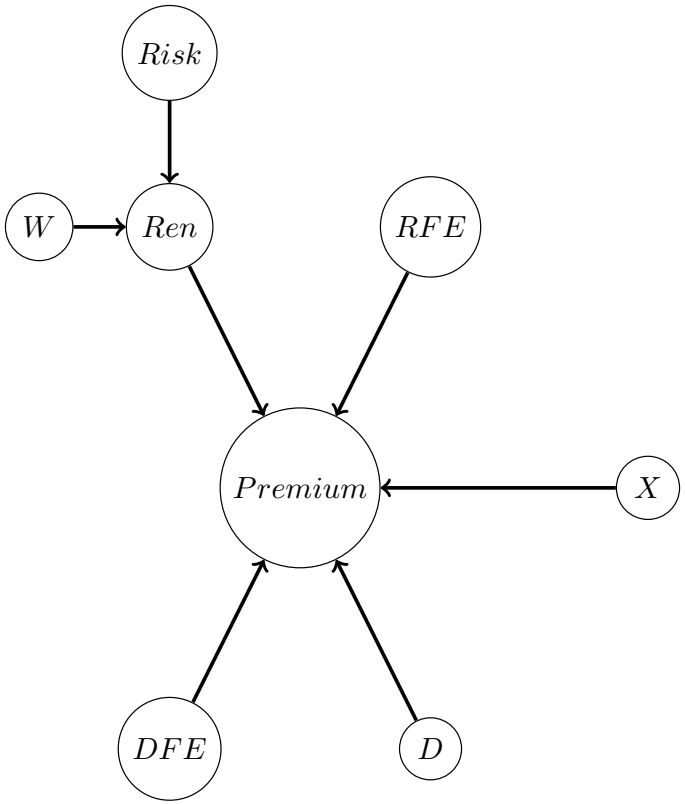


Solar capacity shares

Explanatory variables of interest

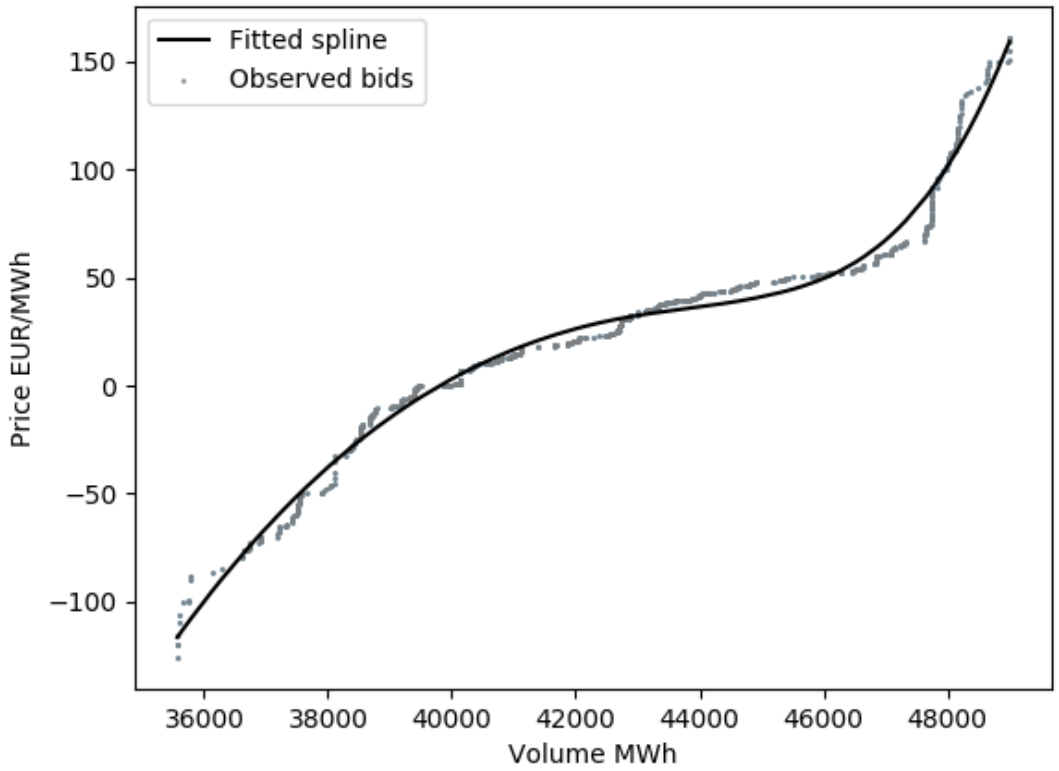
- **Continuous**:
  - Capacity-weighted average output risk
  - Split into high & low price impact regions
    - High if capacity share exceeds 90th percentile
- **Binary**:
  - High output risk in high and low price impact regions
    - High if risk exceeds 90th percentile
- Both for wind and solar
- Qualitative results unaffected by threshold

Regression analysis: Price difference



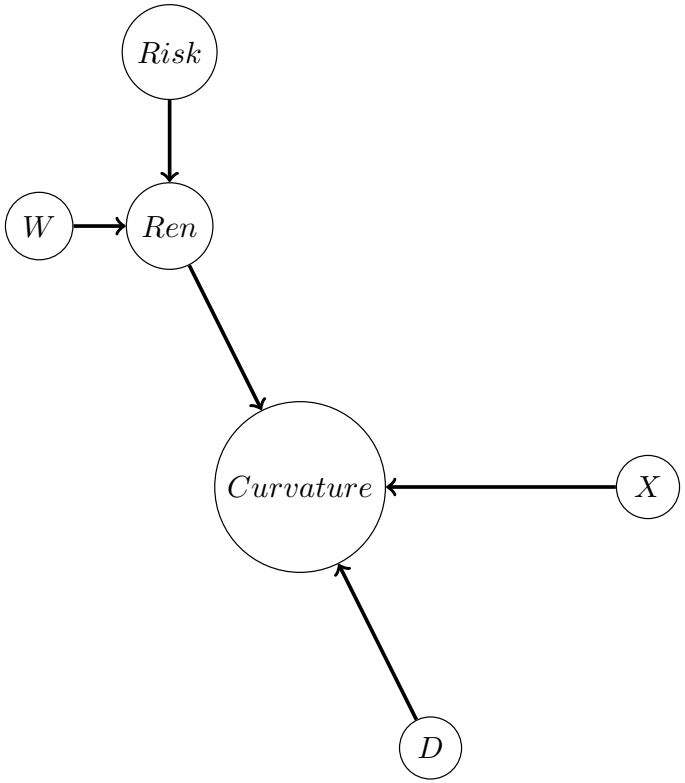
- Dynamically complete time series regression
- No support for direct price effect of renewable risk
- Main drivers of price difference are forecast errors More

Renewable withholding?



- Calculate curvature at market clearing point
- Should increase with renewable withholding, ceteris paribus

Regression analysis: Curvature



- Dynamically complete time series regression
- No support for withholding effect of renewable risk
- Main drivers of curvature are levels of predicted weather Full

Conclusions

- Do not find evidence in favor of hypothesis in Germany based on
  - Price premium
  - Shape of supply curve
- Possible explanations
  - Firms do not have access to this information
  - Output risk is not considered to be relevant information (Rational Inattention)
  - Expected benefits do not exceed costs of acquiring knowledge

Thank you

Please reach out:

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Literature

Acemoglu, D., Kakhbod, A., & Ozdaglar, A. (2017). Competition in Electricity Markets with Renewable Energy Sources. *The Energy Journal*, 38(01), 137-155.

Bessembinder, H. & Lemmon, M. L. (2002). Equilibrium Pricing and Optimal Hedging in Electricity Forward Markets. *The Journal of Finance*, 57(3), 1347–1382.

Ketterer, J. C. (2014). The impact of wind power generation on the electricity price in Germany. *Energy Economics*, 44, 270-280.

Kiesel, R. & Paraschiv, F. (2017). Econometric analysis of 15-minute intraday electricity prices. *Energy Economics*, 64, 77-90.

Fraunhofer (2019). Monitoring der Direktvermarktung. *Quartalsbericht 12/2018*.

Coefficients of main interest: price difference

windstd	-0.21 [-0.43 , 0.01]		
radiationstd	0.00 [-0.00 , 0.00]		
windstd_high		0.05 [-0.28 , 0.37]	
windstd_low		-0.42 [-0.83 , -0.01]	
radiationstd_high		0.00 [-0.00 , 0.01]	
radiationstd_low		-0.00 [-0.01 , 0.00]	
windstd_high_high			-0.01 [-0.24 , 0.22]
windstd_low_high			-0.16 [-0.37 , 0.05]
radiationstd_high_high			-0.01 [-0.30 , 0.28]
radiationstd_low_high			0.01 [-0.27 , 0.28]
windmean	-0.02 [-0.06 , 0.03]	-0.02 [-0.07 , 0.02]	-0.02 [-0.06 , 0.03]
radiationmean	-0.14 [-0.91 , 0.63]	-0.19 [-0.96 , 0.58]	-0.12 [-0.82 , 0.58]
FE_wind	-0.42 [-0.49 , -0.35]	-0.42 [-0.49 , -0.35]	-0.42 [-0.49 , -0.35]
FE_solar	-0.62 [-0.72 , -0.51]	-0.61 [-0.72 , -0.51]	-0.60 [-0.70 , -0.50]
FE_load	0.07 [0.04 , 0.10]	0.07 [0.04 , 0.10]	0.07 [0.04 , 0.10]
exploard_DE	-0.00 [-0.01 , 0.01]	0.00 [-0.01 , 0.01]	0.00 [-0.01 , 0.01]
Constant	1.03 [0.44 - 1.63]	1.10 [0.50 - 1.70]	0.83 [0.23 - 1.42]

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Coefficients of main interest: Curvature

windstd	-0.31 [-0.67 - 0.06]		
radiationstd	-0.00 [-0.01 - 0.01]		
windstd_high		-0.48 [-0.98 - 0.02]	
windstd_low		0.17 [-0.45 - 0.80]	
radiationstd_high		-0.00 [-0.02 - 0.01]	
radiationstd_low		0.00 [-0.01 - 0.02]	
windstd_high_high			-0.25 [-0.61 - 0.10]
windstd_low_high			-0.05 [-0.38 - 0.28]
radiationstd_high_high			-0.21 [-0.79 - 0.37]
radiationstd_low_high			0.23 [-0.36 - 0.82]
windmean	-0.39 [-0.46 - -0.32]	-0.39 [-0.46 - -0.32]	-0.39 [-0.46 - -0.33]
radiationmean	-0.01 [-0.01 - -0.00]	-0.01 [-0.01 - -0.00]	-0.01 [-0.01 - -0.00]
expload_DE	0.00 [0.00 - 0.00]	0.00 [0.00 - 0.00]	0.00 [0.00 - 0.00]
Constant	-3.61 [-4.62 - -2.60]	-3.58 [-4.61 - -2.55]	-3.69 [-4.69 - -2.69]

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