Wind Power Intermittency and Volatility in Electricity Markets

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Section 1: Overview

There are many environmental and economic benefits of wind power, but integrating large amounts of wind power capacity into existing power systems is not without its difficulties. Since wind turbines rely on environmental conditions to generate electricity, wind power fluctuates and cannot be perfectly forecasted. This intermittency can potentially increase both price volatility and the need for ancillary services from fossil fuel burning generators to restore market equilibrium and maintain the reliability of the power supply. Thus, some of wind power's benefits may be offset by its stochastic nature as it becomes more prevalent in existing systems.

The objective of this paper is to quantify impacts of wind power generation on price volatility to determine how well existing power systems can accommodate large scale integration of an intermittent renewable energy. This work also contributes to existing energy literature through an exploration and synthesis of the variety of price volatility metrics in previous renewable energy research. This includes an econometric analysis of the relationship between wind power and the distributional properties of power prices, specifically how wind influences the variance of real-time market prices. Primary data was compiled from the Electric Reliability Council of Texas (ERCOT), the state's central operator of electric power. The prioritization of renewable energy integration, the benefits of a nodal system on analytical precision, and the isolation of ERCOT relative to the eastern and western interconnections are advantageous qualities that make the Texas interconnection a prime focus for market analysis.

Section 2: Methods

There is a lack of uniform methodological conventions for modelling price volatility in the current literature. The present study recognizes that analyzing the distributional properties of reported prices by itself is inadequate, as price volatility also includes the nature and magnitude of price fluctuations. In fact, previous studies on the impacts of wind power on price volatility have either considered the distributional properties of observed prices (e.g., Jónsson, Pinson, and Madsen, 2010 and Shcherbakova et al., 2013) or the distributional properties of price changes (e.g., Woo et al., 2011 and Ketterer, 2014), but not both. Still others develop measures using frequencies of price spikes (Milstein and Tischler, 2015) and extreme positive or negative events (Ederer, 2015). For this reason, our paper analyzes price volatility using four distinct measures. Our metrics better characterize electricity price volatility and can be used to explain discrepancies and gaps in previous studies. The econometric analysis uses pooled cross sectional data from 2015-2017. Results in the following section highlight findings from OLS regressions, though the present study also incorporates quantile regressions into its complete methodological approach.

Because wind power has no marginal cost, it is expected to have a negative effect on prices as it displaces generation from higher cost power plants. By itself, this effect would also decrease price volatility as the average price moves down to a flatter section of the energy supply curve. Due to its intermittent nature, however, wind power's volatility could also increase electricity price volatility, threatening system reliability. In addition to wind power, the model accounts for system load, the Henry Hub natural gas price, generation from nuclear plants, and time fixed effects.

Controlling for these explanatory variables, the analysis of volatility examines variance for daily price distributions (Measure A). Wind power is also expected to influence the erratic and unpredictable nature of price changes. To account for the magnitude of intraday price movements, a second set of dependent variables (Measure B) was created by taking the first difference of all sequential prices and calculating the variance of these differences for each day. Two further measures, intraday range (IR) and realized variance (RV) are adopted from a previous study seeking to compare volatility measurements (Frommel et. al., 2014). IR is the square of the intraday range in observations, calculated using the maximum and minimum of the respective variable on a particular day. RV is the sum of squared hourly changes over a day and is very similar to Measure B. Analyses are re-run with each specification for price volatility, and results are contrasted with findings from earlier studies that use price volatility metrics that are more limited in scope.

Section 3: Results

West Load Zone Real Time Market and Volatility Analysis

	Price	Volatility - A	Volatility - B	Volatility - RV	Volatility - IR
Intercept	-13.71**	5211.82	1117.96**	-94993.61**	-20860.82
Wind	-1.71***	-177.16***	-94.07***	-2979.79***	-6400.48***
Wind volatility		86.72**	12.01	698.06**	442.05***
Load	1.09***	123.84**	34.96*	2641.39***	2074.03
Load volatility		16.30*	12.11	-41.65	85.06*
Natural gas price	2.77	91.14	-549.77	3118.81	-18981.80
Nuclear	-1.14*	116.59	-52.79	-501.88	2370793.24
Month*Year FE	YES	YES	YES	YES	YES

* $p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.001$

Section 4: Conclusions

Generally, the effects of all explanatory variables on the price are in line with expectations. According to the results in the first column, a 1 GW increase in wind power decreases the real time price for power by $1.71/MW, whereas a similar increase in load increases price by $1.09/MW. Nuclear power, which has the lowest marginal cost of dispatchable power in the interconnection, decreases the price for power. An additional 1 GW from nuclear power decreases the price by $1.14 on average. The price for natural gas has a positive effect on the electricity price, though this effect is not statistically different from zero.

Results in columns two through four report the marginal effects on price volatility when calculated using our four different volatility metrics. Results for wind power confirm our hypotheses. An increase in wind power actually decreases price volatility since wind power displaces generation from high-cost generators. And this effect is countered by wind volatility, which increases prices volatility. Importantly, the relative size of these two effects varies depending on the volatility metric used, indicating that a single metric to analyze price volatility is insufficient.

Various econometric applications in energy literature have uncovered several price volatility dynamics at play when introducing intermittent renewable energy sources. However, little attention is paid to the underlying theoretical framework. This study bases its expectations on a thorough understanding of supply and demand interaction within the electricity market. The results of the empirical analysis confirm our understanding of the energy supply curve. As expected, market prices decrease with the integration of cheap energy in the system. But increases in wind power specifically create competing effects which increase and decrease price volatility, contradicting findings from prior literature. This is a robust anomaly across a comprehensive set of volatility metrics and gives insight into the potential for wind power to become scalable across more complex energy systems

References

Ederer, N. (2015). The market value and impact of offshore wind on the electricity spot market: Evidence from Germany. *Applied Energy*, *154*, 805–814.

Frömmel, M., Han, X., & Kratochvil, S. (2014). Modeling the daily electricity price volatility with realized measures. *Energy Economics*, *44*, 492–502.

Jónsson, T., Pinson, P., & Madsen, H. (2010). On the market impact of wind energy forecasts. *Energy Economics*, *32*(2), 313–320.

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

Milstein, I., & Tishler, A. (2015). Can price volatility enhance market power? The case of renewable technologies in competitive electricity markets. *Resource and Energy Economics*, *41*, 70–90.

Shcherbakova, A., Kleit, A., Blumsack, S., Cho, J., & Lee, W. (2014). Effect of increased wind penetration on system prices in Korea's electricity markets. *Wind Energy*, *17*(10), 1469–1482.

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