PRICE VOLATILITY IN THE ELECTRICITY MARKET: A CLUSTER ANALYSIS

Kun Li, Beijing Normal University, +86-18230332003, kunli@bnu.edu.cn
Joseph D. Cursio, Illinois Institute of Technology, +1-708-205-6599, jcursio@hawk.iit.edu
Mengfei Jiang, University of Edinburgh, s1036494@sms.ed.ac.uk

Overview

Electricity supply and demand have become an important topic related to economic development and environmental sustainability. As electricity cannot be readily stored in a large amount, plus the compensation of tax credit to the new power generation such as wind, there are more and more extreme price values appeared in the electricity market, such as price spike and negative pricing. These extreme price records imply larger and more frequent inequilibria of power supply and demand, compared with other asset markets, and bring larger uncertainty and mystery in the market.

Our study investigates new methods to study the pattern of such price anomalies in the electricity market, and sheds light on how these volatile prices affect the other market conditions for the policy makers. We focus on the phenomenon of volatile prices, especially negative prices, in the electricity market and investigate its pattern, impact, and origin. We derive a cluster analysis and find out the factor that dominates the volatility of electricity price.

The optimal resource allocation in the electricity market is tightly related to the investigation of calendar anomalies. Our study uses a new method to detect the calendar effects of electricity price and their significance in the electricity market.

Our study uses the real-time pricing (RTP) data from the wholesale Pennsylvania, New Jersey and Maryland (PJM) electricity market between 2013 and 2015. It includes over 12,000 transmission lines, and their RTP records update hourly and includes 26,280 hours (24 hours×365 days×3 years) for each transmission line.

Methods

Calendar Effects Analysis: We derive a powerful test for calendar specific anomalies, and assess the significance of the full universe of possible calendar effects. We implement our test to the PJM electricity market and assess the calendar effects in different time frequencies (Day-of-the-week, Hour-of-the-day, Month-of-the-year, Day-of-the-month and season). Our results show that calendar effects exist in every time frequency, and also specify those calendar effects with statistical significance. The assessment of calendar effects will help improve the market efficiency and environmental sustainability of the electricity market.

Cluster Analysis: to compare the effects on price volatility from negative prices and peak load spike prices, we construct a Principal Component Analysis (PCA) model instead of the traditional multivariate regression. We find that PCA provides more useful outcomes by separating the peak load pricing and negative pricing effects into individual components.

Results

Our results are two-folds.

First, through a cluster analysis, we find that price spikes have larger explanatory power compared with negative prices, indicating that over-supply is more prevalent than power shortage in the current electricity market. But as a further investigation, we find that occurrences of negative price have concentrations from the prespective of time series. In the cross-sectional analysis, our results depict that negative price has become more and more prevelant in the electricity market. Second, we investigate the impact of negative price on the price volatility across individual electricity nodes. We find that the occurrence of negative price does not enlarge the fluctuation of price but lower it. Nodes with occurrence of negative price ususally have a smaller volatility than those without negative price records.

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References

Barbour, Edward, Grant Wilson, Peter Hall and Jonathan Radcliffe."Cannegative electricity prices encourage inefficient electrical energy storage devices?".*International Journal of Environmental Studies*. 2014. Vol. 71 Issue 6, 862-876.

Baradar, M., and M. R. Hesamzadeh. "Calculating negative LMPs from SOCP-OPF". *Energy Conference (ENERGYCON), 2014 IEEE International* IEEE, 2014:1461-1466.

Bessembinder, Hendrik, and Michael L. Lemmon. "Equilibrium pricing and optimal hedging in electricity forward markets."*the Journal of Finance*. 2002. 57.3. 1347-1382.

Borovkova, Svetlana, and HelyetteGeman. "Analysis and modelling of electricity futures prices." *Studies in Nonlinear Dynamics & Econometrics*, 2006, Volume 10, Issue 3.

Byström, Hans. "Extreme value theory and extremely large electricity price changes." *International Review of Economics & Finance*. 2005Vol 14. Issue 1:41–55.

Chakrabarty, Bidisha, and Tyurin, Konstantin. "Market Liquidity, Stock Characteristics and Order Cancellations: The Case of Fleeting Orders." *Financial Econometrics Modeling: Market Microstructure, Factor Models and Financial Risk Measures*. Ed. Gregoriou, Greg N. and Razvan, Pascalau. Palgrave Macmillan, 2011. 33-66.

Chelmis, Charalampos, JahanviKolte, and Viktor Prasanna. "Patterns of Electricity Demand Variation in Smart Grids." Working paper, University of Southern California Engineering Department, 2015

Egloff, Daniel, Markus Leippold, and Liuren Wu. "The term structure of variance swap rates and optimal variance swap investments." *Journal of Financial and Quantitative Analysis*, 2010. Vol. 45, 1279-1310.

Engle, Robert F, and Andrew J, Patton."What Good is a Volatility Model?"*Quantitative Finance* 2001. 1: 231-245.

Evans, Lewis, Graeme Guthrie, and Steen Videbeck. "Assessing the integration of electricity markets using principal component analysis: Network and market structure effects." *Contemporary Economic Policy*. 2008. Vol. 26, Issue 1. 145-161.

Geman, Hélyette, and Andrea Roncoroni. "Understanding the fine structure of electricity prices."*The Journal of Business*. 2006. Vol. 79 Issue 3. 1225-1261.

Genoese, Fabio, M. Genoese, and M. Wietschel. "Occurrence of negative prices on the German spot market for electricity and their influence on balancing power markets." *Energy Market (EEM), 2010 7th International Conference on the European* IEEE, 2010:1 - 6.

Hadsell, L., Marathe, A., andShawky, H. A. "Estimating the volatility of wholesale electricity spot prices in the US". *The Energy Journal*, 2004. Vol. 25 Issue 4, 23-40.

Hadsell, L., andShawky, H. A. "Electricity price volatility and the marginal cost of congestion: An empirical study of peak hours on the NYISO market, 2001-2004". *The Energy Journal*. 2006. Vol. 27 Issue 2, 157-179.

Hansen, P. R., Lunde, A., & Nason, J. M. (2005). Testing the Significance of Calendar Effects. Federal Reserve Bank of Atlanta, Working Paper Series, 2005(2).