EXTREMAL DEPENDENCE IN AUSTRALIAN ELECTRICITY MARKETS

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Overview

In recent decades, many countries have transformed the electricity power sector from monopolistic, government controlled systems into deregulated, competitive markets. Like other commodities, electricity is now traded under competitive rules, using spot and derivative contracts (Harris, 2006). Despite recent progress on energy storage techniques, electricity has to be considered as a rather non-storable good, where relatively small changes in load or generation can cause large changes in the spot price in a very short period of time. This typically leads to electricity prices being far more volatile than other commodities. Next to extreme volatility, the strong relationship between demand and price also leads to features of electricity prices such as mean reversion, seasonality and short-lasting but often extreme price spikes (Pilipovic, 1997; Kaminski, 1999; Bessembinder and Lemmon, 2002; Weron, 2006). Therefore, the risk of extreme outcomes in electricity spot markets is of significant concern to market participants.

This paper examines extremal dependence between spot electricity prices in regional markets of the Australian National Electricity Market (NEM). The market operates as an interconnected grid, comprising several regional networks, providing supply of electricity to retailers and end-users. So far only a limited number of studies have concentrated on the dependence or a multivariate analysis of different regional electricity markets. Our study is aimed to give a better understanding of the persistance of extreme price outcomes in electricity markets as well as of the relationship between extreme events across regional electricity spot markets. Hereby, we use of the extremogram (Davis and Mikosch, 2009; Davis et al., 2012) to capture this complex relationship. We provide important insights with respect to extreme spot electricity prices, the persistance of such events, spillover effects and the impact of interconnection within Australian electricity markets. We complement and extend existing work by Higgs and Worthington (2005); Worthington et al. (2005); Higgs (2009); Smith et al. (2012); Ignatieva and Trück (2015) on Australian electricity markets, by providing a deeper analysis of the actual dependence structure between extreme price observations. Our results are of great interest to electricity traders, but also for the development of risk management and hedging strategies for market participants such as large producers and retailers. Also so-called merchant interconnectors who may earn revenue by purchasing electricity in a lower priced region and selling it to a higher priced region have a strong interest in the persistant and dependence of extreme events in regional spot electricity markets.

Methods

We conduct a pioneer study on the use of the extremogram (Davis and Mikosch, 2009; Davis et al., 2012) to measure extremal dependence in Australian electricity markets. While a number of authors have examined the connection between different regional electricity markets, none of these studies has applied the extremogram to examine the persistance and dependence of extreme price outcomes in individual and interconnected markets. The extremogram provides a quantitative measure of dependence of extreme events in a stationary time series. It can be viewed as the extreme-value analog of the autocorrelation function (ACF) of a stationary process. However, while the ACF has limited value in assessing dependence between extreme events, the extremogram is specifically designed for dealing with extreme observations and only considers observations, or groups of observations, which are large. Our study concentrates on Australian electricity markets that differ from other countries and continents in a sense that the market operates as a nationally interconnected grid, providing strong linkage between the regional markets. Using half-hourly spot electricity prices from January 1, 2009 to March 31, 2015 we examine extremal dependence between wholesale electricity prices in five Australian regions: New South Wales (NSW), Queensland (QLD), South Australia (SA), Tasmania (TAS) and Victoria (VIC). These regions have also been considered in the previous literature, see e.g. Higgs and Worthington (2005); Worthington et al. (2005); Higgs (2009); Smith et al. (2012); Ignatieva and Trück (2015).

Results

With regards to univariate extremograms, we find that the regional markets in QLD and TAS have the highest persistence in extreme price outcomes. On the other hand, markets in NSW and VIC show significantly lower persistence of extreme price outcomes after the occurrence of a price spike. With regards to cross-extremograms, we find that the strongest extremal dependence is generally exhibited for regional markets that are well connected via interconnector transmission lines such as NSW and QLD (two interconnectors); NSW and VIC (one interconnector) and SA and VIC (two interconnectors). These markets seem to have a strong tendency to jointly exhibit extreme price behaviour and indicate persistance and spillover effects for extreme price observations. On the other hand, we find significantly lower extremal dependence between markets that are not directly interconnected, such as QLD and SA, NSW and QLD and SA and TAS. Interestingly, despite the existing Basslink merchant interconnector between VIC and TAS, the extremal dependence between prices in these two regional markets is also rather low.

Conclusions

We examine extremal dependence between spot electricity prices in regional Australian electricity market. The risk of extreme outcomes in electricity spot markets is of significant concern to market participants. However, so far only a limited number of studies have concentrated on the dependence between different electricity markets. We apply a relatively new econometric technique, the extremogram, to provide important insights on the nature of extreme price outcomes in spot electricity markets. In particular we examine the persistance of extreme price events, spillover effects and the impact of interconnection within Australian electricity markets. Our study helps to provide a better understanding of the persistance of extreme price outcomes in individual electricity markets as well as of the relationship between extreme events across regional electricity spot markets.

References

Bessembinder, H., Lemmon, M., 2002. Equilibrium pricing and optimal hedging in electricity forward markets. *Journal of Finance* 57, 1347-1382.

Bollino, C., Polinori, P., 2008. Contagion in electricity markets: does it exist? Working Paper.

Davis, R. A., Mikosch, T., 2009. The extremogram: A correlogram for extreme events. Bernoulli 15, 977-1009.

Davis, R. A., Mikosch, T., Cribben, I., 2012. Towards estimating extremal serial dependence via the bootstrapped extremogram. *Journal of Econometrics* 170, 1, 142-153.

De Vany, A., Walls, W., 1999. Cointegration analysis of spot electricity prices: insights on transmission efficiency in the Western US. *Energy Economics* 21(5).

Füss, R., Mahringer, S., Prokopczuk, M., 2015. Electricity Spot and Derivatives Pricing when Markets are Interconnected. *Working Papers on Finance* 1323, University of St. Gallen, School of Finance.

Higgs, H., 2009. Modelling price and volatility inter-relationships in the australian wholesale spot electricity markets. *Energy Economics* 31(5), 748-756.

Higgs, H., Worthington, A., 2005. Systematic features of high-frequency volatility in the Australian electricity market: intraday patterns, information arrival and calendar effects. *The Energy Journal* 26(40, 1-20.

Higgs, H., Worthington, A., 2008. Stochastic price modelling of high volatility, mean-reverting, spike-prone commodities: The Australian wholesale spot electricity market. *Energy Economics* 30, 3172-3185.

Ignatieva, K., Trück, S., 2015. Modeling spot price dependence in australian electricity markets with applications to risk management. *Computers and Operations Research* forthcoming.

Le Pen, Y., Sevi, B., 2010. Volatility transmission and volatility impulse response functions in European electricity forward markets. *Energy Economics* 32(4).

Micola, R., Bunn, D., 2007. Two markets and a weak link. *Energy Economics* 29(1).

Park, H., Mjelde, J., Bessler, D., 2006. Price dynamics among U.S. markets. *Energy Economics* 28(1).

Pilipovic, D., 1997. Energy Risk: Valuing and Managing Energy Derivatives. McGraw-Hill.

Smith, M. S., Gan, Q., Kohn, R. J., 04 2012. Modelling dependence using skew t copulas: Bayesian inference and applications. *Journal of Applied Econometrics* 27 (3), 500-522.

Weron, R., 2006. Modeling and Forecasting Loads and Prices in Deregulated Electricity Markets. Wiley, Chichester.

Worthington, A., Kay-Spratley, A., Higgs, H., 2005. Transmission of prices and price volatility in Australian electricity spot markets: A multivariate garch analysis. *Energy Economics* 27(2), 337-350.

Zachmann, G., 2008. Electricity wholesale market prices in Europe: Convergence? *Energy Economics* 30(4).