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Bidding structure, market efficiency and persistence in a multi-time tariff setting☆

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ABSTRACT

The purpose of this study is to examine the fractal dynamics of day ahead electricity prices by using parametric and semi parametric approaches for each time zone in a multi-time tariff setting in the framework of bidding strategies, market efficiency and persistence of exogenous shocks. We find that that electricity prices have long term correlation structure for the first and third time zones indicating that market participants bid hyperbolically and not at their marginal costs, market is not weak form efficient at these hours and exogenous shocks to change the mean level of prices will have permanent effect and be effective. On the other hand, for the second time zone we find that price series does not exhibit long term memory. This finding suggests the weak form efficiency of the market in these hours and that market participants bid at their marginal costs. Furthermore this indicates that exogenous shocks will have temporary effect on electricity prices in these hours. These findings constitute an important foundation for policy makers and market participants to develop appropriate electricity price forecasting tools, market monitoring indexes and to conduct ex-ante impact assessment.

1. Introduction

In recent years most electricity markets have been restructured and in this setting, energy-based financial products and electricity price analysis become substantially important for both policy makers and market participants. After the famous California blackout in 2000, a significant increase in the number of studies on price forecasting was observed. Preliminary studies focused on the basic characteristics of electricity differed from those of financial assets, namely; non-storability, seasonality and inelasticity of supply/demand (Geman and Roncoroni, 2006; Lucia and Schwartz, 2002; Sensfuss et al., 2008; Simonsen et al., 2004; Zachmann, 2008). Following studies focus on spikes, causing asymmetry in the underlying distribution; nonstationarity and mean reversion (Haugom et al., 2011; Janczura et al., 2013; Knittel and Roberts, 2005; Simonsen, 2003; Weron and Przybylowicz, 2000).

Considering security of supply, another crucial feature of electricity is the intraday volatility arising from demand fluctuations during the course of the day. Regulatory authorities usually oblige the system operators to adopt multi-time tariff mechanisms in order to manage peak-time volatility. In these tariff settings, different rates are applied for the consumption at defined time zones during the day. The bills of the subscribers under this setting are arranged by considering their consumptions at the defined time zones and the rates for these time zones with the aim of shifting the load from peak time to off-peak time and thereby enable the end user to manage his energy costs and allow generators to operate efficiently. This situation results in different incentives on generators side. Generators, with the ability of flexible offering, tend to adopt different bidding strategies at super peak, peak and off-peak times.

Studies on analysing dynamics of day ahead prices ignore the different characteristics of time zones in multi-time tariff settings and consider the daily average prices.[1] However daily average prices do not capture the microstructure of the day ahead market since level of

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[1] For a comprehensive overview, see Huisman et al. (2007), Eydeland and Wolyniec (2003) and Bunn and Karakatsani (2003).

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mean reversion and volatility structure are not constant throughout the day (Huisman et al., 2007). Other studies consider hourly prices as a stack and ignore the fact that day ahead electricity prices are determined a day before the trading day for all 24 hours, that is traders cannot update their information set hourly. Under this setting, information set is not constant throughout the day and updates over the days. Applying a classic time series approach to hourly day ahead prices can be misleading from a statistical point of view. Huisman et al. (2007) model each hour as a separate time series through a panel data methodology and find the mean reversion of day ahead prices is significantly lower over the super-peak hours (18:-22:00). Thus prices are less predictable in these hours. Moreover they show there exists clear blocks of cross-sectional correlation between specific hours. The first block appears in 24:00 – 06:00, second block shows up through 6:00 to 19:00 and also there is very high correlation between specific two adjacent hours (between hours 20 and 21; between hours 15 and 16). These findings reveal the different dynamics in hourly prices but similar characteristics in each time zone.

There are also emerging studies of applied mathematics in the field of electricity pricing and market modelling, especially, by the use of game theory, stochastic differential equations and mathematics supported data mining (Vasin, 2014; Vasin et al., 2013). However the literature on electricity price analysis focuses mostly on the features of autocorrelation, stochasticity and nonlinearity. Only a small number of studies analyse the presence and quantification of fractality (long term correlation structure) and very few of them relate these findings to basic financial concepts; namely multi-time tariff mechanism, market efficiency, bidding structure or policy development.

Accurate measurement of fractality is crucial for correct statistical inference and forecast uncertainty (Lildholdt, 2000). There are three reasons stimulating this fact. First, ignoring the long memory property in a series can lead to confidence intervals for a process mean that are too optimistic by orders of magnitude. Second, there are many important economic time series exhibiting long term correlation structure (Beran, 1994). Moreover the potential for spurious regressions of stationary variables depend on the level of fractal noise (Tsay and Chung, 2000).

Economic intuition of the presence of long memory structure in electricity prices is important on several fronts. First, if electricity prices are nonstationary in levels, shocks to electricity prices will have only transitory effects. On the other hand, if electricity prices are stationary, shocks to electricity prices will have permanent effects. The nature of a shock has implications for transmission of that shock from electricity prices to other sectors of the economy. If shocks to electricity prices are permanent, then the probability of transmission of such a shock to other sectors of the economy, where energy prices have a substantial impact on expenditures, would be higher than the probability of transmission of a transitory shock.

Secondly, the presence of fractal noise in electricity prices can be used to capture the bidding strategies of market participants. In restructured electricity markets, the probability of setting the price each hour is not the same for all market participants, mostly because they have different marginal costs. Each hour, the market clearing price is determined by just one generator, called the marginal generator, whose bid is at the intersection of the supply and demand curves. Generators whose bids are higher in the merit order curve are called inframarginal generators. Each generator knows only the past market prices and their own bids. In this setting, the inframarginal generators' strategy is to not bid higher than the marginal generator's bid (Sapio, 2004).Thus, they observe and analyse past prices and offer their current bids according to past information. For off-peak hours, if marginal generators bid at their marginal costs, then there is no fractal noise. This observation allows for testing of firms' bidding behaviour based on marginal cost structures. For peak hours, if there exists a long-term correlation in prices, we can suggest that marginal generators use the prices of the day and week before, which means applying hyperbolic bidding rules. Moreover this observation is contrary to Fama's (1970) weak-form efficient market hypothesis (WEMH), which assumes the absence of long-term correlation between price increments for any time scale. If markets are weak-form efficient, then market participants cannot earn excess profits in the presence of trading rules based on past prices or returns (Eoma et al., 2008; Farmer et al., 2006; Mun et al., 2008). Such a WEMH can be tested using historical data through short- and long-range correlations (Couillard and Davison, 2005; Lillo and Farmer, 2004).

Thirdly; considering the persistence of a series, the presence and degree of long term correlation structure have policy implications.[2] Persistence is a measure of the speed at which a series returns to its mean level after a shock. In the context of this paper, a shock can be a new policy design/regulation or the introduction of an innovation to the market. In this sense, when the degree of persistence is small, a shock tends to have more temporary effects. In the case of electricity prices, deviating from the mean level of the price is not easy. It is more costly and difficult to permanently affect electricity prices when persistence is low. On the other hand, if the degree of persistence is high, a shock tends to have a more long-lasting effect. Thus, the degree of persistence of electricity prices makes a difference in the effectiveness of energy policies/regulations. Therefore results of this study can be an input for regulatory bodies and policy makers to make evidence-based ex-ante policy impact analysis which has recently been a popular approach used by UNDP, EU, OECD and World Bank.[3]

In this paper, our aim is to investigate fractal phenomena in level electricity prices for each time zone separately. We focus on the essential statistical properties of fractal noise and identify appropriate instruments for measuring fractality in day ahead electricity prices. Our paper contributes to the literature firstly by comprehensively discussing the theoretical characteristics of a fractal pattern and demonstrating the crucial steps of a fractal analysis approach adapted to capture the dynamics of electricity prices. We employ both parametric and semiparametric methods to benefit from their different statistical properties. Secondly, prior studies have focused on hourly price differences or daily average price differences rather than on level prices. This first differencing approach is a natural fit for most financial assets because of their nonstationary dynamics. However, this property may not exist for electricity prices depending on the maturity of the market, the time interval, the technology mix and other contaminating factors. For instance; markets with low diversity of generation, low maturity or non-reservoir hydro dependence may experience many spikes which can affect the evaluation of the long memory differencing parameter based on returns. As stated by Uritskaya and Uritsky (2015) using level prices is more consistent with the original formulation of the parametric long memory estimation methods, like DFA. Thus, studies on long memory for level prices can provide useful information to improve existing models and to assess limitations on prediction. Lastly, previous studies have investigated either daily average or hourly prices. However, Alvarez-Ramirez and Escarela-Perez (2010) and Erzgraber et al. (2008) show that fractal properties of electricity price vary over time. Accordingly we introduce a new time unit based on time zones in a multi-time tariff mechanism considering the fact that electricity market participants have different incentives, risk management and forecasting

[2] For details, see Chen and Lee, 2007; Gil-Alana et al., 2010; Peraire and Belbuta, 2012; Apergis and Tsoumas, 2012.

[3] For details, see http://ec.europa.eu/dgs/energy_transport/evaluation/activites/doc/reports/energie/intelligent_energy_ex_ante_en.pdf
https://ec.europa.eu/energy/intelligent/files/doc/2011_iee2_programme_ex_ante_en.pdf
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