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Anti-correlation and multifractal features of Spain electricity spot market

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Abstract

We use multifractal detrended fluctuation analysis (MF-DFA) to numerically investigate correlation, persistence, multifractal properties and scaling behavior of the hourly spot prices for the Spain electricity exchange-Compania O Peradora del Mercado de Electricidad (OMEL). Through multifractal analysis, fluctuations behavior, the scaling exponents and generalized Hurst exponents are studied. Moreover, contribution of fat-tailed probability distributions and nonlinear temporal correlations to multifractality is studied.

1. Introduction

In recent years, there have been widespread moves to deregulate, liberalize and privatize electricity power industries (EPI) across the world: vertically integrated utilities have been legally or functionally unbundled. The electricity market deregulation trend is now in full swing worldwide: in all markets, deregulation is seen as the way to increase the efficiency of already installed generation assets and hence to reduce prices for end-users. As a result, the EPI is moving from a national monopoly structure to a more competitive one. Competition has been introduced both in the wholesale generation and retailing of electricity. These changes opened up for competition on the price of electric energy. The opening of markets has exposed energy producers and consumers to new forms of market and price risks thus calling for models that are able to capture the dynamics in electricity prices. In fact, parallel to deregulation in electricity markets, in the academic literature there has been a growing interest in modeling electricity prices during the last decade. The evidence of non-storability, seasonality at different levels, volatility and price spikes in the electricity market makes it an important challenge for researchers. As we know, electricity resulting from the degradation of different forms of energy cannot be stored economically once generated. Additionally, electricity cannot be

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transported from one region (country) to another one, because of existing bottlenecks, or limited transportation capacity. This implies that prices are dependent on a local demand and supply. As demand for energy is highly influenced by (cyclical) exogenous factors such as e.g. the weather, energy prices tend to fluctuate cyclically. Moreover, electricity prices have a high volatility which is variable over time [1]. In addition, volatility tends to increase with prices, a phenomenon known under the name of *volatility clustering*. Consequently, electricity prices experience higher volatility during peak hours (period of the day displaying the highest energy consumption and energy prices) than in off-peak hours. Moreover, electricity prices are spiky, resulting from generation or transmission outages, or from sudden and unanticipated changes in the demand [2]. Therefore, modeling electricity prices is particularly challenging and has inspired a variety of different lines of models. So far, there does not seem to be much consensus on which line of modeling to prefer as they tend to focus on different aspects of electricity prices. Recently, the statistical properties of electricity prices have been investigated by some methods in chaos theory, multifractal analysis, long memory analysis and other stochastic methods for managing electricity price risk, valuing electricity derivatives and predicting future prices [3–7]. The multifractal detrended fluctuation analysis (MF-DFA) method allows us to determine the multifractal characterization of non-stationary and stationary time series. Applying the concept of MF-DFA to electricity spot prices can be used to gain deeper insight into the processes occurring its non-stationary dynamic market system. In fact, the main characteristics of financial time series like as fat-tailness of probability distributions and volatility clustering have been factored into risk management instruments, such as hedging contracts. Ignoring theseproperties can make pricing of derivative contracts unreliable, and at best difficult to parametrize. Multifractal data exhibit fat-tailed probability distributions and clustered volatility, so, all of these properties can be described using the techniques of multifractal analysis. In this paper, we would like to characterize the complex behavior of Spain's electricity market prices through the computation of the time series scaling exponents which quantify its correlation exponents and multifractality. New mathematical methods based on multifractals can more robustly model derivative prices, by properly characterizing volatility. Multifractal models can correctly reproduce and characterize the statistical properties of systems such as financial markets. Multifractal methods provide powerful tools for analyzing very volatile series like electricity prices.

The paper is organized as follows. The data used to investigate the multifractal nature of price fluctuations in the Spanish electricity market are described in Section 2. In Section 3 we briefly describe the MF-DFA method. Sources of multifractality in the electricity prices are studied in Section 4 by comparing the MF-DFA results for the original data set to those obtained for shuffled and phase randomized (surrogate) time series. Section 5 concludes with a discussion of the main findings and offers directions for further research.

2. Data analysis

To gain a more profound insight in the structure of electricity spot prices, time series data from the Spanish electricity market OMEL are analyzed. This time series contains spot prices of electricity for every hour since January 1st, 1998, 0:00 until May 31st, 2006, 24:00. The database therefore consists of 73 008 hourly prices and 73 007 hourly increments. The data are available online at http://www.omel.es. The analysis is mainly based on hourly logarithmic increments of OMEL prices (that is, $\ln P(t)/\ln P(t+1)$). In Fig. 1 time series corresponding to hourly prices of OMEL along with its increments over the above-mentioned period are presented. The prices are measured in euros per megawatt hour (Cent/kWh) on the horizontal axis.

Also, Table 1 provides summary statistics of logarithmic increments of exchange rates. According to data in Table 1, the increments are skewed to right side. The probability distribution function of increments also shows a high degree of peakedness and rather fat tails compared to a normal distribution, indicating a clear departure from Gaussian normality. The departure from a Gaussian cumulative distribution function (CDF) can be clearly seen in Fig. 2, where the PDF and CDF of increments against a Gaussian PDF and CDF are depicted, respectively.

Moreover, it can be checked that OMEL increments are non-stationary. We can see the non-stationary property experimentally by calculating the stability of the standard deviation in a moving window, for example, with scale s. Fig. 3 indicates that the standard deviation of OMEL increments versus scale s is not saturate. In a non-stationary situation, a spurious of correlations may be detected, so direct calculation of