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Forecasting electricity spot market prices with a *k*-factor GIGARCH process

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ABSTRACT

In this article, we investigate conditional mean and conditional variance forecasts using a dynamic model following a *k*-factor GIGARCH process. Particularly, we provide the analytical expression of the conditional variance of the prediction error. We apply this method to the German electricity price market for the period August 15, 2000–December 31, 2002 and we test spot prices forecasts until one-month ahead forecast. The forecasting performance of the model is compared with a SARIMA–GARCH benchmark model using the year 2003 as the out-of-sample. The proposed model outperforms clearly the benchmark model. We conclude that the *k*-factor GIGARCH process is a suitable tool to forecast spot prices, using the classical RMSE criteria.

1. Introduction

In finance, commodity price forecasting is a crucial issue, in particular for electricity. Indeed, price forecasts can help evaluating bilateral contracts. For such a commodity, price forecasts can be based on a spot price analysis. Since electricity spot prices have a behavior which presents specific features, the price forecasts problem can be complex. In another hand, electricity price volatility has a marked variability in time. We observe both high and low periods of price reaction. Recently spot price volatility has been studied and modelled using a volatility model depending on time. Using such a model, Benini et al. [1] investigate several markets. In addition, electricity spot prices exhibit long memory behavior combined with a periodic behavior. Recent works have taken into account these last features using related ARFIMA models, see Koopman et al. [13] or Diongue et al. [6] or Diongue and Guégan [7].

After modelling these electricity prices, the forecasting problem arises. In the literature, two approaches have been considered: parametric models using AR, ARX, AR–GARCH, ARX–GARCH and Regime switching models, Misiorek et al. [14]; and non-parametric methods like the neuronal nets for instance, Ramsay and Wang [15] and Conejo et al. [3].

In this paper, in order to provide robust forecasts for spot electricity prices, we propose a new approach based on the *k*-factor GIGARCH process [10], which allows taking into account a lot of stylized facts observed on the electricity spot prices, in particular stochastic volatility, long memory and periodic behaviors. The investigation of this model is done in [11]. Diongue and Guégan [5] introduced the parameter estimation of the *k*-factor GIGARCH process. Here, we provide new developments which concern the expression of the forecasts using the *k*-factor GIGARCH process and we give their properties. We apply these results on the German electricity prices market providing forecasting prices up until a one-month ahead. These results are totally new in the sense that, in most published papers, the previsions concern mostly the one-day ahead horizon and here we are interested by long term prediction. For comparison purpose, we compare our approach with a benchmark model in terms of forecasting, using the RMSE criteria.

This paper is organized as follows. The next section presents the data and contains the main empirical findings. In Section 3, we specify some notations, define the *k*-factor GIGARCH process along with new theoretical results on forecasting in mean and in variance. In Section 4, we provide forecasts for the German spot prices data set. The last section is dedicated to conclusions.

2. The data set

We consider the hourly series of the EEX spot prices, denoted $(S_t)_{t=1,\dots,N}$, from August 15, 2000 to December 31, 2003, which yields $N = 29{,}616$ hourly observations. For this electricity spot

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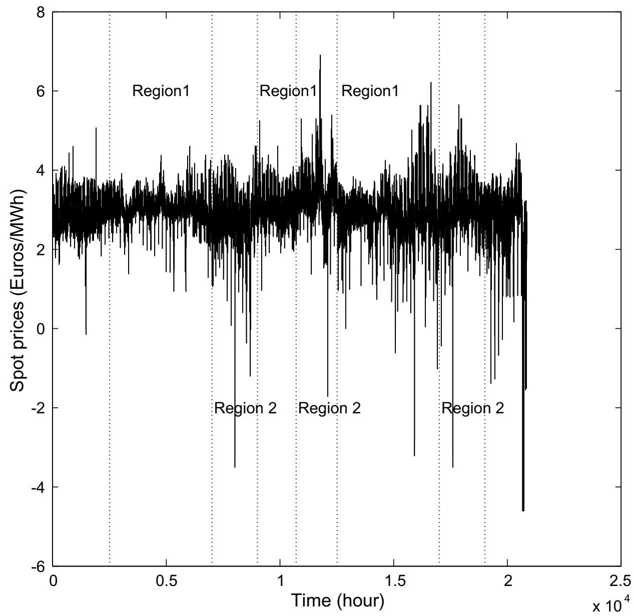

Fig. 1. Evolution of the EEX spot market prices in its logarithmic scale from 15/08/2000 to 31/12/2002.

market, the prices are fixed each day, for each of the 24 h of the next day. This spot market has two particular interests. On the one hand, it allows a buyer (seller) to supply their bid (load) on an hourly basis (physical market) and on the other hand, the spot market could correspond to the price reference for the contracts. In order to make the series $(S_t)_{t=1,\ldots,N}$ stationary, we take its logarithmic form and define $(X_t)_t$ such that, $\forall t = 1,\ldots,N$, $X_t = \log(S_t)$. We build two subsets from the original series. The first one, from August 15, 2000 to December 31, 2002 (Fig. 1) and containing $T = 20{,}856$ observations, is used for the parameter estimation procedure and the second one, from January 1, 2003 to December 31, 2003, is used for validation. In Fig. 1, we observe that there are periods of low volatility (Fig. 1, Regions 1) following by periods

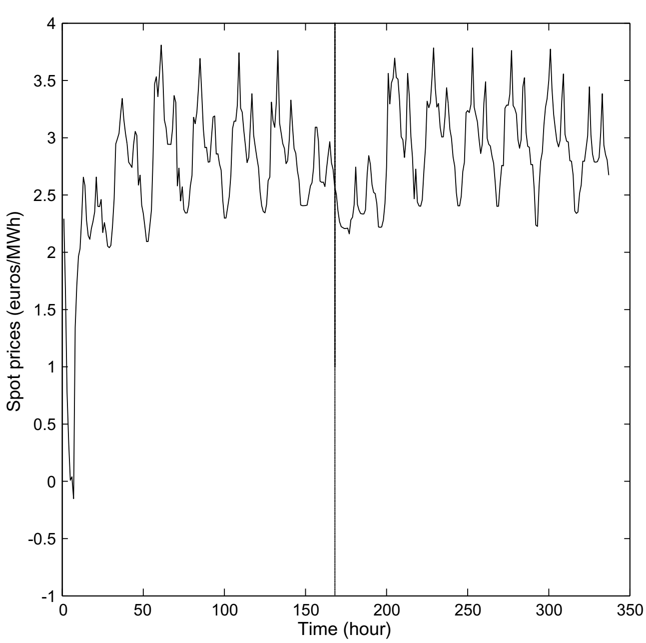

Fig. 2. Two weeks zoom concerning the evolution of the EEX spot market prices in its logarithmic scale from october 14, 2000 to october 27, 2000.

Table 1
Statistics of daily log returns of the S&P 500 stock market index

Number of observations	20,856	Skewness	−2.6
Mean	2.97	Kurtosis	29.67
Standard deviation	0.6241	Jarque-Bera test	7.3098×10^5
Minimum	−4.6052	$Q(24)$	8.4597×10^4
Maximum	6.5387	$Q^2(24)$	3.7156×10^4

The Jarque-Bera test critical value at significance level of 5% is 5.85423. Q and Q^2 are the Box–Pierce statistics for the levels and square of the log electricity spot prices, respectively, using 24 lags. The critical value at level 5% is 36.4150.

of high volatility (Fig. 1, Regions 2). Fig. 2 provides a zoom on the evolution of the spot prices, in its logarithmic scale, from October 14, 2000 to October 27, 2000 (two weeks). We observe that the series exhibit two kinds of seasonality: daily and weekly seasonalities.

Table 1 gives the summary statistics of the log electricity spot prices. The mean and the standard deviation are quite small, while the estimated measure of skewness, −2.6, is significantly negative, indicating that the log electricity spot prices has non-symmetric distribution. Furthermore, the large value of the kurtosis statistic, 29.67, suggests that the underlying data are leptokurtic, or fat-tailed and sharply peaked around the mean when compared with the standard normal distribution (Fig. 3). The results of the non-normality test agree with previous literature concerning this kind of behavior for these log electricity spot prices data, Misiorek et al. (2006). The Box–Pierce Q-tests of up to 24th order serial correlation for the levels and squares of the mean-corrected log electricity spot prices ($Q(24)$ and $Q^2(24)$) are both significant. In summary, the diagnostics suggest that a GARCH-class model would be appropriate to explain the evolution of the log electricity spot prices, along with an error distribution that allows for greater kurtosis than the Gaussian distribution.

The autocorrelation function of the EEX spot prices (Fig. 4) exhibits a slow decay pattern at two seasonality lags corresponding to daily and weekly seasonalities. The autocorrelation function does not converge exponentially to zero in covariance sense, ([12], for discussions on this concept), thus we assume that the series has a long-range dependence behavior. Moreover, the spectral density represented by the periodogram (Fig. 5), is unbounded at three frequencies corresponding respectively, to the daily, weekly and half daily seasonalities.

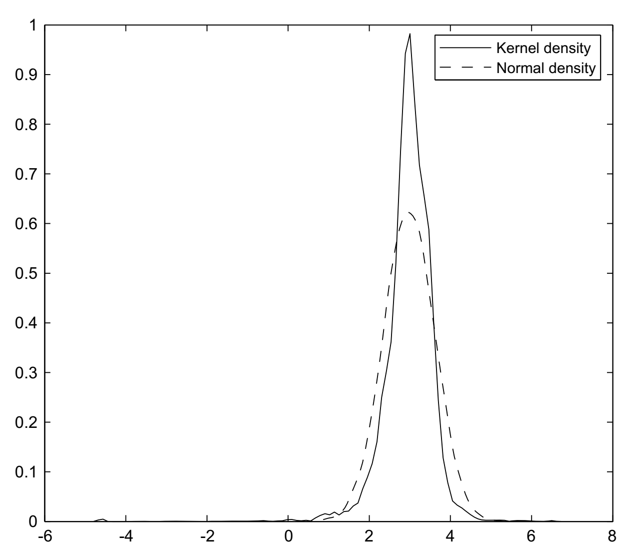

Fig. 3. Non-parametric density of the log electricity spot prices (solid line) and probability density function of the normal distribution (dotted line).