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Stable distribution and long-range correlation of Brent crude oil market

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HIGHLIGHTS

- The stable distribution of Brent crude oil returns is derived.
- Long-range correlation of the Brent crude oil market is verified.
- After the financial crisis 2008, the Brent crude oil market becomes more persistence.

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ABSTRACT

An empirical study of stable distribution and long-range correlation in Brent crude oil market was presented. First, it is found that the empirical distribution of Brent crude oil returns can be fitted well by a stable distribution, which is significantly different from a normal distribution. Second, the detrended fluctuation analysis for the Brent crude oil returns shows that there are long-range correlation in returns. It implies that there are patterns or trends in returns that persist over time. Third, the detrended fluctuation analysis for the Brent crude oil returns shows that after the financial crisis 2008, the Brent crude oil market becomes more persistence. It implies that the financial crisis 2008 could increase the frequency and strength of the interdependence and correlations between the financial time series. All of these findings may be used to improve the current fractal theories.

1. Introduction

As one of the fundamental energy source and important chemical raw materials, crude oil is crucially important to any country and is considered as the blood of industry. Meanwhile, as one of unique strategic resources, crude oil will have potential impacts on economic fields and many financial markets. Therefore, investigating the dynamics of crude oil market seems to be crucial and necessary.

Alvarez-Ramirez, Cisneros and Soriano analyzed the international crude oil market using multifractal analysis. They found that the crude oil market is a persistent process with long-range memory using the Rescaled Range analysis [1]. Serletis and Andreadis studied the random fractal structure in North American energy markets and they provide evidence for a random multifractal turbulent structure for WTI crude oil prices. However, Henry Hub natural gas pieces are only consistent with a random fractal model [2]. Serletis and Rosenberg studied the Hurst exponent in energy future prices and found that the energy future returns of the New York Mercantile Exchange display long-range memory and the form of long-range memory is anti-persistence [3]. Tabak and Cajueiro analyzed the efficiency of crude oil markets (Brent and West Texas Intermediate) using Rescaled Range Hurst analysis and found evidence that crude oil prices possessed long-range dependence;

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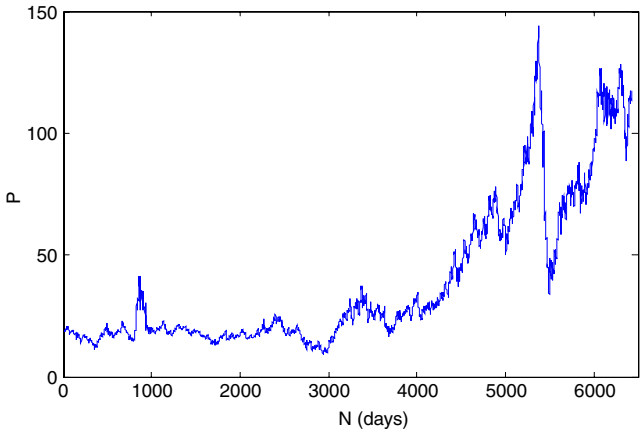

Fig. 1. Daily brent crude oil prices.

however, the degree of long-range had decreased over time [4]. Alvarez-Ramirez, Alvarez and Rodriguez analyzed the auto-correlation of international crude oil prices on the basis of the estimation of Hurst exponent dynamics for returns. The results found that the market exhibited a time-varying short-term inefficient behavior [5]. Alvarez-Ramirez, Alvarez and Solis also further studied the efficiency of crude oil markets by using lagged detrended fluctuation analysis. The results showed that the crude oil market presented important deviations from efficiency [6]. In addition, Wang and Liu tested for the efficiency of WTI crude oil market through observing the dynamic of local Hurst exponents using the method of rolling window based on multiscale detrended fluctuation analysis. They found that the small fluctuations of WTI crude oil market were persistent. However, the large fluctuations had high instability [7]. Gu, Chen and Wang studied the multifractal nature of international crude oil markets based on multifractal detrended fluctuation analysis and found that two crude oil markets become more and more efficient for long-term and two Gulf Wars cannot change time scale behavior of crude oil return series [8]. Wang and Wei studied the auto-correlations in return series of WTI crude oil spot and futures markets using DFA. And they also studied the cross-correlations between these two markets using DCCA [9].

The main objective of this article is to investigate the characteristics of Brent crude oil market. Our study extends the previous work in several respects. First, the distribution of Brent crude oil returns is performed. It is found that the empirical distribution of Brent crude oil returns cannot be fitted by a Gaussian distribution; however, it can be fitted well by a stable distribution. Second, using detrended fluctuation analysis, the long-range correlation of the Brent crude oil returns is studied. It is found that the exponent of DFA is greater than 0.5, indicating that there is long-range correlation for Brent crude oil returns. In addition, we also find that the Bent crude oil market become more persistent after the financial crisis 2008. The paper is organized as follows: in Section 2, we describe the data. In Section 3, the distribution of Brent crude oil returns is presented. In Section 4, the long-range correlation of Brent crude oil market is performed using DFA. In Section 5, a brief conclusion is given.

2. Data

The original data are taken from the daily closing prices of Europe Brent Spot Price FOB (USA dollars per Barrel) (hereinafter abbreviated to Brent), dating from May, 20th, 1987 to September, 18th, 2012, which contain 6429 observations. The graphical representation of daily closing spot prices of Brent over time for the whole sample periods is illustrated as Fig. 1. The data which is analyzed are the logarithmic Brent returns: let P_t denote the price of crude oil on day t. The daily price return, r_t, is calculated as its logarithmic difference, $r_t = \log(P_t) - \log(P_{t-1})$.

From the above time series, some standard statistical parameters were evaluated. The specific statistics of logarithmic Brent crude oil returns are shown in Table 1. From Table 1, a negative skew is seen. Therefore, it indicates that a normal distribution was not suitable for the description of Brent crude oil returns as the coefficient of kurtosis was larger than 3 and the coefficient of skewness is less than zero.

3. Distribution of returns

Paul Levy proposed a general method with the Gaussian as only a special case, to identify probability distributions which their sum has the same probability distribution. A stable Levy distribution as the standard answer is represented by Ref. [10]

$$L_\alpha(N, \Delta t) \equiv \frac{1}{\pi}\int_0^\infty \exp(-\gamma \Delta t q^\alpha)\cos(qN)\mathrm{d}q \tag{1}$$

where α is the characteristic exponent $0 < \alpha \leq 2$, N is the return, γ is the scale factor, and Δt is the time interval.