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Multifractal characterization of energy stocks in China: A multifractal detrended fluctuation analysis

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HIGHLIGHTS

- Energy stock returns and volatilities are multifractal.
- Crude oil market activity contributes to multifractality in Chinese energy stock index.
- Fat-tail distribution is the most important source of multifractality.

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ABSTRACT

In this paper, we investigate the impacts of oil price changes on energy stocks in Chinese stock market from the multifractal perspective. The well-known multifractal detrended fluctuation analysis (MF-DFA) is applied to detect the multifractality. We find that both returns and volatilities of energy industry index display apparent multifractal behavior. Oil market activity is an important source of multifractality in energy stocks index in addition to long-range correlations and fat-tail distributions.

1. Introduction

As well known, many empirical results show that financial time series display multifractal behaviors and mainly attribute the multifractality to different long-range temporal correlations for small and large fluctuations or the fat-tailed probability distributions of variations. For example, Bolgorian and Raei found that trading behavior of individual and institutional traders in the Tehran Stock Exchange(TSE) displayed multifractal behavior. The multifractality for investors in TSE was mainly due to long-range temporal correlations for small and large fluctuations while for S&P 500, the fat-tailed probability distributions of variations were the main source of multifractality [1]. Zhou found that long-range correlation, fat-tailed probability distributions and nonlinear structure all influence on the multifractality of Dow Jones Industrial Average series [2]. Cao et al. showed that the main source of asymmetric scaling behavior in the Shanghai stock market are long-range correlations, whereas that in the Shenzhen stock market is fat-tailed distributions [3]. However, few existing research considered the impacts of oil market activity on the multifractality of stock market. In fact, crude oil is one of the most important commodities in global financial markets [4]. It is considered as the life support of many economies and may serve as the underlying asset in the trading of various financial instruments. Casual evidence suggests that stock markets are sensitive to oil price changes [5]. For instance, the Financial Times on August 21, 2006 reported that US stock prices declined due to an

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increase in crude oil prices caused by geopolitical risk in the Middle East (including the Iranian nuclear program and terrorist attacks by Islamic militants). The same newspaper on October 12, 2006 attributed the strong rally in global equity markets to a slide in crude oil prices. Until the oil bust of late 2008 followed by the subprime lending crisis, financial press in the US and Western Europe routinely attributed stock price changes on a given day to oil price movements. While a large number of studies in finance literature have focused on the effects of oil changes on stock returns in different economies. For example, Jones and Kaul for the US, Canada, Japan, and the UK [6]; Faff and Brailsford for Australia [7]; Basher and Sadorsky for emerging economies for 15 countries in the Asia-Pacific regions [8]; Park and Ratti for the US and 13 European countries [9]; and Driesprong, Jacobsen, and Maat for 18 developed countries and 30 emerging economies [10]. In recent years, some studies have analyzed the cross-correlations between crude oil market and stock market from multifractal perspective. For example, Wang and Xie investigated cross-correlations between the crude oil market and US stock market [11], and they found that the cross-correlated behavior between WTI crude oil market and US stock market was nonlinear and multifractal. Similarly, Ma et al. investigated the cross-correlations between the crude oil market and the six Gulf Cooperation Council (GCC) stock markets [12]. They found linear regression models cannot be used to describe the dynamics of cross-correlations between the crude oil and the six GCC stock markets. In this paper, we consider crude oil price changes is a source of multifractality and try to investigate the impacts of oil price changes on energy stocks in Chinese stock market from multifractal perspective. This is a new idea in the study, which contributes to intensively understanding of sources of multifractality of finance time series. We focus on the multifractality of the performance of energy stocks in Chinese stock market.

Many existing literatures research the multifractality of performance of stock market using the data of stock index [2,13–18]. For example Wang et al. analyzed the efficiency for Shenzhen stock market using the daily closing price of Shenzhen Component Index [13]. Suárez-García and Gómez-Ullate used the data of price ticks of the index Ibex35 of the Madrid Stock Exchange to analyze multifractality of finance time series [14]. Wei et al. compared the direct and cross hedging effectiveness of the copulaMFV model using high-frequency intra day quotes of the spot Shanghai Stock Exchange Composite Index (SSEC), spot China Securities Index 300 (CSI 300), and CSI 300 index futures [15]. Therefore, in our research, to analyze the effects of oil price changes on Chinese energy stock market, we study the dynamics of the energy sub-industry index (ESI) returns in China A share market from multifractal perspective. Moreover, (Multi-)fractals have been a 'stylized fact' in financial markets [19–25] and crude oil market [12,26–28]. Kantelhardt et al. [29] proposed a multifractal detrended fluctuation analysis(MF-DFA) which can be used to investigate the multifractality in nonstationary time series. Thus, in this paper, we try to employ MF-DFA method to investigate the multifractality of the energy sub-industry index (ESI) returns in China A share market.

The remainder of this paper is organized as follows. Section 2 describes the data of WTI crude oil price and energy stocks index in Chinese stock market. Section 3 mainly focuses upon the description of MF-DFA method. Section 4 provides the empirical results and Section 5 is the conclusions.

2. Data

We choose the daily closing prices of the CSI energy sub-industry index(ESI) from 4 January 2005 to 15 June 2015 to analyze energy stocks. CSI energy sub-industry index(ESI) aims to reflect the price fluctuation and performance of energy shares in China A share market. Based on CSRC or CSI Industry Classification Standard, energy and so on are classified as energy sub-industry. Top 50 ranked stocks by average daily market cap in energy sub-industries are selected as constituents of CSI energy sub-industry index. We also choose the daily closing data of spot prices of West Texas Intermediate (WTI) crude oil from 4 January 2005 to 15 June 2015. Let P_t denotes the closing price of index or crude oil. The daily price return, r_t, is calculated as its logarithmic difference, $r_t = \log(P_t) - \log(P_{t-1})$. The graphical representation of ESI returns is illustrated in Fig. 1, and the descriptive statistics of ESI returns are shown in Table 1. We eliminate crude oil returns effect by the equation below:

$$r_{(t)} = \varphi_1 r_{(t-1)} + \varphi_2 r_{(t-2)} + \cdots + \varphi_{21} r_{(t-21)} + \phi_0 r_{o,t} + \phi_1 r_{o,t-1} + \cdots + \phi_{21} r_{o,t-21} + \varepsilon_{o,t}. \quad (1)$$

The vector autoregression (VAR) model is an econometric model used to capture the interdependencies among multiple time series. In order to eliminate the effects of crude oil price changes on energy stocks market, we adopt VAR model using the energy stocks index returns as dependent variable and the lagged variables include crude oil returns and energy stocks index returns as independent variables in Eq. (1). Considering the temporal correlations may exist for around a month, we choose the lagged differences up to 21st order. The residual value series in Eq. (1), ε_o, denotes the returns series that the effect of crude oil returns is eliminated.

3. Methodology

Econophysics is a new science evolved from the combination of other sciences including physics, mathematics, economics and finance [1]. Recently, the detrended fluctuation analysis (DFA) method [30] has become a widely used technique for the characterization of fractal scaling properties and the detection of long-range correlations in noisy, nonstationary time series [31,32]. As an extension, Kantelhardt et al. [29] proposed a multifractal DFA which can be used to investigate the multifractality in nonstationary time series. Gu and Zhou [33] extended DFA and MF-DFA to higher-dimensional versions.