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Multi-fractal fluctuation features of thermal power coal price in China

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ABSTRACT

Within the current energy structure in China, coal consumption accounts for 60% of the total energy consumption. Understanding the features of coal prices is important to the energy industry as the prices have a profound impact on the energy development, especially to the thermal power business. This paper uses the multi-fractal theory introduced from financial price field to examine the fluctuations of thermal power coal price by multi-fractal detrended fluctuation analysis (MFDFA). A steam coal Free-on-Board (FOB) price in Qinhuangdao Port, China's largest port of coal storage and transportation, was chosen to represent the thermal power coal price and to reflect the price fluctuation. The analysis shows that the thermal power coal price has multi-fractal features. Consequently, a Quarterly Fluctuation Index (QFI) for thermal power coal price was proposed to forecast the coal price caused by market fluctuation as the fractal model based on QFI had a better forecasting ability when the prices fluctuate wildly. Especially, the QFI can help both government and enterprises to improve their capabilities to manage the fluctuation risks. This study also provides a useful reference to understand the multi-fractal fluctuation features in other energy prices.

1. Introduction

Primary energy plays an important role in the global energy market. As a major source of primary energy, coal has been widely used and consumed due to its abundant reserve. In 2014, coal consumption was 3.88 billion tones, accounting for 30.05% of global energy consumption, which remained as the world's second leading fuel following oil's share of 37.3% [1]. Furthermore, in spite of the rapid development of renewable energy globally in recent years, coal consumption still dominates the energy growth in many developing countries such as China and India, occupying 50.6% and 9.3% share of world coal consumption respectively. In China, coal energy is still the main energy resource nowadays. In 2014, the total energy consumption was 4.26 billion tons of standard coal equivalents and coal consumption accounted for 66% [2]. By the end of 2014, China's installed thermal power capacity was 920 million kW (accounting for 67% of the total power generating installed capacity), 61% of which was from coal-fired power generation [3].

Meanwhile, the coal price in China shows dramatic fluctuations which were influenced by various factors such as demand, supply, and economic situation (i.e. the financial crisis and petroleum price fluctuation). Thus it is imperative for governments to take measures to stabilize coal market, for example, building an efficient regulatory mechanism [4,5]. To avoid coal price fluctuation risks and ensure reliable energy supply, the government administrates the energy prices, especially the thermal power coal price [5]. Accordingly, most of the coals were purchased by the power generation firms with preferential prices determined by favorable policies. For a long time, the thermal power coal price, protected by the government, could not reflect the real price features in the coal market. As a result, despite the advancement of coal price marketization reform in China, the feature of the coal price has not been revealed, which increases the difficulties of decision-making and management.

However, understanding coal price features is challenging. A large amount of coal market information can affect the coal prices, such as the coal production and the consumption, the imports and exports of the raw coal, and the economic factors and policies influential to the price fluctuations. To address this, Coal Price Indexes (CPIs), which reflect coal price features, have been popularly built in different countries to predict the international or local coal market prices, such as the Newcastle (NEWC) in Australia, the Amsterdam-Rotterdam-Antwerp (ARA) in Europe, and the Richards Bay (RB) in South Africa.

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In China, by dividing the areas and choosing different kinds of coals, China National Coal Association and China Coal Transportation & Sale Society had built a China Coal Price Index (CCPI) to describe, monitor and predict the changing trends of coal prices. However, in this CCPI system, there is no index for thermal power generation coal to meet the needs of the thermal power industry. Thus a specialized index should be established and considered to reflect the price features of thermal power generation coal. In this paper, the multi-fractal theory and multi-fractal detrended fluctuation analysis (MFDFA) method, which are usually used to analyze the features of financial market prices, will be introduced to reveal the fluctuation features of thermal power generation coal prices. A Quarterly Fluctuation Index (QFI) will be proposed for thermal power generation coal. Finally, the practical implications of using QFI for both governments and thermal power enterprises will be discussed.

2. Literature review

There are various studies on the coal or energy prices in recent years. These studies mainly focus on two aspects, i.e. drivers to energy prices changes and methods for analyzing the energy price features.

As the basis of energy prices analysis, a number of influencing drivers to energy price changes were identified. Based on the coal market relationships between demand and supply, Cui et al. [6] found the main drivers influential to the thermal power coal price can be classified into supply factors and demand factors. The supply factors include coal resource constraints, investment and production capacity of coal enterprises, industry mining technology and production efficiency, and coal transportation capacity. The demand factors cover economic growth level, the efficiency of energy utilization, alternative energy supply, and industrial structure. To reveal the relationships between impact factors and price fluctuations, Wang et al. [7], using time series of coal prices, take a quantitative measurement approach to explore the causes of coal price fluctuations and found that there is a long-term equilibrium relationship between coal demand and supply. Especially, the domestic coal demand and international coal price play strong guiding roles to local coal prices. According to the fluctuations of thermal power generation demand and thermal power coal consumption, Zhou [8] analyzed the transmission channel in the coal and electricity prices of China, and identified the main reasons causing the coal price distortion are monopsony power in the electricity market, decrease of coal industry concentration, and government's excessive intervention to thermal power coal price. Zhou also pointed out that the price reform of thermal power coal will influence the coal-electricity price mechanism in the near future. Thus, understanding the complicated rules and risks of changing coal price is becoming increasingly important.

On the other aspect, various models were developed to study the behavior and features of energy prices. For example, Özbek and Özlale [9] analyzed the fluctuation features of crude oil price via trend-cycle decomposition and found that the fluctuation feature was the inherent attribute of crude oil price which was mainly driven by supply side of the oil market. Lin and Wesseh Jr. [10]. improved the Markov-switching volatility model and used it to analyze the weekly natural gas price. Out-of-sample tests indicated that the improved model can provide a better framework for policy makers. And the risk-hedging decisions relied critically on assumptions about volatility of natural gas price. Shahbaz et al. [11] employed the method of panel unit root tests to verify whether the natural gas consumptions in various countries exist fluctuations. It was concluded that most countries had steady trends of natural gas consumption. The consumption fluctuations had a small and short-term impact on the natural gas prices. Via uncertainty-augmented model, Scott et al. [12] analyzed the rational habits of gasoline demand across a panel of 29 countries from 1990 to 2011. The result showed that price uncertainty did in fact depress the price responsiveness of demand, and consumer sensitivity to gasoline price was proved to be an important influencing factor to fluctuations. Nazlioglu et al. [13] also conducted a volatility spillover analysis of WTI crude oil price and found that the spillover feature of WTI crude oil price was influenced by long term fluctuation of international crude oil price. Meanwhile, the volatility spillover causality test revealed that the fluctuation risks will transfer from oil prices to financial stress before financial events (such as financial crisis) happened. These existed models are effective in analyzing impact factors and uncertainty of energy prices, and provide useful references for the coal price study in this paper.

3. Research methods

3.1. Multi-fractal features and MFDFA

Although various methods were used in the studies of energy prices, there is no specific method to reveal the features and changing rules of the thermal power coal price. This study will employ the MFDFA method to identify and verify the multi-fractal features of thermal power coal in China. Fractal features widely exist in the time series of different fields. Fractal structures and fractal features were primarily found in biomedical time series from a wide range of physiological phenomena. The multi fractal spectrum identifies the deviations in fractal structure within time periods with large and small fluctuations. This was the primary application of the MFDFA method [14]. Currently, the MFDFA has been used widely in the fields of mathematics, geology, signal processing, meteorology, finance, etc. [15–19]. The purposes of those studies were to research the variation in the series' fractal structure and get their fluctuant features.

At present, the main methods to identify the fractal features include multi-affine analysis, multi-fractal spectrum analysis and multi-fractal detrended fluctuation analysis (MFDFA) [20–22]. MFDFA was proposed by J.W. Kantelhardt in 2002, which overcame some drawbacks of other methods as it has been proved as more effective to verify the multi-fractal features of nonstationary time series. It has been widely used in the nonlinearity, randomness and aperiodicity time series researches aiming at determining the behaviors and probabilities of these time series in different intervals and describing these features by related indexes. Considering the fluctuant and complex features of power generation coal price, it's imperative to explore its multi-fractal features using MFDFA.

For a time series $\{x_i\}$ ($i = 1, 2, 3, \ldots, N$), which have N samples. The general analysis steps of MFDFA are as follows.

(1) The cumulative difference of $\{x_i\}$ should be calculated to reduce the influence of time fluctuations. The new series $y(i)$ can be determined via Equation (1).

$$y(i) = \sum_{i=1}^{N} (x_i - x_{mean}), i = 1, 2, \ldots, N \quad (1)$$

where x_{mean} stands for the average value of $\{x_i\}$ from 1 to i, $y(i)$ also has N samples.

(2) Dividing $y(i)$ into disjoint and isometric intervals with step length s, $Ns = \text{int}(N/s)$ intervals can be got. Because N may not be divided exactly by s, another division should be done from