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Finite-size effect and the components of multifractality in transport economics volatility based on multifractal detrending moving average method

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HIGHLIGHTS

- Multifractal characteristics of freight rate returns in MF-DMA analysis.
- Reflection of the fluctuation size on multifractality.
- Quantitative analysis of multifractality to identify the possible source(s) considering the finite-size effect.

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ABSTRACT

Analysis of freight rate volatility characteristics attracts more attention after year 2008 due to the effect of credit crunch and slowdown in marine transportation. The multifractal detrended fluctuation analysis technique is employed to analyze the time series of Baltic Dry Bulk Freight Rate Index and the market trend of two bulk ship sizes, namely Capesize and Panamax for the period: March 1st 1999–February 26th 2015. In this paper, the degree of the multifractality with different fluctuation sizes is calculated. Besides, multifractal detrending moving average (MF-DMA) counting technique has been developed to quantify the components of multifractal spectrum with the finite-size effect taken into consideration. Numerical results show that both Capesize and Panamax freight rate index time series are of multifractal nature. The origin of multifractality for the bulk freight rate market series is found mostly due to nonlinear correlation.

1. Introduction

The study of financial time series has been the focus of intense research by the physics community in the last several years since Mantegna and Stanley [1] introduced the method of scale invariance from the complexity science into the economic systems for the first time. Moreover, new paradigms and a range of complex systems such as nonlinear dynamics and statistical mechanics have been coherently set up and investigated which may produce results relevant for both physics and economics by physicists with a background of economics [2]. Nowadays, some excellent compilations are but not limited to Mantegna and Stanley [3], Bouchaud and Potters [4], Drożdż et al. [5] and Yuan et al. [6] and Grech [7]. It is widely

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acknowledged that the international shipping industry which facilitates 90% of world trade is tightly linked to the global economy, thus various studies are deserved to investigate the dynamicity and volatility of shipping market for investment purposes like any other financial asset or commodity [8–11]. As is generally known, the dry bulk carrier market is more competitive and typical, hence in this paper, the Baltic dry bulk freight rate index, which is considered by the investment community as a leading indicator of economic activity in shipping market [12], is investigated and analyzed.

In general, a fractal is a rough or fragmented geometrical shape that can be subdivided into parts, each of which is (at least approximately) a reduced-size copy of the whole.

Scaling phenomena is found in many systems, from geophysical to biological, thus Mantegna et al. [1] explored the possibility that it also exists in economic systems. A fractal system is usually described by a scale invariant parameter called fractal dimension [13]. Many fractals require a set of parameters to specify such objects are known as multifractals. Several approaches have so far been developed and applied to explore the fractal properties. One is the rescaled adjusted range analysis method by Hurst [14]. The rescaled analysis is difficult to capture long-range correlations of nonstationary series. A new method to investigate the multi-affine fractal exponents and the correlation coefficient is introduced by Castro et al. [15]. Peng et al. [16] proposed detrended fluctuation analysis (DFA) as an alternative approach. Subsequently, DFA is used to test for the presence of long-term correlations in the return intervals [17–20]. But DFA cannot properly describe multi-scale and fractal subsets of time series data though many records do not exhibit a simple monofractal scaling behavior. The definition of multifractality was first introduced in turbulence and it was soon applied to finance because its heavy tails and long-term dependence nature [19]. Weber et al. [21] examined the spectra and correlations of climate data with a novel method called pth-degree DFA where p refers to a real number and for $p = 2$ recover the usual DFA. In this way some of the multifractal time series can be identified. Bacry et al. [22] developed a method for the simplest type of multifractal analysis based on the standard partition function multifractal formalism. This is a highly successful method for the multifractal characterization of normalized and stationary measures, but it has difficulty in giving the correct result for nonstationary time series. The multifractal detrended fluctuation analysis (MF-DFA) introduced by Kantelhardt et al. [23] for the multifractal characterization of nonstationary time series based on a generalization of the DFA method is a remarkable powerful technique. It has so far been applied to various fields of stochastic analysis, for instance, in biophysics [24,25], in geophysics [26,27], applied physics [28,29] and in markets return analysis [30–35]. The detrending moving average (DMA) method is largely used in quantifying the long-term correlations of nonstationary time series both in real world and synthetic ones [36,37]. Considering the moving average function of the original series and based on the moving average method. DMA is highly efficient in obtaining scaling properties. Before long, MF-DMA is first proposed by Gu and Zhou in 2010 which is a further extension of DMA to higher-dimensional versions [38]. They analyzed the multifractal characteristics of Shanghai Stock Exchange Composite Index using MF-DMA method and found that the backward MF-DMA algorithm has a significant advantage over MF-DFA in detecting the scaling exponents with a comparison result presented.

The prime objective of this kind of analysis is to characterize the statistical properties of the time series and have a better understanding of the underlying dynamics mechanism. Moreover, such knowledge might be crucial to tackle relevant problems in finance. For analysts and policy makers, the importance of an accurate forecast of volatility and dynamicity to tasks such as risk management, portfolio allocation, value-at-risk assessment and option cannot be exaggerated [34,39–44]. Henceforth our discussion will be restricted to the time series analysis of dry bulk freight market. Presently the fluctuations of dry bulk freight market become almost impossible to predict its accurate rise or fall. As we know, over 70% of average freight rate changed between the first half year and the second one in year 2008. Sometimes such change is insignificant, for instance in year 2010. Also, freight rate feature of different ship sizes interested us, since the results of Lu et al. [45] is not consistent with that of Kavussanos [46]. He found that larger vessels tend to experience fiercer volatility, whereas Lu et al. reached the conclusion that smaller vessels react to market's shocks more intensively, owing this phenomenon to the complexity of the freight rate market after the year 2003. Whatever may be the reason, the dynamical nature of the dry bulk freight market is quite complex, and one needs to study the time series of price index from all possible angles in order to understand the underlying mechanism.

In this article we apply the MF-DFA technique to characterize the time series of dry bulk freight rate index and the most popular ship sizes of Capesize and Panamax during the period March 1st, 1999 to February 26th, 2015. In order to visualize the recent market pattern after year 2007 with larger fluctuation, we separately analyze the series of period I from Mar 1st 1999 to Feb 21st 2007 and period II from Feb 22nd 2007 to Feb 26th 2015. Various multifractal variables, such as the Hurst exponent, probability distribution of Hurst exponent and multifractal spectrum are calculated. Furthermore, special quantitative analysis is given to identify the possible source(s) of multifractality in these series since the multifractal nature of the original time series results from three components, which are linear correlation, nonlinear correlation and the fat-tailed probability distribution (PDF) components, respectively [47,48]. For this purpose, we analyze a randomly shuffled series whose multifractal nature is caused by the PDF part only, and a surrogate series whose multifractal property is due to the linear correlation and PDF part, corresponding to the original series BCI, through measuring the width of the multifractal spectra [49]. In order to get more accurate estimates of the possible sources of multifractality in BCI series, we apply MF-DMA method which is proven to have a better performance compared with MF-DFA in quantifying the components of multifractal spectrum [38].

The paper is further organized as follows: Section 2 introduces the MF-DFA method and MF-DMA method; Section 3 describes the data; Section 4 discusses the results and the article is summarized in Section 5.