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Extreme values in the Chinese and American stock markets based on detrended fluctuation analysis

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HIGHLIGHTS

- Applied DFA method to define thresholds in financial market.
- Compared the thresholds of the Chinese and American stock markets, and the percentile and DFA methods.
- Time-clustering of extreme events in stock markets is discussed.
- The effect of extreme value on the cross-correlation of stock markets is investigated.

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ABSTRACT

This paper focuses on the comparative analysis of extreme values in the Chinese and American stock markets based on the detrended fluctuation analysis (DFA) algorithm using the daily data of Shanghai composite index and Dow Jones Industrial Average. The empirical results indicate that the multifractal detrended fluctuation analysis (MF-DFA) method is more objective than the traditional percentile method. The range of extreme value of Dow Jones Industrial Average is smaller than that of Shanghai composite index, and the extreme value of Dow Jones Industrial Average is more time clustering. The extreme value of the Chinese or American stock markets is concentrated in 2008, which is consistent with the financial crisis in 2008. Moreover, we investigate whether extreme events affect the cross-correlation between the Chinese and American stock markets using multifractal detrended cross-correlation analysis algorithm. The results show that extreme events have nothing to do with the cross-correlation between the Chinese and American stock markets.

1. Introduction

The stock market plays an important role as the barometer of national economy. Therefore, the frequency and strength of extreme events in stock markets have a huge effect on the economy and social life, attracting the attention of more scholars.

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The reasonable forecasting of the fluctuation of stock price, the appearance of extreme event forecasting, and the effective risk of fluctuation of stock price forecasting have become the research focus of government regulators, financing institutions, scholars, and investors.

Extreme events do not occur in the scope of normal systematic state of its own evolution, but in the course of systematic evolution or the abnormal state caused by the interference outside the system. In other words, the state of events seriously deviates from the average behavior. Events that rarely occur can be called extreme events in the statistical sense. Numerous studies focus on extreme events, and most of them focus on the extreme events of the climate. For example, Karagiannidis et al. [1] used data from 280 stations in Europe to analyze the climatic characteristic of rainfall in this region. They discovered that the extreme rainfall events have a downward trend in most of the regions in Europe. Burgueño, Lana, Serra, and Martínez [2] conducted a research on extreme climatic temperature in Catalonia, Spain. Verdelhos, Cardoso, and Dolbeth [3] separated and classified the extreme wind events according to wind speed.

The global financial crisis, such as the subprime crisis in the US and the debt crisis in Europe, resulted in a world economy in turmoil. Stock risk is usually measured using the VaR model. However, this model is only used to measure risk in a normal market. To evaluate the risk of extreme events, Gnedenko [4] proposed the extreme value theory. Longin [5] was the first to apply this theory in the financial field. Bao et al. [6] used different methods to calculate the VaR values of four countries, and argued that this extreme value model is suitable for the financial crisis. Some scholars regard the stock market as a complex system. They studied the extreme events of stock markets from the dynamics angle and applied the Omori rule (the relation between the times of aftershock exceeding the assigned earthquake magnitude and time) from seismology to the large changes in stock market. For example, Selcuk [7] suggested that the Omori rule existed after a major fall in the stock returns on 27 October 1996 and 31 August 1998 by studying the daily data of 10 emerging stock markets, such as Argentina, Brazil, Hong Kong, Indonesia, Korea, Mexico, Philippines, Singapore, Taiwan, and Turkey. Weber et al. [8] discovered that the Omori rule is not only applicable to extreme events of the stock market such as the market crash and stock plunge, but also to the evolution of some variables after the medium shock of the stock market based on the research of Selcuk. Sornette et al. [9] studied the Standard & Poor's 500 index after 19 October 1987 (Black Monday) and discovered that its invisible variance had a damping trend in power law index with periodic fluctuation. Zawadowski et al. [10] used 15 min of data to study share price, volatility, and bid ask spread evolution of daily extreme events in NYSE and NASDAQ. Their results showed that stock price reversed and appeared to peak in extreme events, and then damped in the power rate. Siokis [11] analyzed extreme economic events in Europe from 2009, and regarded the index of stock market as the index of economic activities. Then, they analyzed the function of government economic aid.

To define extreme events, several studies on climatic extreme events defined extreme events by the threshold. If the value exceeds the threshold, the value can be defined as extreme value and the event can be defined as extreme event. The percentile method is employed in many studies to define the threshold. The threshold exceeds some tercile in the percentile method. A value that exceeds the threshold is considered extreme events. Judit [12] and Gemmer et al. [13] used 99%, 97%, 95%, and 90% to define the threshold of rainfall in the region. This method is influenced by human factors and does not consider the characteristics of the evolution of the data or the system, such as scale invariance, long-range correlations, and so on. The threshold which is obtained by the percentile method, appeared to be uncertain.

To analyze the long-range power-law correlations in the time series, the trend components should be removed; otherwise, the strong trend component will send wrong messages on long-range correlation. Peng et al. [14] first proposed the detrended fluctuation analysis (DFA) when they explored the degree of correlation of the internal molecular chain in DNA. Kantelhardt et al. [15] generalized and extended the DFA to multifractal detrended fluctuation analysis (MF-DFA). The DFA method effectively removes the trend components of each order and explores the long-range correlation of the unsteady time series, removing its spurious correlation. This method has an advantage over the analysis of time series scaling behavior with trend components. In recent years, DFA has been successfully applied in medical science, geology, meteorology, physics, economics [16–18], and so on. Using the DFA method to study extreme events focuses on meteorology. Zhang et al. [19] used DFA to define the threshold of extreme hailstone event in Anhui, China. However, only few people applied this method in the financial field. Therefore, this paper uses the DFA method to confirm the threshold of extreme events and analyze and measure extreme events in Chinese and foreign (US) stock markets. Podobnik and Stanley [20] proposed the detrended cross-correlation analysis (DCCA) to measure the long-term correlation of the two time series. Zebende et al. [21] proposed DCCA cross-correlation coefficient, whose analytical derivations are reported in Ref. [22]. Based on DFA and DCCA, Zhou et al. [23] developed the multifractal detrended cross-correlation analysis (MF-DCCA). Afterwards, MF-DCCA was further studied [24–26] and widely applied in finance [27–31,29,32–36]. Therefore, we also used MF-DCCA to study the relationship between the cross-correlation in the Chinese and American stock markets, as well as the extreme values. The first contribution of this paper is that we applied DFA method to define thresholds in the financial fields and it verifies that the extreme events do not (or slightly) affect the long-range correlation of the entire system. The second contribution is that we compared the thresholds of the Chinese and American stock markets, made comparison of the percentile and DFA methods, time-clustering of extreme events, and discussed the effect of extreme value on the cross-correlation of the Chinese and American stock markets.

The rest of this paper is organized as follows. Section 2 presents the MF-DFA, MF-DCCA and threshold estimation methods. Section 3 presents and standardizes the data. In Section 4, we present the empirical analysis on the Chinese and American stock markets. Section 5 presents the discussion including the choosing the value of parameter d and replacing the extreme values. Section 6 draws the conclusions.