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Price–volume multifractal analysis and its application in Chinese stock markets

Ying Yuan *, Xin-tian Zhuang, Zhi-ying Liu

School of Business Administration, Northeastern University, Shenyang, 110819, China

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ABSTRACT

An empirical research on Chinese stock markets is conducted using statistical tools. First, the multifractality of stock price return series, $r_i(r_i = \ln(P_{t+1}) - \ln(P_t))$ and trading volume variation series, $v_i(v_i = \ln(V_{t+1}) - \ln(V_t))$ is confirmed using multifractal detrended fluctuation analysis. Furthermore, a multifractal detrended cross-correlation analysis between stock price return and trading volume variation in Chinese stock markets is also conducted. It is shown that the cross relationship between them is also found to be multifractal. Second, the cross-correlation between stock price P_i and trading volume V_i is empirically studied using cross-correlation function and detrended cross-correlation analysis. It is found that both Shanghai stock market and Shenzhen stock market show pronounced long-range cross-correlations between stock price and trading volume. Third, a composite index R based on price and trading volume is introduced. Compared with stock price return series r_i and trading volume variation series v_i, R variation series not only remain the characteristics of original series but also demonstrate the relative correlation between stock price and trading volume. Finally, we analyze the multifractal characteristics of R variation series before and after three financial events in China (namely, Price Limits, Reform of Non-tradable Shares and financial crisis in 2008) in the whole period of sample to study the changes of stock market fluctuation and financial risk. It is found that the empirical results verified the validity of R.

1. Introduction

The financial market can be thought of as a complex system and thus the operating law of the financial market is difficult to understand and describe. Traditional financial market theory relies on the Efficient Market Hypothesis (EMH) [1]. Under the frame of EMH, stock returns follow a normal distribution and price behaviors obey 'random-walk' hypothesis. However, in some recent papers, a deviation from EMH was recently reported for both transition and some developed economies [2–4]. For example, the deviation from EMH was reported for the European transition economies by Podobnik et al. [4]. The results demonstrated that many time series of major indices exhibit power-law correlations in their returns. Therefore, it is necessary to develop an alternative method to extract the characteristics of the price fluctuation to enable an accurate estimate for risk prevention and control purpose.

In 1963, Mandelbrot observed the process of returns showing time scaling property in his analysis of cotton prices [5]. After that, Mandelbrot & Stantely introduced the method of scaling invariance from the complexity science into the economic systems for the first time [6]. The fractal theory was applied to redescribe the scaling invariance property theoretically. The existence of scaling invariance characteristics was further confirmed by some prominent approaches, including rescaled range analysis [7], the Levy stable distribution [8] and detrended fluctuation analysis [9–11]. However, these models could not be used to address the scaling behavior of the probability distributions in financial time series due to the limitation of retrieving recapitulatory information.

* Corresponding author. Tel.: +86 24 83686784; fax: +86 24 23891569.
E-mail address: yuanying1980@126.com (Y. Yuan).

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In order to make up the limitation of single fractal methods, Mandelbrot advanced a new method, namely, multifractal method [12]. Multifractal analysis can be used to divide a complex system into various regions according to their complexity and therefore is able to describe market volatilities. Therefore, many scholars analyzed multifractality of different markets using multifractal tools. In fact, the presence of multifractality has been a "stylized fact" in financial markets [13]. It has been verified that multifractality widely existed in financial markets such as stock markets, future markets, spot markets, foreign exchange markets, derivative markets, interest rate markets and so on [14–22]. Prior researches concentrated on confirming the multifractality of different financial markets, and nowadays some scholars try to explore the complicated statistical characteristics. Ho et al. conducted a multifractal analysis on the Taiwan stock price index. He found that one scaling exponent is insufficient to capture the time dynamics of Taiwan stock market and the nature of multifractal phenomena in Taiwan stock market might be interpreted using the multiplicative cascade process of stock market information [23]. Sun et al. investigated statistically the correlations between the parameters of the multifractal spectrum and the variation of close returns [24]. Chen et al. predicted the price movements using two kinds of sign sequences as given conditions. One is the parameter of the multifractal spectrum Δf based on the minute indices, and the other is the variation of the closing index. Results showed that large fluctuations of the closing price and the conditions are strongly connected in these two methods and some sign sequences of the parameter Δf can be used to predict the probability of near future price movements [25]. Wei et al. proposed a multifractal volatility (MFV) model based on the multifractal spectrum of one trading day. His empirical results showed that the MFV model has the forecasting accuracy [26]. We also measured the multifractality of stock price fluctuation and advanced two risk measures based on generalized Hurst exponents [27]. In addition, another robust and powerful technique is Multifractal Detrended Fluctuation Analysis (MF-DFA), which is proposed by Kantelhardt in 2002 [28]. The advantages of MF-DFA over many techniques are that it permits the detection of long-range correlations embedded in seemingly non-stationary time series, and also avoids the spurious detection of apparent long-range correlations that are an artifact of nonstationarity.

In addition, it should be noted that although some statistical characteristics of stock market data such as stock returns, price series and volatility series have become stylized fact, behavior of other related variables such as trading volume is less studied. In fact, as a most important index, the trading volume contains much of useful information about the dynamics of price formation, which can help us understand the behavior of financial markets. Mu & Zhou studied the long memory and multifractality in trading volumes for Chinese stocks and got some meaningful results [29]. Cross-correlation function is a well-known statistical method used to establish the degree of correlation between two time series. This is done considering that stationarity characterizes both time series under investigation. However, most time series are hardly stationary. Therefore, when the time series need to be seen and analyzed as a whole cross-correlation function is not always a valid choice. Podobnik and Stanley advanced a new method that deals with nonstationary time series, named Detrended Cross-Correlation Analysis (DCCA) [9]. Then long-range power-law volatility cross-correlations in finance were reported between couple of time series by using DCCA and between large number of simultaneously recorded time series [30–34]. For example, Podobnik et al. analyzed the cross-correlations between volume change and price change and power-law cross-correlations were reported between the absolute values in price changes and volume changes [30]. On the basis of DCCA, Zhou proposed a Multifractal DCCA (MF-DCCA) method to combine multifractal detrended fluctuation analysis and DCCA method [10]. Furthermore, Arianos and Carbone advanced a method for estimating the cross-correlation $C_{xy}(\tau)$ of long-range correlated series $x(t)$ and $y(t)$, at varying lags τ and scales n [35].

On the basis of previous literature, in this paper, we conduct an empirical research on Chinese stock market using statistical tools. This study extends previous work in several respects. Firstly, the multifractality of stock price return series and trading volume variation series are confirmed using MF-DFA. Furthermore, a multifractal detrended cross-correlation analysis between stock price return series and trading volume variation series in Chinese stock markets is also conducted. It is shown that the cross relationship between them are also found to be multifractal. Secondly, the cross-correlation between stock price P_i and trading volume V_i is empirically studied using cross-correlation function and detrended cross-correlation analysis. It is found that both Shanghai stock market and Shenzhen stock market show pronounced long-range cross-correlations between stock price and trading volume. Thirdly, a composite index R based on price and trading volume is advanced. Compared with stock price return series r_i and trading volume variation series v_i, R variation series not only remain the characteristics of original series but also demonstrate the relative correlation between stock price and trading volume. Finally, we analyze the multifractal characteristics of R variation series before and after three financial events in China (namely, Price Limits, Reform of Non-tradable Shares and financial crisis in 2008) in the whole period of sample to study the changes of stock market fluctuation and financial risk. It is found that the empirical results verified the validity of R.

The structure of the paper is as follows. Section 2 describes the research method. Section 3 introduces the empirical data. Section 4 presents the empirical results. Section 5 is a brief conclusion of the paper.

2. Research methods

2.1. Multifractal Detrended Fluctuation Analysis (MF-DFA)

Kantelhardt introduced a multifractal method called Multifractal Detrended Fluctuation Analysis (MF-DFA) [28]. The operation of MF-DFA on the series $x(i)$, where $i = 1, 2, \ldots, N$ and N is the length of the series, is as follows. With $\bar{x}$ we indicate the mean value of series $x(i)$.