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Detrended cross-correlation analysis approach for assessing asymmetric multifractal detrended cross-correlations and their application to the Chinese financial market

Guangxi Cao [a,b,*], Jie Cao [a], Longbing Xu [b], LingYun He [c]

[a] School of Economics and Management, Nanjing University of Information Science & Technology, Ningliu Road 219, Nanjing 210044, PR China

[b] School of Finance, Shanghai University of Finance and Economics, Guoding Road 777, Shanghai 200433, PR China

[c] Centre for Future and Financial Derivatives, College of Economics and Management, China Agricultural University, Beijing 100083, PR China

HIGHLIGHTS

- Multifractal asymmetric detrended cross-correlation analysis method is proposed.
- Asymmetric multifractal cross-correlation is studied in the Chinese financial market.
- Cross-correlation between SSCI and RMB/USD is more persistent when any one is falling.
- Asymmetric cross-correlations in the selected financial markets are multifractal.

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ABSTRACT

We propose a new method called the multifractal asymmetric detrended cross-correlation analysis method (MF-ADCCA) to investigate the asymmetric cross-correlations in non-stationary time series that combine the multifractal detrended cross-correlation analysis (MF-DCCA) and asymmetric detrended fluctuation analysis (A-DFA). The study aims to determine whether different scaling properties of the cross-correlations are obtained if a one-time series trending is either positive or negative. We apply MF-ADCCA to analyze empirically the scaling behavior of the cross-correlations among the Chinese stock market, the RMB exchange market, and the US stock market. Empirical results indicate that the cross-correlations between the Chinese stock market and the RMB/USD exchange market are more persistent when any one of the markets is falling. On the contrary, the cross-correlations between the Chinese stock market and the RMB/EU, RMB/GBP, RMB/JPY exchange markets and the US stock market are more persistent when one of the markets is rising. Moreover, asymmetric cross-correlations between any two of the selected financial markets are multifractal.

1. Introduction

Hedging crucially relies on the correlations between the assets hedged and the financial instruments used. The presence of asymmetric correlations can potentially cause problems with hedging effectiveness. Furthermore, standard

* Corresponding author at: School of Economics and Management, Nanjing University of Information Science & Technology, Ningliu Road 219, Nanjing 210044, PR China. Tel.: +86 25 58695638.
E-mail addresses: caoguangxi@nuist.edu.cn, caoguangxi@yahoo.com.cn (G. Cao).

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mean–variance investment theory advises portfolio diversification, but the value of this advice may be questioned if all stocks tend to fall as the market falls [1]. Recently, several studies focus on asymmetric properties of financial markets or asset returns [2–4]. Login and Solnik [5] find that international markets have greater correlations with the US market when the latter is going down than when going up. Ang and Chen [6] detect strong asymmetric correlation between stock portfolios and the US market.

Ang and Bekaert [2] use the two-regime-switching model to determine the connection between low returns and high correlation. Longin and Solnik [5], defining a new concept termed exceedance correlation, report a large correlation between large negative returns, and zero correlation between large positive returns. Ang and Chen [6] use the exceedance correlation test to show that asymmetric correlation exists in different types of domestic portfolios. Hong and Zhou [1] propose a model-free method and confirm such asymmetry in the US stock market. Although these methods are able to detect the presence of asymmetric correlations, they also depend on assumptions, such as the use of a model or the selection of the threshold value. Therefore, the method of assessing asymmetric correlations is worth studying further.

Recently, Podobnik and Stanley [7] and Zhou [8] propose the detrended cross-correlation analysis (DCCA) and multifractal DCCA (MF-DCCA) methods, respectively. MF-DCCA is used widely to detect the cross-correlation between financial markets [9–19]. Although several researchers [20–29] discuss the DCCA methodology, little attention focuses on the asymmetries of the cross-correlation. Alvarez-Ramirez, Rodriguez, and Echeverria [30] provide a new method called asymmetric detrended fluctuation analysis (A-DFA) to assess asymmetries in the scaling behavior of time series as a straightforward modification of the DFA method [31]. Cao, Cao, and Xu [32] apply A-DFA in investigating the asymmetric multifractal scaling behavior in the Chinese stock market. Although A-DFA only detects asymmetries of the time series itself, this method provides a new idea in measuring asymmetries of the cross-correlation which cannot be distinguished by MF-DCCA method proposed by Podobnik and Stanley [7] and Zhou [8].

Therefore, the first contribution of this paper is to propose a straightforward modification of MF-DCCA to detect the asymmetric cross-correlation between two nonstationary series. We combine MF-DCCA and A-DFA, and then propose the multifractal asymmetric detrended cross-correlation analysis method (MF-ADCCA). MF-ADCCA has three appealing features. First, it is model free. Unlike the test of Ang and Chen [6], ours is computed without having to specify a statistical model for the data. Second, MF-ADCCA is easy to implement. The MF-ADCCA scaling exponents are directly computed and several properties are given. Third, MF-ADCCA can also measure the multifractal characteristic of the different cross-correlations. The proposed method can be directly applied to a variety of fields to provide insights in assessing whether the asymmetric cross-correlation exists or not.

The second contribution of this paper is to investigate the asymmetric cross-correlation between Chinese stock returns with the exchange rate of the Chinese Yuan (RMB) to different main foreign currencies and US stock returns. We assess the asymmetric cross-correlations between Chinese stock returns with the other financial returns in China when the Chinese market is rising and falling, and when the other financial markets are going up and down. Furthermore, the multifractal features of various asymmetric cross-correlation are also discussed. We find that the asymmetries exist in the cross-correlation of the Chinese stock market and the RMB exchange market, and the asymmetric cross-relations are multifractal. Moreover, the cross-correlations between the Chinese stock market and the RMB/USD exchange market are more persistent when any one of the markets is falling. On the contrary, the cross-correlations between the Chinese stock market and the RMB/EU, RMB/GBP, RMB/JPY exchange markets, and the US stock market are more persistent when any one of the markets is rising. In addition, the asymmetries of the cross-correlations between the Chinese stock market and the different RMB exchange markets present different persistences for large and small price fluctuations.

The remainder of this paper is organized as follows. Section 2 presents the MF-ADCCA method, and discusses the properties of the scaling exponents. Section 3 presents and describes the basic statistical properties of the data. Section 4 applies the proposed method to Chinese financial markets. Section 5 concludes.

2. Multifractal asymmetric detrended cross-correlation analysis method

We combine MF-DCCA and A-DFA, and propose the MF-ADCCA method, which is described as follows. Assume that two time-series $\{x^{(1)}(t)\}$ and $\{x^{(2)}(t)\}$ exist, $t = 1, 2, \ldots, N$, where N is the length of the series. The MF-ADCCA method can then be summarized as follows.

Step 1: We construct the profile

$$y^{(i)}(j) = \sum_{t=1}^{j}(x^{(i)}(t) - \overline{x^{(i)}}), \quad j = 1, 2, \ldots, N, i = 1, 2 \tag{1}$$

where $\overline{x^{(i)}} = \frac{1}{N}\sum_{t=1}^{N} x^{(i)}(t)$.

Step 2: The time series $\{x^{(i)}(t)\}$ and its profile $\{y^{(i)}(t)\}$ $(i = 1, 2)$ are divided into $N_n = \mathrm{int}(N/n)$ non-overlapping subtime series (i.e., boxes) of equal length n, respectively. The record length N does not need to be a multiple of the considered time scale n, and thus, a short part of the profile will remain in most cases. The same procedure is repeated starting from the other end of the record to account for the aforementioned part. Thus, $2N_n$ segments are obtained altogether. Let $S_j^{(i)} = \{s_{j,k}^{(i)}, k = 1 \ldots, n\}$ denote the j-th subtime series of length n and $Y_j^{(i)} = \{y_{j,k}^{(i)}, k = 1, \ldots, n\}$ denote the according