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Volatility-constrained multifractal detrended cross-correlation analysis: Cross-correlation among Mainland China, US, and Hong Kong stock markets

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HIGHLIGHTS

- A volatility-constrained MFDCCA method is proposed.
- The directionality of influence between stock markets is discussed.
- A simulation experiment conducted for optimized selection of method is made.

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ABSTRACT

This study focuses on multifractal detrended cross-correlation analysis of the different volatility intervals of Mainland China, US, and Hong Kong stock markets. A volatility-constrained multifractal detrended cross-correlation analysis (VC-MF-DCCA) method is proposed to study the volatility conductivity of Mainland China, US, and Hong Kong stock markets. Empirical results indicate that fluctuation may be related to important activities in real markets. The Hang Seng Index (HSI) stock market is more influential than the Shanghai Composite Index (SCI) stock market. Furthermore, the SCI stock market is more influential than the Dow Jones Industrial Average stock market. The conductivity between the HSI and SCI stock markets is the strongest. HSI was the most influential market in the large fluctuation interval of 1991 to 2014. The autoregressive fractionally integrated moving average method is used to verify the validity of VC-MF-DCCA. Results show that VC-MF-DCCA is effective.

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1. Introduction

As a complex system, the financial market has become increasingly interconnected worldwide. The recent bankruptcy of Lehman Brothers in 2008 and the Euro crisis made the overall market crisis a global epidemic. Disruption in a single market may exert a significant effect on other financial markets because of interdependence. Several scholars have studied financial markets by using various approaches, ranging from statistical physics and nonlinear dynamics to computer science.

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The multifractal characteristics of financial markets have also elicited the interest of several scholars. Various fractal analysis methods are currently available, and detrended fluctuation analysis (DFA) is one of the widely used ones. The DFA method was proposed by Peng et al. [1] when they explored the degree of correlation of the internal molecular chain in DNA. This method removes the trend components and analyzes the long-term power-law correlations of the unsteady time series. Kantelhardt et al. [2] generalized and extended DFA to multifractal detrended fluctuation analysis (MF-DFA). Podobnik and Stanley [3] proposed detrended cross-correlation analysis (DCCA) to measure the long-term correlation of two time series. Zhou et al. [4] referred to DFA and DCCA and developed multifractal detrended cross-correlation analysis (MF-DCCA). The MF-DCCA method reveals the multifractal characteristics of two unsteady time series that are cross-correlated. Thereafter, the MF-DCCA method was widely applied in finance. Cao et al. [5] used the MF-DCCA algorithm to investigate whether extreme events affect the cross-correlation between Chinese and American stock markets. Their results showed that extreme events are unrelated to the cross-correlation between Chinese and American stock markets. Wang et al. [6] investigated the cross-correlation between price returns and trading volumes for China Securities Index 300 (CSI 300) futures and found that returns and trading volumes exhibit long-term cross-correlation. In addition, the test results of the lead–lag effect proved that the contemporaneous cross-correlation of return and trading volume series is stronger than the cross-correlations of leaded or lagged series. Pal et al. [7] applied MF-DCCA to investigate the fractal nature of and cross-correlation between two non-stationary time series. They discovered that gold and oil prices are uncorrelated, and the remaining bivariate time series demonstrates persistence. He et al. [8] investigated the geographically far but temporally correlated agricultural future markets of China and the United States. The researchers discovered that a power-law cross-correlation exists between the two markets and that multifractal features are significant in both markets. Zhuang et al. [9] adopted a new perspective and studied the cross-correlations between carbon and crude oil markets. By using MF-DCCA, they also investigated the dynamic behavior of these markets. The researchers found power-law cross-correlations between carbon and crude oil markets; the cross-correlated behavior of small fluctuations is more persistent than that of large fluctuations.

In recent years, several scholars have developed different MF-DCCA methods to describe the cross-correlation between two non-stationary time series; some of these methods include MF-X-DFA [10]; MF-X-DMA [11], which is based on MF-DMA [12] and DMA [13]; MF-HXA [14]; MF-X-PF [15]; and MF-DPXA [16]. Cao et al. [17–19] proposed the multifractal asymmetric detrended cross-correlation analysis (MF-ADCCA) method to investigate asymmetric cross-correlations in non-stationary time series. Zhang et al. [20] also used MF-ADCCA to study the asymmetric characteristics of cross-correlations between PM2.5 concentration and meteorological factors. In addition, Cao et al. [21] developed an asymmetric MF-DCCA method that is conducted based on the different directions of risk conduction (DMF-ADCCA). Shi et al. [22] introduced a method called "multiscale multifractal detrended cross-correlation analysis" (MM-DCCA); MM-DCCA may help present significantly richer information than MF-DCCA by sweeping all the ranges of scale at which the multifractal structures of complex systems are discussed. Yin et al. [23] used multiscale detrended fluctuation analysis and multiscale detrended cross-correlation analysis to investigate the auto-correlation and cross-correlation between American and Chinese stock markets from 1997 to 2012. Liu et al. [24] used empirical mode decomposition (EMD), MF-DCCA, and principal component analysis (PCA) to propose the EMD-MFDCCA-PCA method. When Zhao et al. [25] studied the traffic signals using the MF-DCCA method, they found that crossovers arising from extrinsic periodic trends made the scaling behavior difficult to analyze. Therefore, they introduced a Fourier filtering method to eliminate the trend effects and systematically investigate the multifractal cross-correlation of simulated and real traffic signals. Pal et al. [26] characterized the multifractal nature and power-law cross-correlation between any pair of genome sequence through an integrative approach that combines 2D MF-DCCA and chaos game representation. From their analysis, they observed the existence of multifractal nature and power-law cross-correlation behavior between any pair of genome sequences.

Several studies have investigated the volatility of the financial market from different viewpoints. For example, scholars have analyzed the volatility clustering of the financial market [27–32]. Junior et al. [33] found that high-volatility markets are directly related to strong correlations between markets. Maskawa et al. [34] discovered that market-wide price co-movement becomes prominent before and after a large price decline, such as an endogenous market crash. Wang et al. [35] established long-term power-law cross-correlations in the absolute values of returns that quantify risk and found that these cross-correlations decay significantly more slowly than cross-correlations between returns. Podobnik et al. [36] established long-term magnitude cross-correlations in price fluctuation and physiological time series; both of which are healthy and pathological. Moreover, a new methodology was proposed to assess and quantify inter-market relations. The approach was based on the correlations among market index, index volatility, market index cohesive force, and meta-correlations [37]. Although research on cross-correlation and volatility is abundant, only a few studies have been conducted on volatility-constrained cross-correlation. Therefore, a volatility-constrained multifractal detrended cross-correlation analysis (VC-MF-DCCA) method was developed in the present study to investigate the cross-correlation among the markets of Mainland China, United States, and Hong Kong, as based on [38].

Several studies have also investigated the risk contagion of stock markets. Chinese scholars have studied the contagion effect of Mainland China and Hong Kong stock markets. Zhang et al. [39] found that the response to the events of the mainland market is earlier than that of the Hong Kong stock market. Liao [40] discovered the single-direction spillover effect on liquidity from Shanghai to Hong Kong markets in the beginning of the crisis. In the late stage of the crisis, a one-way spillover effect on liquidity and volatility was observed from Hong Kong to Shanghai markets. Several foreign scholars have also studied the contagion effect of Chinese and American stock markets. Morales et al. [41] found that the US crisis did not exert contagion effects on Asian economies. If US equity markets influence Asian economies, then scholars should

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