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Time-clustering behavior of sharp fluctuation sequences in Chinese stock markets

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ABSTRACT

Sharp fluctuations (in particular, extreme fluctuations) of asset prices have a great impact on financial markets and risk management. Therefore, investigating the time dynamics of sharp fluctuation is a challenge in the financial fields. Using two different representations of the sharp fluctuations (inter-event times and series of counts), the time clustering behavior in the sharp fluctuation sequences of stock markets in China is studied with several statistical tools, including coefficient of variation, Allan Factor, Fano Factor as well as R/S (rescaled range) analysis. All of the empirical results indicate that the time dynamics of the sharp fluctuation sequences can be considered as a fractal process with a high degree of time-clusterization of the events. It can help us to get a better understanding of the nature and dynamics of sharp fluctuation of stock price in stock markets.

1. Introduction

Sharp fluctuations (in particular, extreme fluctuations) of asset prices have a great impact on financial markets and risk management. Therefore, investigating the time dynamics of sharp fluctuation is a challenge in the financial fields.

Many scholars showed their interests on this issue and found some meaningful conclusions. Chen et al. [1] analyzed the daily Hang Seng index in the Hong Kong stock market. They predicted the future price movements using two kinds of sign sequences as given conditions. One is the parameter of multifractal spectrum Δf based on the indexes recorded in every minute, and the other is the variation of the close index Δi. Results show that correlation between large fluctuations of the close price and the condition in these two methods is strong and some sign sequences of the parameter Δf can be used to predict the probability of the near future price movements. Muchnik et al. [2] studied the long term memory in extreme returns of financial time series and revealed that the returns exhibit pronounced long-term memory. This "stylized fact" can shed further insight on price dynamics that might be used for risk estimation. We also studied the sharp fluctuation of stock price index in Chinese stock market using multifractal spectrum and multifractal detrended fluctuation analysis (MF-DFA), respectively, and found that when the stock price index fluctuates sharply, a strong variability is clearly characterized by multifractal parameters and the generalized Hurst exponents [3,4]. Zhang et al. [5] tried to capture the fluctuations caused by the extreme event on crude oil prices variation during the analyzed period using an empirical mode decomposition (EMD-based) event analysis approach. It was found that this method provided a feasible solution to estimate the impact of extreme events on crude oil prices variation. In addition, many relative researches have been performed in order to capture the main features of extreme fluctuations [6–12], all of these results are meaningful and important and can lead to a better understanding of complex stock markets.

However, it is noted that most of the previous researches concentrated on the time series analysis of capital price series and capturing the statistical characteristics of financial time series, and few focused on the temporal dynamics of financial sharp fluctuation (or extreme fluctuation) sequences. In fact, the temporal dynamics of sharp fluctuation sequences are very useful information for understanding

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possible causes of sharp fluctuation, improving sharp fluctuation prediction and financial risk management as well as for improving predictive models. Nevertheless, the temporal dynamics of sharp fluctuation are still seldom known because the dynamics of sharp fluctuation result from many complex interaction factors and also factors involving human activities. It is very important and meaningful to study the temporal behavior and dynamics characteristics of sharp fluctuation of financial markets. Therefore, a further research work will help us to get a better understanding of the nature of stock price dynamics.

On the other hand, Telesca et al. [13–22] studied the characterization of temporal fluctuations in other complex systems, such as seismic sequences, car accident sequence and forest fire sequence, etc. The fundamental principle of these researches is that extreme event sequence can be assumed to be a realization of a point process. The discrete-time process can be derived from the stochastic point process in two equivalent ways (1) using the inter-event time series or (2) forming its relative counting process. In the first representation a discrete-time series is formed by the rule $\tau_i = t_{i+1} - t_i$, where t_i indicates the time of event numbered by the index i. In the second representation, the time axis is divided into equally spaced contiguous counting windows of duration T. The duration T of the window is called counting time or timescale. The latter approach considers the extreme events as the events of interest and assumes that there is an objective clock for the timing of the events. The former approach emphasizes the interspike intervals and uses the event number as an index of the time [16,17]. This research idea can also be applied in the temporal fluctuation analysis on sharp fluctuation in stock markets, for sharp fluctuation (or extreme fluctuation) sequences can also be viewed as a realization of a stochastic point process.

In this context, our study aims to analyze the time-clustering characteristics of sharp fluctuation sequences of stock markets in China. We performed a detailed statistical analysis to investigate the time-clustering properties of the sharp fluctuation sequences of stock markets in China. The statistical tools include coefficient of variation, Allan Factor, Fano Factor as well as R/S (rescaled range) analysis. All of these empirical results suggest that the sequences are characterized by a high degree of time-clusterization. It can help us to get a better understanding of the nature and dynamics of sharp fluctuation of stock price in stock markets.

2. Methods

Sharp fluctuation sequences can be viewed as a realization of a stochastic point process. A stochastic point process describes events that occur at some random locations in time and is completely defined by the set of the event times. The series can be represented by a finite sum of Dirac's delta functions centered on the occurrence time t_i:

$$y(t) = \sum_{i=1}^{N} \delta(t - t_i) \tag{1}$$

where N represents the number of events recorded. Then dividing the time axis into equally spaced contiguous counting windows of duration τ, which is called timescale, we produce a sequence of counts $\{N_k(\tau)\}$, with $N_k(\tau)$ denoting the number of events in the kth window:

$$N_k(\tau) = \int_{t_{k-1}}^{t_k} \sum_{j=1}^{N} \delta(t - t_j)\mathrm{d}t \tag{2}$$

This sequence is a discrete-random process of non-negative integers. The importance of this representation is that it preserves the correspondence between the discrete time axis of the counting process $\{N_k\}$ and the "real" time axis of the underlying point process, and the correlation in the process $\{N_k\}$ refers to correlation in the underlying point process. Such a process may be called fractal when a number of relevant statistics exhibit scaling with related scaling exponents, which indicate that the represented phenomenon contain clusters of points over a relatively large set of timescales.

In order to analyze time behavior and time-clustering properties of sharp fluctuation (or extreme fluctuation) sequences, we used several statistical measures to feature the time properties. These methods have been extensively used to analyze the time-clustering properties in complex systems such as seismic sequences, car accident sequence and forest fire sequence, etc. [13–24]. These methods include coefficient of variation (CV), Allan Factor (AF), Fano Factor (FF) and rescaled range (R/S) analysis. Two of them (CV, R/S analysis) are related to the inter-event interval representation, while the remaining two (AF, FF) are related to the counting process representation. We will give a brief introduction of these measures.

2.1. Coefficient of variation

The C_v is a commonly used measure to evaluate the clustering behavior of a point process, it is defined as

$$C_v = \frac{\sigma_\tau}{\langle\tau\rangle} \tag{3}$$

where $\langle\tau\rangle$ is the mean inter-event time and σ_τ is its standard deviation, a Poissonian process (completely random) has a $C_v = 1$, but a clusterized process is characterized by a $C_v > 1$. This coefficient does not give information about the timescale ranges where the process can be reliably characterized as a clustered process. Nevertheless, a complex phenomenon can be deeply known only if the different timescales governing its dynamics are well understood [16].

2.2. Fano Factor

The Fano Factor (FF) is defined as the variance of the number of events in a specified counting time or timescale τ divided by the mean number of events in that counting time; that is

$$FF(\tau) = \frac{\left\langle N_k^2(\tau)\right\rangle - \langle N_k(\tau)\rangle^2}{\langle N_k(\tau)\rangle} \tag{4}$$

where $\langle\rangle$ indicates the average value. In order to evaluate the presence of scaling, the timescale T is varied and a relationship $FF(\tau) \sim \tau$ is obtained [17].