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Physica A 383 (2007) 65–70
PHYSICA A
www.elsevier.com/locate/physa

Probability distribution function and multiscaling properties in the Korean stock market

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Available online 8 May 2007

Abstract

We consider the probability distribution function (pdf) and the multiscaling properties of the index and the traded volume in the Korean stock market. We observed the power law of the pdf at the fat tail region for the return, volatility, the traded volume, and changes of the traded volume. We also investigate the multifractality in the Korean stock market. We consider the multifractality by the detrended fluctuation analysis (MFDFA). We observed the multiscaling behaviors for index, return, traded volume, and the changes of the traded volume. We apply MFDFA method for the randomly shuffled time series to observe the effects of the autocorrelations. The multifractality is strongly originated from the long time correlations of the time series.

Keywords: Econophysics; Probability density function; Multifractality; Detrended fluctuation analysis; Stock market

1. Introduction

Recently, concepts and techniques from statistical physics have been widely applied to economics [1–14]. The complex behaviors of economic systems have been found to be very similar to those of complex systems customarily studied in statistical physics. Stock-market indexes around the world have been accurately recorded for many years and therefore represent a rich source of data for quantitative analysis, and the statistical behaviors of stock markets have been studied by various methods, such as probability distribution functions [7–9,13], correlation functions [9–11], multifractal analysis [13,15–17], and network analysis of the market structure [12].

Scaling behaviors in economics have been reported in many time series, such as stock indexes [5,7,13,17], foreign exchange markets [18,19], individual wealth [20–22], and business sizes [23,24]. In the stock market the probability distribution function (pdf) of the return shows a power law at tail parts [7,25–28]. The pdf of the volatility also follows the power law. The exponents of the power law for the volatility are close to 3 in US stock market [9]. The pdf of the traded volume for individual stock price shows a power law, $P(Q)\sim Q^{-(1+\lambda)}$ at large fluctuation with the exponent $\lambda = 1.7$ where Q is the traded volume [29]. Kaizoji and Nuki reported the

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doi:10.1016/j.physa.2007.04.112

scaling law for the distribution of fluctuations in share volume. The cumulative distributions have an exponent close to unity [30].

Multiscaling properties have been reported for many economic time series [31–40]. Multifractality has been observed in stock markets [15,36,41–44], the price of crude oil [32], the price of commodities [43], and foreign exchange rates [45]. In daily stock indexes and foreign exchange rates, the generalized Hurst exponent H_q decreases monotonically with q [36,41–43,45]. The method of the multifractal detrended fluctuation analysis (MFDFA) has been applied to the high-frequency tick-by-tick data in the stock market [43,46].

In the present work, we consider the pdf of the index, the return, the traded volume and the change of traded volume in the Korean stock market. We report the power law at tail parts of the pdf. We also consider the multiscaling behavior of the original time series and the randomly shuffled time series for the index and the traded volume in the stock market.

2. Probability distribution function in stock market

We consider the 1 min tick data of the Korean stock-market index, KOSPI and the traded volume, from March 30, 1992 to November 30, 1999. We count the time during trading hours and remove closing hours, weekends, and holidays from the data. Let us define the logarithmic return as $r(t) = \log p(t) - \log p(t - t_1)$ where $p(t)$ is the index at a time t and t_1 is the return time. We also define the change of the volume as $V_r(t) = V(t) - V(t - t_1)$ where $V(t)$ is the traded volume at the time t. The pdf of the return has two different regions. The central parts of the pdf deviate from the Gaussian function, but are well fitted by the Lorentzian function. The tail parts of the pdf deviate from the Gaussian function and show fat tails. The tail parts of the pdf of the return decays according to a power law such as $p(r) \sim r^{(1+\alpha)}$ with the exponent $\alpha > 2$. The exponents of the pdf for the return depend on the return time t_1. We obtain exponents $\alpha = 2.16$ ($t_1 = 1$ min), 2.46 ($t_1 = 10$ min), 2.71 ($t_1 = 30$ min), 2.87 ($t_1 = 60$ min), 2.87 ($t_1 = 600$ min) for positive tails of the pdf and $\alpha = 2.29$ ($t_1 = 1$ min), 2.56 ($t_1 = 10$ min), 2.73 ($t_1 = 30$ min), 3.03 ($t_1 = 60$ min), 2.91 ($t_1 = 600$ min) for negative tails of the pdf. The exponents α are not universal because they depend on the return time. The exponents α are smaller than those of the other markets [7].We consider the pdf of the volatility. We define the volatility as the local standard deviation at a time window of length T. The central parts of the pdf for the volatility are well fitted by the log-normal distribution function. However, the tail parts deviate from the log-normal distribution and have fat tails. In Fig. 1, we present the cumulative pdf for the volatility with different

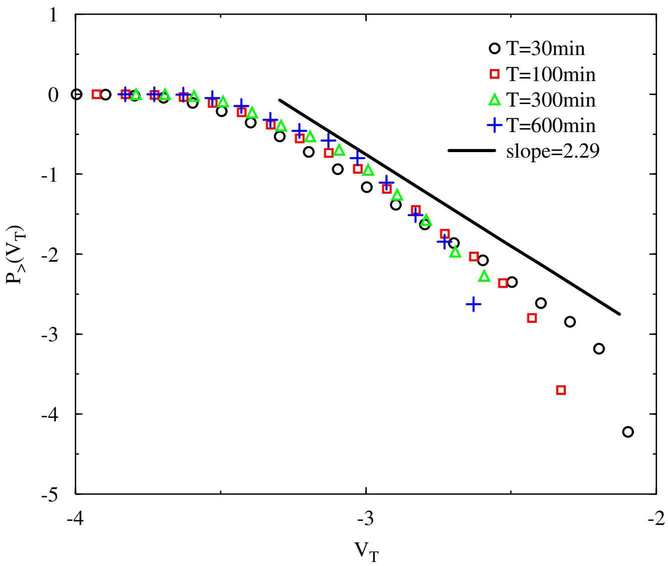

Fig. 1. (Color online) Log–log plot of the cumulative probability density function for the volatility $P_>(V_T)$ versus V_T with the time window of length $T = 30$ min (○), 100 min (□), 300 min (Δ), and 600 min (+).