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Scaling and memory effect in volatility return interval of the Chinese stock market

T. Qiu [a,*], L. Guo [b], G. Chen [a]

[a] School of Electronic and Information Engineering, NanChang Hangkong University, Nanchang, 330063, China

[b] School of Business, East China University of Science and Technology, Shanghai, 200237, China

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ABSTRACT

We investigate the probability distribution of the volatility return intervals τ for the Chinese stock market. We rescale both the probability distribution $P_q(\tau)$ and the volatility return intervals τ as $P_q(\tau) = 1/\overline{\tau} f(\tau/\overline{\tau})$ to obtain a uniform scaling curve for different threshold value q. The scaling curve can be well fitted by the stretched exponential function $f(x) \sim e^{-\alpha x^{\gamma}}$, which suggests memory exists in τ. To demonstrate the memory effect, we investigate the conditional probability distribution $P_q(\tau|\tau_0)$, the mean conditional interval $\langle\tau|\tau_0\rangle$ and the cumulative probability distribution of the cluster size of τ. The results show clear clustering effect. We further investigate the persistence probability distribution $P_{\pm}(t)$ and find that $P_{-}(t)$ decays by a power law with the exponent far different from the value 0.5 for the random walk, which further confirms long memory exists in τ. The scaling and long memory effect of τ for the Chinese stock market are similar to those obtained from the United States and the Japanese financial markets.

1. Introduction

In recent years, physicists have paid much attention on the dynamics of financial markets. Scaling behavior is discovered in the financial system by analyzing the indices and the stock prices $y(t')$, such as the 'fat tail' of the probability distribution $P(Z, t)$ of the two point price change return $Z(t') = \ln\ y(t') - \ln\ y(t'-1)$ [1,2]. The physical origin of the scaling behavior is often related to the long range correlation. It is interested to find, in spite of the absence of the return correlation, the volatility $|Z(t')|$ is long range correlated [3,4].

Recently, the volatility return intervals τ, which is defined as the return intervals that the volatility is above a certain threshold q, is investigated for the United States and the Japanese financial markets [5–10]. Scaling behavior of the probability distribution in the volatility return intervals τ is discovered, and long-range autocorrelation is demonstrated for τ. The scaling and the long-range autocorrelation are rather robust independent of the stock markets and the foreign exchange markets for the developed countries. However, it is known that the emerging markets may behave differently [11–17]. Especially, the Chinese stock market is newly set up in 1990 and shares a transiting social and political system. Due to the special background of the Chinese stock market, it may exhibit special features far different from the mature financial markets in some aspects [11–13]. In Refs. [11,12], the prominent anti-leverage effect of the Chinese indices is reported, in contrast with the leverage effect of the mature markets. It suggests different investment propensity between the mature markets and the emerging markets since it just experiences the first stage of capitalism. It is important to investigate the financial dynamics of the Chinese stock market to achieve more comprehensive understanding of the financial markets.

* Corresponding address: School of Electronic and Information Engineering, Nanchang Hangkong University, 696 South Fenghe Avenue, Nanchang 330063, China.
E-mail address: tianqiu.edu@gmail.com (T. Qiu).

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In this paper, to broaden the understanding of the scaling and memory effect of the volatility return intervals τ for the emerging markets, we investigate the probability distribution and the memory effect of τ for the Chinese stock market. In the next section, we present the data set we analyzed. In Section 3, we show the way to remove the intraday pattern. In Section 4, we show the probability distribution of τ. In Section 5, we investigate the clustering phenomena by analyzing the conditional probability distribution $P_q(\tau|\tau_0)$, the mean conditional interval $\langle\tau|\tau_0\rangle$ and the cumulative distribution of the cluster size of τ. In Section 6, we investigate the persistence probability distribution $P_{\pm}(t)$. Finally comes the conclusion.

2. Data analyzed

The data we analyzed is based on the trade-by-trade data from the stocks of the Shanghai Stock Exchange market (SHSE) and the Shenzhen Stock Exchange market (SZSE). The SHSE was established on November 26, 1990 and put into operation on December 19, 1990. Shortly after, the SZSE was established on December 1, 1990 and put into operation on July 3, 1991. Most A-shares and B-shares are traded in the SHSE and SZSE. The A-shares are common stocks issued by mainland Chinese companies, subscribed and traded in Chinese RenMinBi (RMB), listed in mainland Chinese stock exchanges, bought and sold by Chinese nationals. The A-share market was launched in 1990. The B-shares are issued by mainland Chinese companies traded in foreign currencies and listed in mainland Chinese stock exchanges. The B-share market was launched in 1992.

The Chinese stock market is an order-driven market and is based on the so called continuous double auction mechanism. In the trading day, there are 3 time periods. From 9:15 to 9:25 a.m., it is the opening call auction time, when the buy and sell orders are aggregated to match. From 9:25 to 9:30 a.m., it is the cool period, and then followed by the continuous double auction time. The time period for the continuous double auction is from 9:30 to 11:30 a.m. and from 13:00 to 15:00 p.m. More Information about the development process and the current trading mechanism can be found in Refs. [13,18–20]. Here we analyze 4 high liquid stocks, the Datang Telecom Corporation (the DTT stock), the Chinese Minsheng Banking Corporation (the CMB stock), the China Petrochemical Corporation (the CPC stock) and the Shanghai Lujiazui Finance and Trade Zone Corporation (the SLFT stock), which were listed on the Shanghai Stock Exchange Market (SHSE). The data covers 3 whole year transactions from 2004 to 2006. The data size is about 800,000 on average.

3. The intraday pattern

It is well known that there exists an intra-day pattern of the volatility for the high trading activity in the opening time. Such an intra-day pattern strongly affects the dynamic behavior, for example, there occurs a periodic structure in the analysis of the autocorrelation function [12]. Therefore, it is necessary to remove the the intraday pattern. Here we follow the way in Refs. [4,12,15].

We segment the dataset of each trading day into 240 successive 1-min intervals. For a given stock, we define the intraday pattern as follows,

$$A(t'_{\text{day}}) = \frac{1}{N}\sum_{j=1}^{N}|Z_j(t'_{\text{day}})|, \tag{1}$$

where j runs over all the trading days N, and t'_{day} is the time in a trading day. We divide the volatility $|Z(t'_{\text{day}})|$ with the intraday pattern to remove the daily trend,

$$Z'(t') = |Z(t'_{\text{day}})|/A(t'_{\text{day}}). \tag{2}$$

In order to compare different stocks, we define the normalized volatility $g(t')$ by dividing $Z'(t')$ with its standard deviation,

$$g(t') = \frac{Z'(t')}{(\langle Z'(t')^2\rangle - \langle Z'(t')\rangle^2)^{1/2}}. \tag{3}$$

4. The probability distribution

Here we define the volatility return intervals $\tau(q)$ as the time intervals that volatility $g(t')$ above a certain threshold q, where the sampling time interval for the volatility $g(t')$ is 1 min. Therefore, $\tau(q)$ depends on the threshold q. Fig. 1 shows the volatility return intervals for $q = 0.50$, $q = 1.00$ and $q = 1.50$ in May 2004 of the DTT stock. The big value of q corresponds to the large volatility that rarely occurs in the financial markets. We investigate the probability distribution function (PDF) $P_q(\tau)$ of the volatility return interval $\tau(q)$ with the threshold $q = 0.75$, 1.00, 1.25, 1.5, 1.75 and 2.0.

Fig. 2 (a) shows the PDF $P_q(\tau)$ for the DTT stock and Fig. 2 (b) shows the PDF $P_q(\tau)$ for the CMB stock. The six curves are for $q = 0.75$, 1.00, 1.25, 1.5, 1.75 and 2.0, respectively. The results show that the PDF $P_q(\tau)$ for large q decays slower than that for small q. We rescale $P_q(\tau)$ and τ as $P_q(\tau) = 1/\overline{\tau}f(\tau/\overline{\tau})$, which is mentioned in Refs. [5–10], to collapse the six curves with different threshold q onto a single curve, where $\overline{\tau}$ is the average interval.

Fig. 3 (a) and (b) shows the scaled PDF $P_q(\tau)\overline{\tau}$ as a function of the scaled volatility return intervals $\tau/\overline{\tau}$ for the DTT stock and the CMB stock. Fig. 3 (c) shows the scaled PDF $P_q(\tau)\overline{\tau}$ for the DTT stock, the CMB stock, the CPC stock, the SLFT stock and the Bird Telecom Co., Ltd (BDT) stock.