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Analysis of the efficiency of the Shanghai stock market: A volatility perspective

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ABSTRACT

By applying the rolling window method, we investigate the efficiency of the Shanghai stock market through the dynamic changes of local Hurst exponents based on multifractal detrended fluctuation analysis. We decompose the realized volatility into continuous sample paths and jump components and analyze their long-range correlations of decomposing components. Our results reveal that the efficiency of the Shanghai stock market improved greatly based on the time-varying Hurst exponents.

1. Introduction

As an emerging market, the Shanghai stock market in China has experienced key reforms during the past twenty years. Although it has very short history, the Shanghai Securities Exchange has attracted more and more attention. Usually, we hope that we can find the evidences that the Shanghai stock market is weak-form efficient, or that some evidences give exact answer to what pattern the Shanghai market is. As a center of financial markets in China, the Shanghai stock market is essential for us to analyze, especially the evolution of market efficiency.

The Shanghai Stock Exchange was established on November 26, 1990, and put into operation on December 19. Given to the imperfect operation systems and the irrational behaviors of investors, the fierce fluctuations are always inevitable. The reasons can be described as follows: (1) the speculations in the emerging stock market frequently happened, and there may appear large volume transactions because of arbitrage opportunity. (2) Investors are not confident of themselves. Therefore, many investors may notice that although they have some advanced financial investment tools, investors may be shortsighted to change their investment strategy frequently which may result in great volatility.

In order to capture the market properties, we investigate the realized volatility series which are always decomposed into different components. In empirical financial literature, market volatility is widely investigated. For example, Podobnik et al. [1] found that some stock market volatility of transition economies were characterized by different long-range auto-correlations, and they thought that long memory of the return series could imply the lower efficiency of the market. Based on R/Sanalysis, Cajueiro and Tabak [2] found that long-range auto-correlations of returns of emerging markets became weaker and weaker over time implying a more and more efficient operation. But the R/Smethod usually has the bias estimators when investigating the long memory return series with strong short-term auto-correlations and trends [3]. Therefore, Andersen et al. [4] and Barndorff-Nielsen and Shephard [5] decomposed the realized volatility into the continuous sample paths (C) and jump components (J) in order to improve the ability of forecasting. Li et al. [6] investigated the long-term memory with the decomposing method, which used high-frequency time series data of the Chinese Shanghai stock market. The results showed that the long-term memory phenomenon was an inherent characteristic of data generating process. This

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is a successful attempt using the decomposed model to analyze the stock market. Furthermore, Lanne [7] concluded that the financial series had the properties of smoothness, and discreteness, not frequent continuity. Alvarez-Ramirez et al. [8] also found that crude oil markets became efficient by using time-varying Hurst exponent when the return series had the property of long memory. Alvarez-Ramirez et al. [9] showed that the US stock markets were also becoming more and more efficient over time based on detrended fluctuation analysis.

However, multifractality has been a "stylized fact" which widely exists in financial time series [10]. Theoretically, a time series with random walk behavior have no multifractality property. Thus, the presence of multifractality also implies the inefficiency of a financial market which has been confirmed in several empirical literature. For example, Zunino et al. [11] found that developed markets which had higher degrees of efficiency always showed lower degrees of multifractality, compared to the multifractality of developing markets. Employing the rolling sample test, Wang et al. [12] showed that multifractality degree denoted by the range of generalized Hurst exponents based on MF-DFA could be used to capture the degree of market inefficiency of the Shanghai stock market. Similar results were also confirmed by Wang et al. [13] which investigated the efficiency of another stock market in China.

In this paper, we decompose the realized volatility into continuous sample paths and jump components according to the method in Ref. [4]. Then, the method of multifractal detrended fluctuation analysis (MF-DFA) is employed to detect the evolution of market efficiency of the Shanghai stock market. Using time-varying Hurst exponents based on the rolling window method to detect the evolution of market efficiency is a similar technique to the previous empirical research. But, in this paper, we apply the new realized volatility model, and decompose the realized volatility of the Shanghai stock market into the continuous sample paths and jump components; we analyze each component properties, and combine the Hurst exponents method to test the efficiency of the Shanghai stock market. Empirical results show that the Shanghai stock market becomes more and more efficient due to the Hurst exponents of the different decomposed volatility series. The volatility series of the Shanghai stock market appear to be long-range auto-correlations, which indicates that, when using conventional models such as GARCH, a careful investigation of the volatility series should be carried out.

This paper is organized as follows. Section 2 provides realized volatility model. Methodology description is provided in Section 3. We show empirical results in Section 4. Finally, we provide some conclusions in Section 5.

2. The realized volatility model

2.1. Theoretical models

The logarithm of the asset price follows the continuous-time jump diffusion stochastic model, which can be described as:

$$\mathrm{d}p(t) = \mu(t)\mathrm{d}t + \sigma(t)\mathrm{d}W(t), \quad 0 \le t \le T. \tag{1}$$

The mean $\mu(\cdot)$ denotes a continuous and locally bounded function, $\sigma(\cdot)$ describes a stochastic volatility process, and $W(\cdot)$ denotes the standard Brownian motion.

Then, we define the daily realized volatility at day t with discretely sampled Δ-period returns

$$\Delta r_{t,\Delta} = p(t) - p(t-\Delta). \tag{2}$$

Barndorff-Nielsen and Shephard [5] proposed two general measures for the quadratic variation process – realized variance and realized bi-power variation – which have different distributions.

$$\mathrm{RV}_{t+1}^{(d)}(\Delta) = \sum_{j=1}^{1/\Delta} r_{t+j\Delta,\Delta}^2 \to \int_{t-1}^{t} \sigma_s \mathrm{d}s \tag{3}$$

$$\mathrm{BV}_{t+1}^{(d)}(\Delta) = \mu_1^{-2} \sum_{j=2}^{1/\Delta} \left|r_{t+j\Delta,\Delta}\right| \left|r_{t+(j-1)\Delta,\Delta}\right| \to \int_{t-1}^{t} \sigma_s^2 \mathrm{d}s. \tag{4}$$

Here, $\mu_1 = \sqrt{\pi/2}$ consistently estimates the component of return variation. Therefore, the difference between $\mathrm{RV}_{t+1}^{(d)}(\Delta)$ and $\mathrm{BV}_{t+1}^{(d)}(\Delta)$ is zero when no jump exists there. The difference between $\mathrm{RV}_{t+1}^{(d)}(\Delta)$ and $\mathrm{BV}_{t+1}^{(d)}(\Delta)$ sometimes obtains the negative value. So Barndorff-Nielsen and Shephard [5] suggested to use the following equation to prevent the negative values happening:

$$J_{t+1}^{(d)}(\Delta) = \max[\mathrm{RV}_{t+1}^{(d)}(\Delta) - \mathrm{BV}_{t+1}^{(d)}(\Delta)]. \tag{5}$$

In order to capture the volatility more accurately, we also consider the range of daily realized volatility. A rigorous analysis of intraday ranges, based on the high-frequency data, has been missed in the financial literature, Christensen and Podolskij [14] showed that the pioneering work of Dijk and Martens [15] has studied realized range-based volatility (RRV) for homoscedastic diffusions, but they did not derive a consistence asymptotic distribution. Hence, they provided an efficient estimator to capture the information when investigating the high-frequency data in the stock market, and found that Realized range-based volatility (RRV) was the most efficient estimator.