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Is the efficiency of stock market correlated with multifractality? An evidence from the Shanghai stock market

Rongbao Gu [a,*], Yanmin Shao [b], Qingnan Wang [a]

[a] School of Finance, Nanjing University of Finance & Economics, Nanjing 210046, PR China

[b] Center for Forecasting Science, Chinese Academy of Sciences, Beijing 100190, PR China

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ABSTRACT

In this paper, we propose an efficiency index and multifractality degree for financial markets, and investigate the dynamics of the relationship between the two indices for the Shanghai stock market employing the technique of rolling window. By using the DCCA cross-correlation coefficient, we find that, for the Shanghai stock market, the increase in the degree of market multifractality can lead to a lower degree of market efficiency before the equity division reforms, whereas it can result in a lower degree of market efficiency in the short-term and a higher degree of market efficiency in the long-term after the equity division reforms. This finding reflects the process of development of the Shanghai stock market and also provides strong evidence which supports Liu's argument that the increase in the degree of market complexity can improve the market efficiency Liu (2009) [1].

1. Introduction

Since the efficiency market hypothesis has been introduced by Fama [2], theoretical research and empirical tests of various financial markets, especially stock markets and crude oil markets, have drawn the concern of numerous experts and scholars. By applying a wide range of nonlinear analytical techniques, a series of significant progresses have been achieved in terms of efficiency of financial markets.

The hypothesis of the weak form of the law of market efficiency implies that the serial dependence in asset price changes is negligibly small. So, a market is not weakly efficient if there is long-range dependence in the market. One of the first to consider the existence of long-range dependence in the stock market was Mandelbrot [3]. Since then, many others have supported Mandelbrot's results. Cajueiro and Tabak [4] investigated long-range dependence in the returns of emerging markets for Latin America and Asia employing the Rescaled Range Analysis (R/S) [5] and found that these markets are becoming more efficient over time. Cajueiro and Tabak [6] tested efficiency for Shanghai, Shenzhen, Hong Kong and Singapore stock markets using the median Hurst exponent. They found evidence suggesting that Hong Kong is the most efficient market followed by Shanghai A shares and Shenzhen A shares, and Singapore, and finally by Shanghai B shares and Shenzhen B shares. In Ref. [7], Cajueiro and Tabak investigated long-range dependence in European transition markets and found evidence of strong time-varying long-range dependence in stock returns of these economies, which was in line with evidence of multifractality. Podobnik et al. [8] analyzed the long-range dependence in the capital markets of 10 transition economies in central and east Europe. Apart of Poland and Slovakia, all market indices exhibit long-range dependence of power-law form and all market indices also show long-range dependence on the magnitudes. Tabak and Cajueiro [9] also investigated Brent and the West Texas Intermediate (WTI) oil markets employing R/S analysis. They found evidence that

* Corresponding author.
E-mail addresses: rbgu@sina.com.cn, rbgu@njue.edu.cn, rbgu@sina.com (R. Gu).

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these markets have become more efficient over time and the WTI crude oil prices seem to be more weak form efficient than Brent prices. Alvarez-Ramirez et al. [10] analyzed the auto-correlations of international crude oil prices on the basis of the estimation of the Hurst exponent dynamics for returns and found that the market exhibits a time-varying short-term inefficient behavior that becomes efficient in the long-term.

The weak form of the law of market efficiency states that the present price of a stock depends on all of the information about past prices, and this implies that stock prices at any future time cannot be predicted. Eom et al. [11] investigated the relationships between the degree of efficiency and the predictability in 60 market indexes of various countries. The Hurst exponent was used as the measurement of the degree of efficiency, and the hit rate calculated by the nearest-neighbor prediction method was used for the prediction of the direction of future price changes. They discovered that the relationship between the degree of efficiency (Hurst exponent) and the predictability (hit rate) is strongly positive. That is, a market index with a higher Hurst exponent tends to have a higher hit rate. Zunino et al. [12]studied 18 developed stock markets and 14 emerging markets employing the Multifractal Detrended Fluctuation Analysis (MF-DFA). They found that, employing a binary dependent variable model in Ref. [13], the relationship between the stage of market development and the multifractality degree is negative, i.e., higher multifractality is associated with a less developed (lower efficiency) market. Wang et al. [14] analyzed the long-range dependence of WTI crude oil volatility series employing the MF-DFA. They found evidence suggesting that the WTI volatility series were not efficient, both in the short-term and in the long-term. Analyzing the dynamics of multifractality degrees of auto-correlations of the WTI volatility series for small time scales, they found that the stronger autocorrelations (lower efficiency) were always related to the lower degrees of multifractality by the scatter plots of the variables.

However, even though some evidence shows that market efficiency is related to multifractality, we wonder whether there is any correlation between efficiency and multifractality for a financial market. Recently, Liu [1] has given a theoretical analysis about the relationship between efficiency and complexity of financial markets in China. His research shows that the complexity of the finance market has created an innovative room for the market. This has not only guaranteed the stability of the finance system, but also improved the efficiency of the finance market. He has also suggested that the differences in talent and anticipation of the different investors can lead to stability and balance of the whole market by the investor's different decision making ways, which has enhanced the complexity of the market. The multifractal characteristic of asset prices or returns is a comprehensive reflection of various complex behaviors of a financial market. Liu's research is about the general theoretical analysis of these issues. In this paper, we will give an empirical study on the relation between efficiency and multifractality employing the linear correlation analysis and nonlinear correlation analysis for the Shanghai stock market.

This paper is organized as follows. Section 2 introduces an efficiency index and multifractality degree for financial markets, and analyzes the correlation between the indices. Section 3 shows the nonlinear cross-correlation analysis employed in this paper. The data description and some preliminary analysis are presented in Section 4, and the empirical results and some relevant discussions are provided in Section 5. In the last section, we give a brief conclusion.

2. Choice of indices

2.1. Efficiency index

According to the efficiency market hypothesis which was introduced by Fama [15], efficient markets have three levels, including weak-form efficiency, semi-strong-form efficiency, and strong-form efficiency. A market is deemed as weak-form efficient if the asset prices can reflect all historical information. A market is semi-strong-form efficient if the asset prices can reflect not only all historical information but also all public information. A market is strong-form efficient if the asset prices can reflect not only all historical information and all pubic information but all insider information. If a market is weak-form efficient, all historical information will be included in the current prices and the prices will follow a random walk.

The Hurst exponent, posed by Hurst [5] in studying the Lino river, is an important scale which can be used to test whether a time series follows a random walk. A robust way to calculate Hurst exponent is the Detrended Fluctuation Analysis (DFA) proposed by Peng et al. [16]. The DFA procedure consists of five steps as follows:

Step 1. Let $\{x_t, t = 1, \ldots, N\}$ be a time series, where N is the length of the series. Determine the "profile"

$$xx_k = \sum_{t=1}^{k}(x_t - \bar{x}), \quad k = 1, 2, \ldots, N \tag{1}$$

where $\bar{x}$ denotes the averaging over the whole time series.

Step 2. Divide the profile $\{xx_k\}_{k=1,\ldots,N}$ into $N_s \equiv int(N/s)$ nonoverlapping segments of equal length s. Since the length N of the series is often not a multiple of the considered time scale s, a short part at the end of the profile may remain. In order not to disregard this part of the series, the same procedure is repeated starting from the opposite end. Thereby, $2N_s$ segments are obtained altogether. Introduced by Peng et al. [16], we get $10 < s < N/5$.

Step 3. Calculate the local trend for each of the $2N_s$ segments by a least-squares fit of the series. Then determine the variance

$$F^2(s, \lambda) \equiv \frac{1}{s}\sum_{j=1}^{s}[xx_{(\lambda-1)s+j} - P_\lambda(j)]^2 \tag{2}$$