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A Multifractality Measure of Stock Market Efficiency in Asean Region

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Abstract

This paper investigates the presence of multifractality property of the daily composite stock price index of the six countries in the Association of Southeast Asian Nation (ASEAN) region using the multifractal detrended fluctuation analysis (MFDFA). Covering the period from January 2, 2006 to June 28, 2013, the countries under study are the following: Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. If multifractality is present, then the traditional time series models of fractional Brownian motion and GARCH processes are inadequate to capture the stylized facts observed in financial time series which include long-range correlations and broad fat-tail distributions. The study also employs a sliding window MFDFA to obtain the dynamics of the local Hurst exponents which can be used as a measure of market efficiency.

The findings suggest that the stock price indices of the six countries under study have the properties of multifractality. These suggest that the traditional time series models of fractional Brownian motion and GARCH processes are not appropriate and a call for a better model which incorporates multifractality and non-Gaussian distributions is made. Moreover, an efficiency ranking of stock markets of the six countries under study is provided. This result is important to guide investors seeking profit opportunity which is dependent upon market efficiency. It is also important to help policy makers decide to implement institutional reforms aimed at increasing market efficiency.

Keywords: Efficiency, Financial Markets, Multifractality, Hurst Exponent

1. Introduction

Fractal as introduced by Mandelbrot (1977, 1982) describes a geometric patterns with large degree of self-similarities at all scales. The smaller piece of a pattern can be said to be a reduced-form image of a larger piece. This characteristic is used to measure fractal dimensions as a fraction rather than an integer. Some examples of fractal shapes are rugged coastlines, mountain heights, cloud outlines, river tributaries, tree branches, blood vessels, cracks, wave turbulences and chaotic motions.

However, there are self-similar patterns that involve multiple scaling rules which are not sufficiently described by a single fractal dimension but by a spectrum of fractal dimensions instead. Generalizing this single dimension into multiple dimensions differentiates multifractal from fractal discussed earlier. To distinguish multifractal from single fractal, the term monofractal is used to refer to single fractal in this paper. Among the natural systems that have been observed to have a multifractal property are earthquakes (Parisi and Frisch, 1985), heart rate variability (Goldberger et al., 2002) and neural activities (Zheng et al., 2005).

Mandelbrot (1997) introduced multifractal models to study economic and financial time series in order to address the shortcomings of traditional models such as fractional Brownian motion and GARCH processes which are not appropriate with the stylized facts of the said time series such as long-memory and fat-tails in volatility. Further studies confirmed multifractility in stock market indices (Barunik et al., 2012; Cajueiro, 2009; Hui et al., 2012; Jiang and Zhou, 2008; Katsuragi, 2000; Kristoufek and Vosvrda, 2013; Lu et al., 2012; Lye and Hooy, 2012; Matteo et al., 2005; Norouzzadeh and Jafari, 2005; Oswiecimka et al., 2006; Sun et al., 2001; Yuan et al., 2009; Zunino et al., 2007, 2008 and 2009), foreign exchange rates (Barunik et al., 2012; Ioan et al., 2012; Norouzzadeh and Rahmani, 2006; Oh et al., 2012; and Vandewalle and Ausloos, 1998) and interest rates (Cajueiro and Tabak, 2007).

The Hurst exponent which describes the dimensions of multifractals, is related to the predictability of the time series (Qian and Rasheed, 2004). If a market is efficient, then its return must follow a random walk behavior, hence, unpredictable. Thus, the Hurst exponents can be used to measure market efficiency (Cajueiro, 2009; Ioan et al., 2012; Kristoufek and Vosvrda, 2013; Lye and Hooy, 2012; Matteo et al., 2005; Onali and Goddard, 2011; Zunino et al., 2007 and 2009).

This paper employs the multifractal detrended fluctuation analyses (MFDFA) to detect and characterize the presence of multifractality in the Association of Southeast Asian Nation (ASEAN) stock market indices. The study covers the following ASEAN countries: Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. By using a sliding windows approach, this study dissects the evolution of the local Hurst exponents in each of the stock index time series. A measure of market efficiency is obtained based on the statistical properties of these local Hurst exponents.

This paper proceeds as follows: Methodology is discussed in Section 2. Data is described in Section 3. Presentation of results is in Section 4. Finally, the paper concludes in Section 5.

2. Methodology

In measuring multifractality, the paper uses the method of multifractal detrended fluctuation analysis (MFDFA) as outlined in Kantelhardt et al. (2002). Matlab codes used are based on Ihlen (2012). The procedure is summarized in the following steps.

1. Given a time series u_i, $i = 1, \dots, N$, where N is the length, create a profile
   $Y(k) = \sum_{i=1}^{k} u_i - \bar{u}$,
   $k = 1, \dots, N$, where $\bar{u}$ is the mean of u.
2. Divide the profile $Y(k)$ into $N_s = {}^{N}/_{s}$ non-overlapping segment of length s. Since N is not generally a multiple of s, in order for the remainder part of the series to be included, this step is repeated starting at the end of the series moving backwards. Thus, a total of $2N_s$ segments are produced.
3. Generate $Y_s(i) = Y_s[(v-1)s + i]$ for each segment $v = 1, \dots, N_s$, and
   $Y_s(i) = Y_s[N - (v - N_s)s + i]$ for each segment $v = N_s + 1, \dots, 2N_s$.
4. Compute the variance of $Y_s(i)$ as
   $F_s^2(v) = \frac{1}{s}\sum_{i=1}^{s}[Y_s(i) - Y_v(i)]^2$,
   where $Y_v(i)$ is the m^{th} order fitting polynomial in the v^{th} segment.
5. Obtain the q^{th} order fluctuation function by
   $F_q(s) = \left\{\frac{1}{2N_s}\sum_{v=1}^{2N_s}[F_s^2(v)]^{q/2}\right\}^{1/q}$.

If the time series are long-range correlated then $F_q(s)$ is distributed as power laws, $F_q(s) \sim s^{h(q)}$. The exponent $h(q)$ is called as the generalized Hurst exponent. The value of $h(q)$ tells something about the behavior of the fluctuations in the time series. When $h(q) > 0.5$, the fluctuations are persistent. This means that an increase (decrease) in the previous period is followed by another increase (decrease) in succeeding period. When $h(q) < 0.5$, the fluctuations are anti-persistent. This implies that an increase (decrease) in the previous is followed by a decrease (increase) in succeeding period. The last case of $h(q) = 0.5$ implies that the fluctuations are just random walks.

For monofractals, the Hurst exponent is a constant equal to $h(2)$. The closer the value of $h(2)$ to 0.5, the more closely the time series mimics random walk. Hence, market efficiency can be measured by the distance of $h(2)$ from 0.5. For multifractals however, $h(q)$ varies with q. Thus, a spectrum of $h(q)$ values implies the presence of multifractality.

To capture the dynamics of local Hurst exponents, a sliding window approach is used in applying MFDFA. As explained in Lye and Hooy (2012), the rationale of this approach is that the Hurst exponents for the entire period may not fully reflect the richness of the multifractality as the negative and positive correlations might just be averaged out. Moreover, sliding window will capture the evolution of local Hurst exponents.

Since, the closer the value of $h(2)$ to 0.5, the more closely the time series mimics random walk, then the following measure of efficiency modified from Zunino et al. (2007) which is based on the statistical properties of the Hurst exponents, namely the mean and standard deviation, is used:

$$eff = \frac{|\bar{H} - 0.5|}{\sigma_H}$$

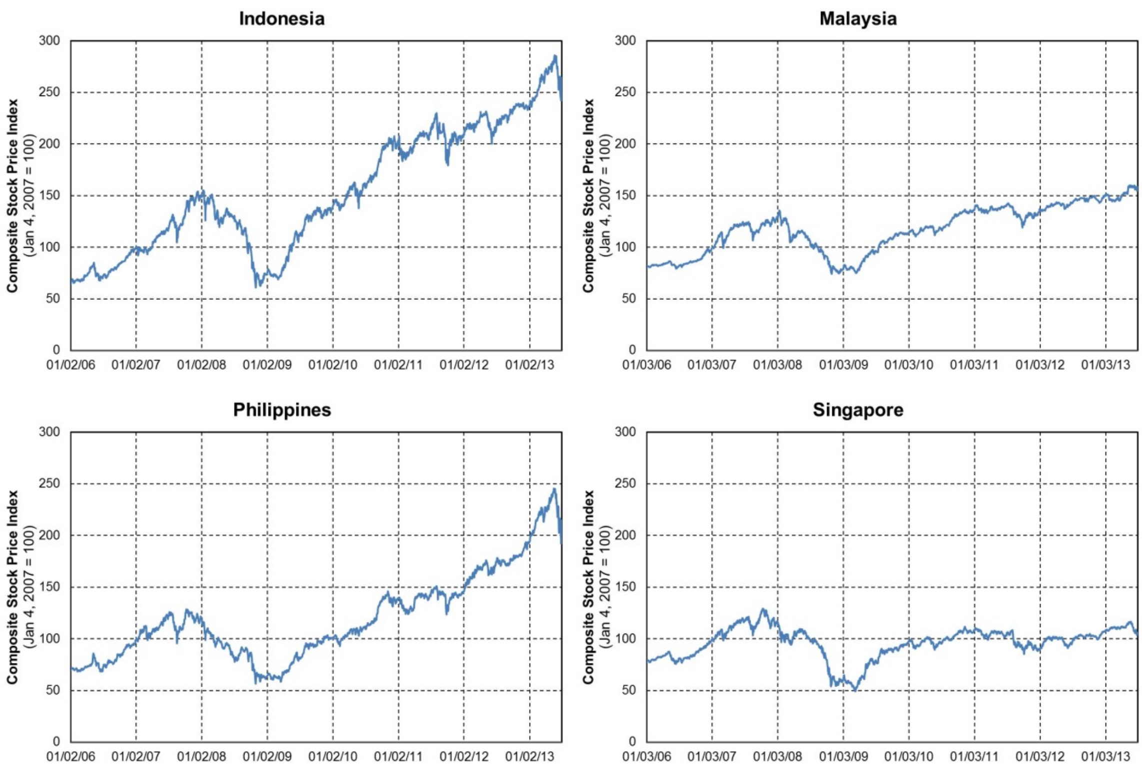
where $\bar{H}$ is the mean of $h(2)$ and σ_H is its standard deviation. The closer the value of eff to zero, the more efficient is the market.

3. Data

The daily composite stock price index of Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam from January 2, 2006 to June 28, 2013 is used. The number of observations ranges from 1830 in Indonesia and Vietnam to 1880 in Singapore. The reason for the variation is due to the differences in the number of trading days in each country as it is also dependent upon by the number of local holidays. The data is downloaded from Asia Regional Integration Center online database website: http://aric.adb.org/macroindicators of the Asian Development Bank. Figure 1 shows the plots of the daily composite stock price index of the six ASEAN countries. The composite stock price is indexed at 100 on January 4, 2007. Figure 2 shows the plots of the corresponding daily returns of stock price index of the six ASEAN countries. The daily returns are computed as the log of the first difference in stock price index.

4. Results

In conducting MFDFA, $m = 3$ is used as the order of polynomial fit in Step 4. The length s varies from 20 to $N/4$ with a step of 4 as suggested in Kantelhardt et al. (2002). Finally, q runs from –10 to 10 with a step of 0.5. A window length of 240 days or around 1 year is chosen with a shift between windows equal to 5 trading days or around 1 week. Figure 3 presents the evolution of the generalized Hurst exponents corresponding to the daily composite stock price index of the six ASEAN countries. It can be readily seen that for each window, the corresponding Hurst exponents is not a single point but rather a spectrum. This manifests the presence of multifractality in all the six panels in Figure 3. This means that the traditional time series models of fractional Brownian motion and GARCH processes are not appropriate for this purpose.



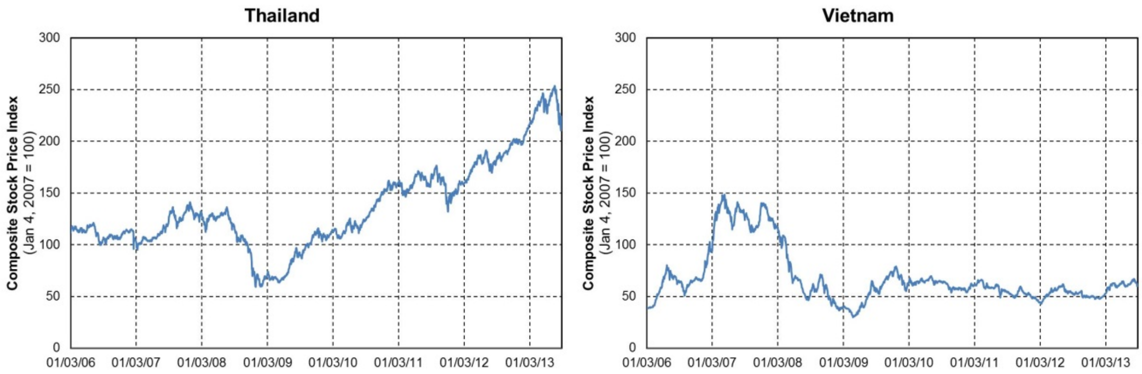


Figure 1. Plots of the composite stock price index of the six ASEAN countries.

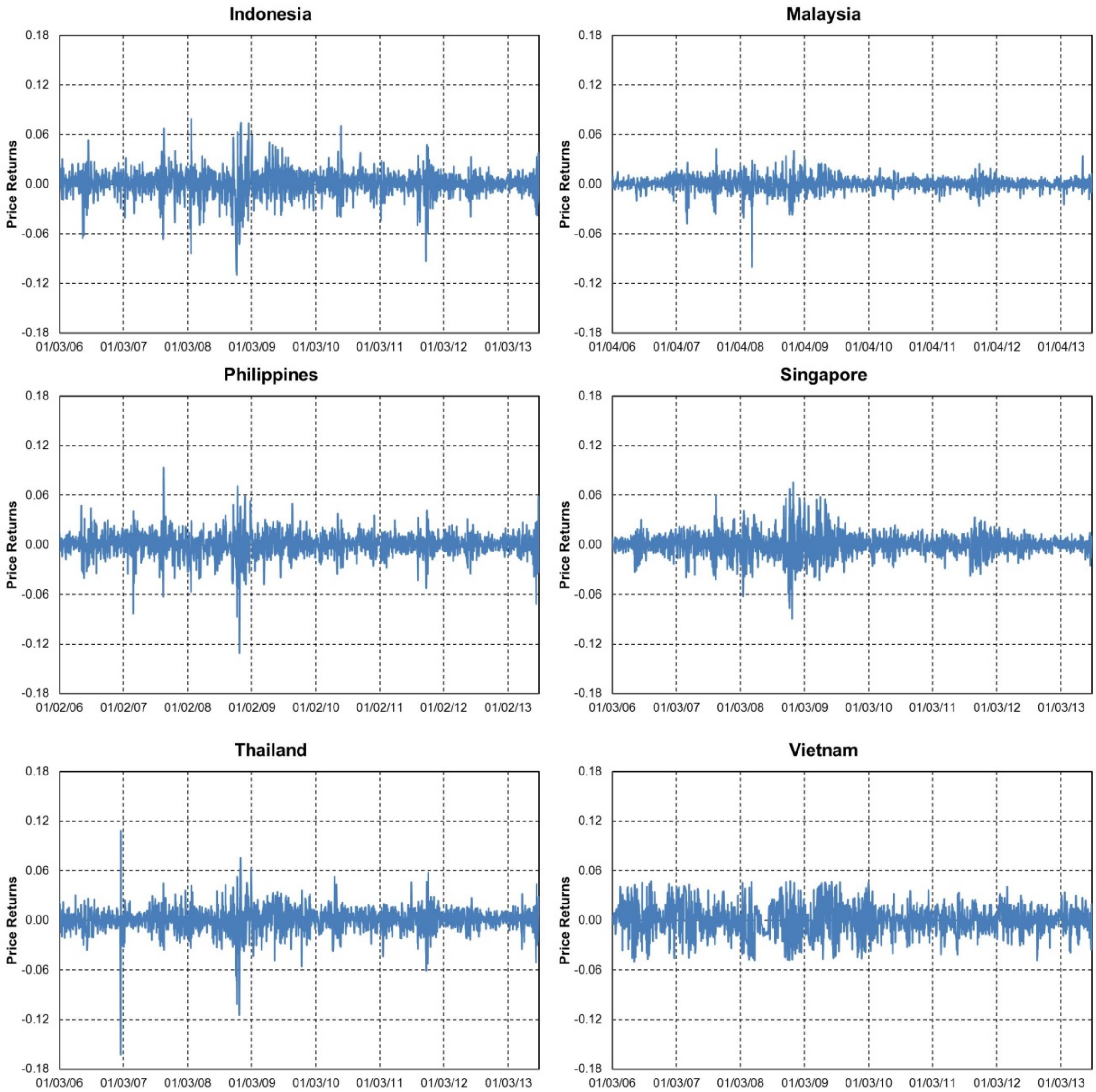


Figure 2. Plots of the daily composite stock price index of the six ASEAN countries.

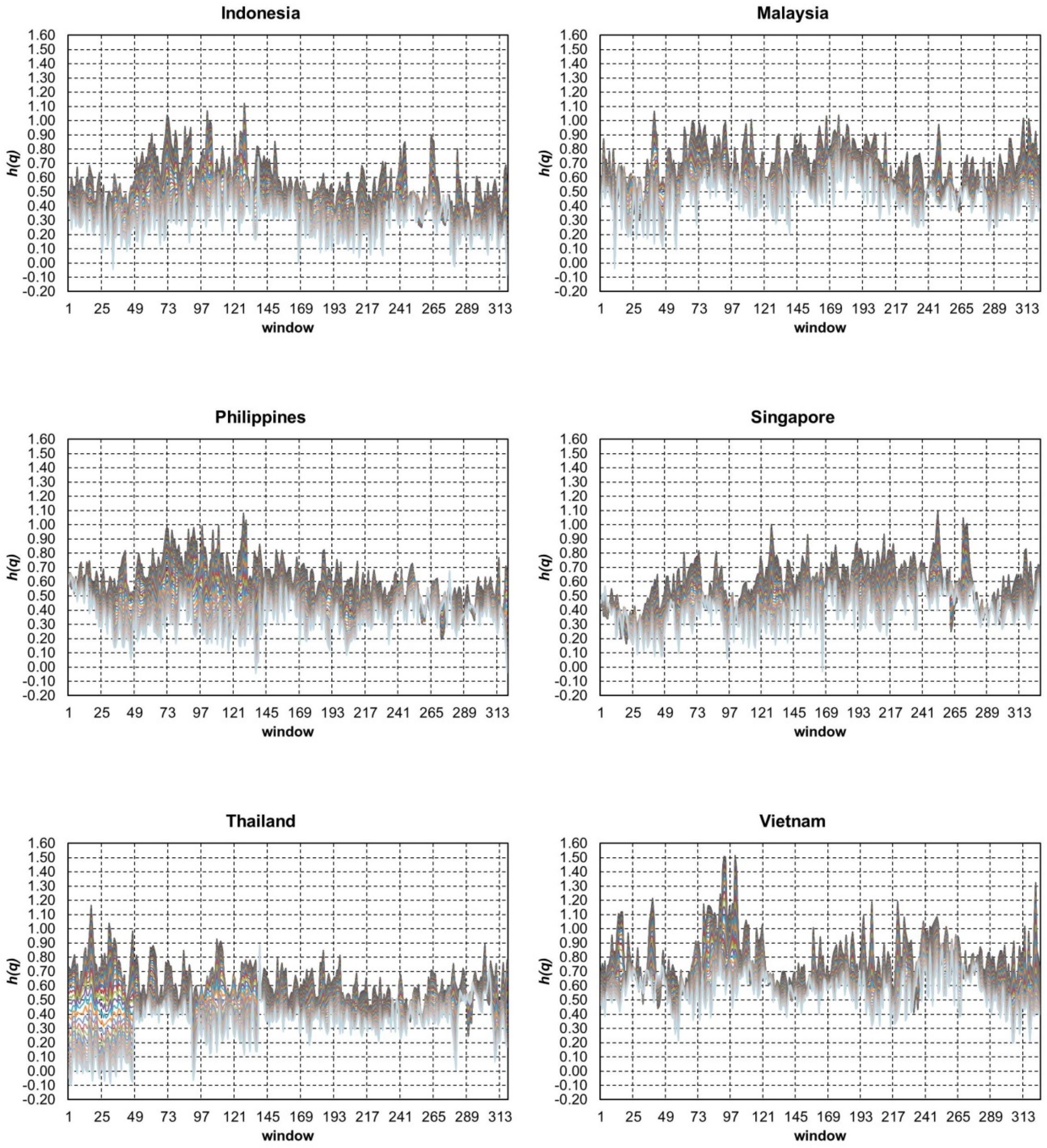


Figure 3. Evolution of the generalized Hurst exponents corresponding to the daily composite stock price index of the six ASEAN countries.

Table 1. Mean, $\bar{H}$, and standard deviation, σ_H, of $h(2)$, efficiency measure, eff, and rank.

Country	$\bar{H}$	σ_H	eff	Rank
Indonesia	0.4005	0.0932	1.0680	5
Malaysia	0.5516	0.0903	0.5707	2
Philippines	0.4543	0.0731	0.6255	3
Singapore	0.4670	0.0866	0.3812	1
Thailand	0.4427	0.0744	0.7700	4
Vietnam	0.6404	0.1006	1.3964	6

Table 1 presents the mean, $\overline{H}$, and standard deviation, σ_H, of $h(2)$ obtained from sliding windows. Alongside is the efficiency measure, eff, introduced in Section 2. The countries' efficiency ranking of their stock markets is provided in the last column. The ranking shows that Singapore has the most efficient stock market while Vietnam is the least efficient in the ASEAN region. This means that Singapore's stock price behavior is closest to random walk while Vietnam's stock price is the least unpredictable in the region. This suggests that profitable opportunity as a result of informational advantage is more likely in Vietnam and least likely in Singapore. A need for institutional reform to eliminate this informational advantage in Vietnam is called for.

5. Conclusions

By applying MFDFA to the daily time series data of the six composite stock price indices in the ASEAN region, the paper provides empirical evidence of the presence of multifractality in these time series. This suggests that the traditional time series models of fractional Brownian motion and GARCH processes do not fully capture the properties of these data. Hence, these traditional models are not appropriate and a call for a better model which incorporates multifractality and non-Gaussian distributions is needed.

The sliding windows approach made possible the computation of efficiency of stock markets in the region. The result shows that among the six countries in the study, Singapore ranks first as the most efficient while Vietnam is the least efficient. Thus, it is most likely to gain from informational advantage in Vietnam. This calls for institutional reform addressed at eliminating this advantage.

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