Are South East Asia Countries Capital Markets Characterized by Nonlinear Structures? 
An Investigation from Indonesia, Philippine and Singapore Capital Market Indices*

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ABSTRACT

This research paper tries to detect the nonlinear structure in the South East Asia Countries Capital Markets. The capital markets of three South East Asia Countries are chosen: Indonesia, Philippines, and Singapore. Daily return data of Capital Markets composite indices are observed: Straits Times Index (STI) of Singapore Exchange from January 04, 1985 to December 31, 2007, Pilipino Stock Exchange Index (PSEi) of Philippines Stock Exchange from March 1, 1990 to December 31, 2007 and Jakarta Composite Index (JCI) of Indonesia Stock Exchange from January 05, 1988 to December 31, 2007.

Should nonlinearity be found, the outcomes of each observation are compared to analyze the implications of each country in global, regional and local position of their competition in the continuously changing world of interdependency environment. The implications of nonlinearity finding in the three ASEAN countries capital markets to the current issues of AFAS on Financial Services, Harmonization among ASEAN countries capital markets in the ASEAN region and ASEAN integration and liberalization on Financial Services are analyzed.

BDS statistic and R/S Analysis as our tools for nonlinearity testing are applied. Nonlinearity evidences in Jakarta Composite Index, Pilipino Stock Exchange Index and Straits Times Index are found.

Keywords: Brock-Dechert-Scheinkman Statistic, Correlation Dimension, Deterministic Non Linear Dynamic System, Embedding Dimension, Fractal, Hurst Exponent, Rescaled Range (R/S) Analysis

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1. INTRODUCTION

In the global competition the role of South East Asia region should not be ignored especially in term of globalization of investment. Although majority of South East Asia countries are developing countries but they have significant economic growth. To accelerate each country growth in this region a free trade area on Financial Services of this region is currently being created through the Association of South East Asia Nations (ASEAN). The ASEAN Free Trade Area on Financial Services agreement to accommodate and facilitate trading freely among ASEAN member countries will be a facility for liberalization and integration of Financial Services among ASEAN member countries. In designing this agreement cautions should be taken on the impact of the agreement by understanding how each country financial market systems had behave and will behave. Failing to understand the system will produce a false policy to be applied to the system. Policy as a system control tool applied inappropriately to the system affects undesired direction of outcome to be controlled. Deepen exploring South East Asia Nations Capital Markets will lead to better understanding of the behavior of the system which might be characterized by nonlinear structure.

Recently there is a trend of rapid growth in foreign investment in Financial Market particularly in stock market. The role of foreign buyers becomes crucial to succeeding securities trading. Liberalization in Financial Markets will facilitate foreign buyers to freely access foreign stock market. For diversification purpose, a continuing growth of internationally oriented financial products has taken place. In the international as well as regional arena, recent developments in many fields especially in information technology progress have increased cross listings of multinational companies in which have impacted stock market. As a result, stock markets have moved toward global integration as well as regional integration in their competition world both globally and regionally. Several empirical studies to assess degree of integration of international stock markets find strong statistical significant level of global integration leading to reduce benefits from international portfolio diversification. Other studies investigate the increased international interdependence by exploring national stock market crashes find the fall of national stock markets simultaneous and mutually reinforcing. Empirical evidence indicates a slowing down of current growth and possible reduction of international portfolio investment. This leads to questioning the efficiency concept of foreign financial market besides efficiency of national financial market.

Since capital market is an informational driven system the role of information technology progress in accelerating dissemination of information has affected financial market in general and stock market particularly. Nowadays people collect information easily by exploring internet. They gather true or untrue, correct or incorrect, right or wrong, valid or invalid information even without any knowledge and understanding of it. Some people have enough knowledge and time to verify any information acquired. Due to high speed of information changes and its high degree of dissemination most people don’t make any verification of information and believe rumors as true material information. How people perceive the information they elaborate will define the decision they make. People’s perception of information becomes crucial to determine the direction of finance and economic. Control of disseminated information through internet becomes uneasy due to limitation in legal, rule and policy across countries in term of internet information system.

In examining stock market efficiency most researches rely on linear techniques to find out a hidden structure that makes the movement of stock prices. This technique fails to detect multi dimensional and non linear patterns. Movements in stock prices are stochastic if not a random walk was taken for granted as a common believe for a long time to explain nonlinearity. Recent studies examine the possibility of nonlinearity in financial data. Some studies find the empirical evidence of nonlinear dependencies in financial time series. Linear methods are related to all regularities of the structure in which small causes lead to small effects and one closed solution will be produced in the outcome. Linear equations lead to exponentially growing or periodically oscillating solution only. Therefore possible causes of irregular behavior in a system are nonlinear and chaos besides random
external input. Uncertainty evolves due to irregularities in which there are many possible solutions. Nonlinear equations produce many possible solutions instead of one closed solution. No one closed solution shows non equilibrium. Irregularities are characteristic of most financial and economic data. Financial players behave irrationally due to uncertainty and irregularities. Behavioral finance studies irrational behavior of financial players.

The aim of this research is to answer our research question whether three South East Asia countries capital markets index return series are better described by linear models or composed by nonlinear specifications as evidence of more complex dependence. Investigation of nonlinear dependence in stock market index return is an integral part of informational efficiency investigation. The analysis of nonlinearity and non random walk finding by elaborating market efficiency and behavioral finance in the national stock market will be used for examining globalization of investments and international integration either regional integration or global integration.

The next section provides review related literatures. In section 3 the methodology is outlined. Section 4 presents preliminary descriptive statistics and describes datasets for each index including time frame. The results are presented and discussed in section 5. The paper concludes with a summary and describes the implications in the sixth section.

2. THEORITICAL BACKGROUND OVERVIEW OF RELATED LITERATURES

Some studies (Brock et al., (1987, 1991), Hsieh, (1989, 1991, 1993), Willey, (1992), and Scheinkman and LeBaron, (1989)) on nonlinear dynamics have found evidence that residuals of whitened stock index returns are not IID (independently and identically distributed). Barnett and Chen (1986, 1988), Brock and Sayers (1988), Barnett and Hinich (1992, 1993), Chen (1988), and DeCoster and Mitchell (1991) provided evidence of nonlinear structures. Philippatos et al., (1993) use the Brock’s Residual test theorem to uncover the presence of similar nonlinear behavior in ten international indexes. Sewell et al., (1993) document nonlinear dependencies in the stock markets of Hong Kong, Korea, Japan, Singapore and Taiwan. Errunza et al., (1994) identify nonlinear dependencies in the market of Germany, Japan, and the emerging markets of Argentina, Brazil, Chile, India and Mexico. Pandey et al., (1998) study deterministic nonlinearity of major European equity markets and the United States. Abhyankar et al., (1997) test for nonlinear dependence and chaos on the world’s four most important stock-market indexes. Empirical evidences on nonlinear dependencies suggest that stock prices may be more predictable than formerly thought (Hinich and Patterson, (1985), Scheinkman and LeBaron, (1989), Peters, (1991, 1994), Hsieh, (1991)).

Previous studies have provided useful information of informational efficiency of financial markets (Atkins and Dyl, 1990 and Ball and Kothari, 1989) but there are very little evidences on the nonlinear dynamics of the major global markets.

Efficient Market Hypothesis (EMH) followers argue that the market price movements are rational and efficient. The concept of the rational investor was crucial to the EMH. The EMH believes that stock prices reflect all information known. EMH claims that the stock market is driven by purely random unanticipated news. EMH holds that there is no systematic structure exists on stock market. EMH has an independence assumption which says that past information does not affect market activity, once the information is known. The EMH justifies the use of probability calculus in analyzing capital markets. However, if the markets are nonlinear dynamic systems, then the use of standard statistical analysis can give misleading results, particularly if a random walk model is used.
3. RESEARCH METHODOLOGY

In this paper two robust enough tests are implemented for nonlinear testing. BDS Statistic is applied to test nonlinear dependence. R/S Analysis test is used to test persistence or strong dependence as an indicator of the presence of Long-Term memory.

BDS Statistic (Brock et al. (1987, 1996)) tests for nonlinearity based on the null hypothesis that a data series is independent and identically distributed (IID). The BDS test statistic attempts to overcome shortcomings of the correlation dimension. The BDS statistic is distributed asymptotically normal and avoids the biases of the correlation dimension. BDS statistic test rely on the limiting value of the correlation integral and transforms it into a formal test statistic which is asymptotically distributed as a standard normal variable under the null hypothesis of IID against an unspecified alternative. Brock et al. (1987) derived the estimator variance providing a basis for tests of the IID hypothesis.

Rejecting the null hypothesis of IID is not enough to claim a data series is chaotic and as an evidence of the presence of nonlinear dynamics. The BDS test rejects IID for linear as well as nonlinear processes. Since the test has power against many forms of deviation from IID, BDS test is usually carried out on the residuals of a linear and/or GARCH-type filter. This step is known as pre-whitening or bleaching and makes it possible to see if further determinism beyond that described by linear or GARCH process is present in the data. After data has been pre-whitened and non stationarity is ruled out, the rejection of the null of IID by the BDS statistic points towards the existence of some forms of nonlinear dynamics.

The BDS test statistic is defined by:

\[
W(m, \varepsilon, T) = \sqrt{T} \frac{C(m, \varepsilon, T) - C(l, \varepsilon, T)^m}{\sigma(m, \varepsilon, T)}
\]

(3.1)

\[
\sigma_m(\varepsilon) = 2\left\{K^m + 2\sum_{j=1}^{m-1}K^{m-j}C(\varepsilon)^{2j}\right\} + (m - 1)^2C_{1,T}(\varepsilon)^2m - m^2KC_{1,T}(\varepsilon)^{2m-2}\right\}^{\frac{1}{2}}
\]

(3.2)

where the correlation integral is defined by:

\[
C_m(\varepsilon) = \frac{1}{(T - m + 1)(T - m)}\sum_{i \neq j} I_x(X_i^m X_j^m)
\]

(3.3)

and K(\varepsilon) is estimated by:

\[
K(\varepsilon) = \frac{6\sum_{i < j < T} h_x(X_i^m, X_j^m)}{(T - m + 1)(T - m)(T - m - 1)}
\]

(3.4)

\[
h_x(i, j, k) = I_x(i, j)I_x(j, k) + I_x(i, k)I_x(k, j) + I_x(j, i)I_x(i, k)
\]

(3.5)

where: 
- \(T = \) the number of observations
- \(\varepsilon = \) a distance measure as chosen proximity parameter
- \(m = \) the number of embedding dimensions
- \(C = \) the Grassberger and Procaccia Correlation integral
- \(\sigma^2 = \) a variance estimated of \( C(m, \varepsilon, T) - C(l, \varepsilon, T)^m \)
- \(\sigma(m, \varepsilon, T) = \) Statistic deviation standard of correlation integral varied by dimension \(m\)

The Rescaled Range (R/S) analysis is an indicator of the persistence of a series where the influence of a set of past returns on a set of future returns is effectively captured.
The Rescaled Range (R/S) analysis was developed by Hurst (1951). The application of Hurst’s technique is explained by Peters (1991). Mandelbrot (1972) suggests using R/S Statistics or the range over standard deviation which is the range of partial sums of deviations of a time series from its mean rescaled by its standard deviation to detect long-range or “strong” dependence. R/S analysis can detect non periodic cycles that are cycles with periods equal to or greater than the sample period. Long-range dependence can be detected by the “classical” Rescaled Range (R/S) statistic which is given by:

\[
(R/S) = \frac{\max_{1 \leq t < N} \left[ \sum_{i=1}^{N} \left( r_i - r_t \right) \right] - \min_{1 \leq t < N} \left[ \sum_{i=1}^{N} \left( r_i - r_t \right) \right]}{S}
\]  

(3.6)

where: R/S = a standardized range of cumulative deviations for all N-length sub periods
\( r_t \) = the \( t \)th observation in the series being analyzed
\( S \) = the standard deviation of the original series

However the most important shortcoming of the rescaled range is its sensitivity to short-range dependence, implying that any incompatibility between the data and the predicted behavior of the R/S statistic under the null hypothesis need not come from long-term memory, but may merely by a symptom of short-term memory (Lo & MacKinlay, 1999). Lo & MacKinlay (1999) suggests using modified rescaled range to distinguish between long-range and short-range dependence by modifying classical R/S statistic so that its statistical behavior is invariant over a general class of short memory processes but deviates for long memory processes as below:

\[
Q_n = \frac{1}{\sigma_n(q)} \left[ \max_{1 \leq k \leq n} \sum_{j=1}^{k} \left( X_j - \bar{X}_n \right) - \min_{1 \leq k \leq n} \sum_{j=1}^{k} \left( X_j - \bar{X}_n \right) \right]
\]  

(3.7)

where

\[
\sigma_n(q)^2 \equiv \frac{1}{n} \sum_{j=1}^{n} \left( X_j - \bar{X}_n \right)^2 + \frac{2}{n} \sum_{j=1}^{n} \omega_j(q) \left\{ \sum_{i=j+1}^{n} \left( X_i - \bar{X}_n \right) \left( X_{i-j} - \bar{X}_n \right) \right\}
\]  

(3.8)

Besides taking the raw data as comparison, methodology for R/S analysis used by Peters (1991) by taking residual of AR(1) for correcting short-range dependence in R/S analysis is applied in this study rather than using modified R/S analysis suggested by Lo & MacKinlay due to its simplicity in data processing.

Hurst (1951) found that R/S could be estimated by the following empirical relationship referred to as Hurst’s Empirical Law:

\[
(R/S) = a \cdot (N)^H
\]  

(3.9)

The logs of above equation:

\[
\log(R/S) = H \times \log(N) + \log(a)
\]  

(3.10)

where: \( a = \) a constant
\( H = \) Hurst Exponent
H can be estimated by performing an OLS regression between observing log (R/S) and log (N) for the linear portion of the plot. For short natural memory cycles, R/S estimates would display persistence or anti-persistence only for a short length period. H = 0.5 implies a non-deterministic process or random process in which the past history does not influence the future of the series. H below 0.5 implies anti-persistent behavior in which a positive trend in a period will be followed by a negative trend in the next period. H above 0.5 implies persistent behavior in which a positive trend will be followed by another positive trend.

4. DATA AND DESCRIPTIVE STATISTICS

This study examines three capital markets of the following countries in the South East Asia Region: Indonesia, Philippine, and Singapore. The data consist of daily closing price indices for the following equity markets: Jakarta, Singapore and Philippine. The Straits Times Index (STI) data from December 06, 1985 to March 15, 2000 were collected from Singapore Exchange – Archived Press Releases of Singapore Press Holding. The Filipino Stock Exchange Index (PSEi) data from March 1, 1990 to December 31, 2007 were collected from Philippines Stock Exchange. The Jakarta Composite Index (JCI) data from January 05, 1988 to December 31, 2007 were compiled from Indonesia Stock Exchange and Thomson Reuters.

To avoid problem showed by Hinich and Patterson (1985) that non-stationarity in time series data may cause a spurious rejection of linearity, the raw data of three time series data Indices: STI, PSEi, and JCI is transformed into return data. The return on each of the series is calculated by:

\[ R_i = \ln \left( \frac{P_i}{P_{i-1}} \right) \] (4.1)

where \( R_i \) is the log return of the \( i^{th} \) time observation.

The summary of descriptive statistics for indexes and their returns is presented in Table 1. All return series are approximately zero mean. Due to non-stationarity all index series are far from zero mean. All series are positively skewed but STI return series is negatively skewed. There is evidence of leptokurtosis in all series but PSEI raw index is platikurtosis. The coefficients of kurtosis for all indices are different from normal distribution. Even though differ from normal distribution PSEI raw index and STI raw index approach normal distribution. All of the series show strong signs of non-normality due to leptokurtosis and skewness. This is a feature of most financial data (Hsieh. 1988). These finding leads to an expectation that the indexes return possess some dependence structure.

5. RESULTS

The results of the BDS tests are given in Table 2, 3 and 4 for each data series for dimensions \( m=2, \ldots, 10 \) and the distance measure \( \varepsilon = 0.25\sigma, 0.5\sigma, 0.75\sigma \) and \( 1.00\sigma \). A high positive BDS statistic indicates that the probability of any two \( m \) histories, \((x_t, x_{t-1}, \ldots, x_{t-m+1})\) and \((x_s, x_{s-1}, \ldots, x_{s-m+1})\), being close together is higher in the non random data than in truly random data. This means some clustering occur too frequently in an \( m \)-dimensional space and some patterns of stock return movements take place more frequently with non random data than with truly random data. A lower \( \varepsilon \) value is a more stringent criterion while a higher \( \varepsilon \) value is the most relaxed one.

We test the return series, the shuffled return series, the filtered return series, the raw index series and the shuffled index series. Since this research concerns with nonlinearity which is the detection of nonlinear dynamics, autocorrelations are filtered out using
autoregressive moving average models. The appropriate lag length is determined by the Akaike Information Criterion (AIC) to expect the best fitted model of return series. The return series are filtered to eliminate linear dependence by taking residual of ARMA process, to eliminate nonlinear dependence by taking residual of GARCH process, and to eliminate linear and nonlinear dependence. The return series are scrambled three times to destroy any linear and non linear dependence.

The results in Table 2, 3 and 4 show a summary rejection of the null hypothesis of IID for all series at all dimensions except for shuffled series. For each embedding dimension, BDS test statistic is insignificant for the shuffled series but significant for all raw index series, filtered return series and return series. Rejection of the null hypothesis of IID for raw index series and return series indicates existence of non random processes in the raw index data that might be caused by linear process, stochastic nonlinear process, combine of linear and nonlinear process or chaotic process.

Filtering through a GARCH model which is residual of GARCH model does not reduce the BDS value or change the rejection of the null hypothesis of IID. This indicates that dependence on return series cannot be explained by stochastic non linear model. Filtering through ARMA model for JCI and STI return indexes does not reduce BDS value. For PSEi return, filtering through an ARMA model will reduce the BDS value a little bit but it does not change the rejection of the null hypothesis of IID. Residual of a true stochastic process (linear or non linear) should be random. This means that PSEi return might be created by linear process but since the null hypothesis of IID for the residual of the linear process is rejected thus there remains further dependence in the data that cannot be explained by reference to linear models.

The results of the R/S Analysis can be found in Table 5. Figure 2, 8 and 14 displays the rescaled ranges and V-Statistic for return of JCI, PSEi and STI respectively. V-statistic is used to find the non periodic cycle. In this test, pre-whitening or bleaching will not be applied. Only return series is applied without filtering them since the results of BDS statistic show data series are not affected by linear process. BDS statistic results show stochastic process is not robust enough in the return series and high nonlinearity found in the return series is not generated by stochastic processes.

However Peter’s technique by taking residual of AR(1) is applied to correct for short-range dependence. The result of R/S Analysis and V-Statistic of AR(1) residual is shown in Figure 6, 12 and 18 for return series of JCI, PSEi and STI respectively.

Scrambling will destroy the structure of the system and also the long memory process which indicated by drop value of Hurst Exponent H. Figure 4, 10 and 16 displays the rescaled ranges and V-Statistic for shuffled return series of JCI, PSEi and STI respectively. E(H) which is expected R/S values under the random null hypothesis is used as significance test of H. For shuffled return series H will approach and close to E(H) and 0.5. For non scrambled series H will be higher enough than E(H). Non random walk series or non gaussian series will have H above 0.5. Due to insufficiency of scrambling procedure (applied only 3 times) H of index and return shuffle series might be above E(H).

The objective of forecasting the behavior of index (or prices) makes using return is inappropriate since return whitens data by eliminating serial dependence and makes the data appropriate for linear analysis and independence. Finance and economics have a long tradition of using returns but returns are not an appropriate transformation of prices for research of nonlinear dynamic systems. Using returns complicates the problem dramatically in the other side using prices involves a different problem of continuously growing value of assets without bound because of economic growth and inflation (Peters, 1991). Very high H value of index series proves this phenomenon. Therefore raw index series and shuffle index series are also tested. Odd number figures (Figure 1, 3, 5, …, 17) present the rescaled ranges and V-statistics for index series, shuffle index series and residual AR(1) index series of JCI, PSEi and STI respectively. Due to non stationarity, H of raw index series is very persistence with a high value of H. Non periodic cycles of Index series are less than return series.

All series show persistence with Hurst Exponent H is less than 0.6 for return series and more than 0.7 for raw index series. Closer values to 0.5 indicate bias caused by (1) the
existence of noise and (2) insufficient data caused by insufficient length of data period or over sampling (Peter, 1991 & 1994). STI series has a longest non periodic memory cycle (999 days) and in the other hand PSEi series has a shortest non periodic memory cycle (775 days). JCI has a strongest evidence of temporal persistence dependency with a highest H value of 0.585 and a lowest fractal dimension of return time series (1/H = 1.709) but STI is in the opposite side. JCI return series will last for cycles of approximately 869 days. STI return series show weak persistence and weak nonlinear temporal dependency with Hurst exponent of 0.556 that last for a longest non periodic memory cycles. Removing short-dependence by taking out AR(1) will drop H to approaching E(H) and 0.5. By comparing the result of AR(1) residual series and shuffle series it can be concluded that there are still dependencies on the residual series although the results show very marginal persistence and very weak nonlinear temporal dependency with Hurst Exponents are below 0.55. Short memory cycle (less than 1000 days) suggest that only short term predictability is possible.

6. IMPLICATION AND CONCLUSION

The results of this study provide the evidences of nonlinearity in all examined daily raw indexes and returns. Hypothesis of independence for all raw indexes and returns are rejected which indicates nonlinearity. Even though Hurst exponents of return series have only small value above Hurst Exponent of random walk process R/S analysis shows the existence of persistence temporal dependency in all return series. A high H value shows less noise, more persistence and clearer trends than do lower values. Higher values of H mean less risk because there is less noise in the data (Peters (1991)). Predictability may be feasible in the short term because of short memory cycles are ranging from 775 days for PSEi return and 186 days for PSEi index to 999 days for STI return and 333 days for STI index. Peters (1990) suggests to testing R/S analysis in lower sampling period such as weekly data therefore it is better to rerun R/S analysis for weekly index return series.

Nonlinearity structure found in all return series suggests the stock market of Indonesia, Singapore and Philippine are not efficient or reject EMH model. EMH holds in the efficient capital market, prices reflect all public information.

All series have different degree of complexity which suggests different degree of risk due to their Hurst exponent value. Different degree of risk among international markets as well as among regional markets, in this case among ASEAN member countries markets, provides opportunity of diversification by applying foreign investment in lower risk market. Foreign investment for diversification purpose leads to integration of companies from different countries. Integration as a way to reduce risk by diversification will be more promising to gain competition. Liberalization to invest in less risk foreign countries will be supported by riskier countries. Since each stock market has different complexity, then one policy for all can not be applied. Regional policy to accommodate integration and liberalization will affect differently in each stock markets.
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|          | JCI          | PSEI         | STI          |
|----------|--------------|--------------|--------------|
| SAMPLES  | 01/04/1988  | 01/05/1988  | 01/04/1985  | 01/07/1985  |
|          | 12/31/2007  | 12/31/2007  | 12/31/2007  | 12/31/2007  |
| NUMBER OF OBSERVATIONS | 5216 | 5215 | 4654 | 4653 | 5997 | 5996 |
| MEAN     | 625.4506    | 0.000672    | 1942.007    | 0.000272    | 1587.406    | 0.000286 |
| STANDARD DEVIATION | 463.3537 | 0.016917 | 767.1365 | 0.015234 | 655.8818 | 0.013446 |
| SKEWNESS | 2.337672    | 3.039809    | 0.432037    | 0.475608    | 0.748393    | -1.868788 |
| KURTOSIS | 8.839385    | 86.7847     | 2.177641    | 11.88103    | 3.888675    | 54.27394 |
| MAXIMUM  | 2810.962    | 0.403102    | 3873.5      | 0.161776    | 3875.77     | 0.154812 |
| MINIMUM  | 82.6        | -0.225811   | 516.205     | -0.097442   | 456.35      | -0.291862 |
| NORMALITY| 12161.38    | 1533392     | 275.9238    | 15466.86    | 757.1494    | 660306.2 |

Table 5. R/S Analysis

|          | JCI          | PSEI         | STI          |
|----------|--------------|--------------|--------------|
| Return   | Return AR(1) | Residual     | Shuffle Return | Raw Index | Index AR(1) | Residual | Shuffle Raw Index |
| H        | E(H)         | H            | E(H)         | E(H)       | E(H)         | H        | E(H) |
| 0.585    | 0.525        | 0.544        | 0.525        | 0.513      | 0.523        | 0.794    | 0.523 |
| 0.584    | 0.525        | 0.531        | 0.523        | 0.525      | 0.531        | E(H)     |

Non Periodic Cycle

| 869 days = antilog 2.93901977644867 | 869 days = antilog 2.93901977644867 | 237 days = antilog 2.3747483460101 |
|-------------------------------------|-------------------------------------|-----------------------------------|
| Fractional Dimension | Fractional Dimension | Fractional Dimension |
| of Time Series | of Time Series | of Time Series |
| 1.949 (1/0.513) | 1.259 (1/0.794) | 1.883 (1/0.531) |

PSEI

| Return   | Return AR(1) | Residual | Shuffle Return | Raw Index | Index AR(1) | Residual | Shuffle Raw Index |
| H        | E(H)         | H        | E(H)         | E(H)       | E(H)         | H        | E(H) |
| 0.566    | 0.524        | 0.537    | 0.524        | 0.522      | 0.524        | 0.779    | 0.524 |
| 0.564    | 0.524        | 0.518    | 0.524        | 0.525      | 0.518        | 0.525   |

Non Periodic Cycle

| 775 days = antilog 2.88930170250631 | 775 days = antilog 2.88930170250631 | 186 days = antilog 2.26951294421792 |
|-------------------------------------|-------------------------------------|-----------------------------------|
| Fractional Dimension | Fractional Dimension | Fractional Dimension |
| of Time Series | of Time Series | of Time Series |
| 1.916 (1/0.522) | 1.284 (1/0.779) | 1.773 (1/0.564) |
| 1.93 (1/0.516) |

STI

| Return   | Return AR(1) | Residual | Shuffle Return | Raw Index | Index AR(1) | Residual | Shuffle Raw Index |
| H        | E(H)         | H        | E(H)         | E(H)       | E(H)         | H        | E(H) |
| 0.556    | 0.526        | 0.533    | 0.526        | 0.526      | 0.538        | 0.525    | 0.525 |

Non Periodic Cycle

| 999 days = antilog 2.990656548922598 | 999 days = antilog 2.990656548922598 | 333 days = antilog 2.5224423350632 |
|-------------------------------------|-------------------------------------|-----------------------------------|
| Fractional Dimension | Fractional Dimension | Fractional Dimension |
| of Time Series | of Time Series | of Time Series |
| 1.887 (1/0.53) | 1.255 (1/0.797) | 1.802 (1/0.555) |
| 1.859 (1/0.538) |
Table 2. BDS Statistics test for the Jakarta Composite Index

| m | ε/σ | Index | Shuffle Index | Return | Shuffle Return | Linear Filter Return | Nonlinear Filter Return | Linear and nonlinear filter Return |
|---|-----|-------|---------------|--------|---------------|----------------------|------------------------|----------------------------------|
| 2 | 0.25 | 242.53 | -1.2015 | 24.831 | 1.8702 | 26.727 | 24.833 | 27.167 |
| 3 | 0.25 | 446.29 | -0.65467 | 37.305 | 0.65011 | 39.689 | 37.308 | 39.365 |
| 4 | 0.25 | 895.92 | -0.43188 | 52.005 | 0.30683 | 56.547 | 52.008 | 55.677 |
| 5 | 0.25 | 1953.4 | -0.0030853 | 74.639 | 0.22372 | 81.887 | 74.646 | 80.635 |
| 6 | 0.25 | 4532.7 | 0.15102 | 111.44 | 0.10899 | 126.86 | 111.45 | 125.4 |
| 7 | 0.25 | 11009 | -0.016235 | 181.65 | -0.13979 | 209.62 | 181.66 | 205.55 |
| 8 | 0.25 | 27654 | -0.070945 | 312.67 | -0.59533 | 365.44 | 312.7 | 355.09 |
| 9 | 0.25 | 71239 | 0.15387 | 561.08 | 0.042495 | 658.04 | 551.13 | 620.34 |
| 10 | 0.25 | 187080 | -0.20441 | 1053.5 | 0.39358 | 1260.7 | 1053.6 | 1149.8 |
| 2 | 0.5 | 142.95 | -0.78674 | 24.133 | 1.2814 | 24.269 | 24.133 | 25.228 |
| 3 | 0.5 | 182.04 | -0.23557 | 32.425 | 0.51078 | 32.881 | 32.425 | 33.583 |
| 4 | 0.5 | 239.08 | -0.1651 | 39.913 | 0.48131 | 41.219 | 39.912 | 41.778 |
| 5 | 0.5 | 327.95 | 0.076833 | 48.921 | 0.41049 | 51.303 | 48.92 | 51.892 |
| 6 | 0.5 | 467.29 | 0.18461 | 60.429 | 0.27979 | 64.89 | 60.427 | 65.725 |
| 7 | 0.5 | 687.34 | 0.02201 | 77.91 | 0.064044 | 84.594 | 77.907 | 85.8 |
| 8 | 0.5 | 1037.8 | -0.23737 | 103.05 | -0.077925 | 113.71 | 103.05 | 114.92 |
| 9 | 0.5 | 1601 | -0.34842 | 139.18 | 0.0078243 | 156.69 | 139.18 | 157.86 |
| 10 | 0.5 | 2513.9 | -0.41946 | 193.56 | 0.091872 | 222.03 | 193.55 | 223.21 |
| 2 | 0.75 | 118.85 | 0.017022 | 23.558 | 0.97316 | 24.468 | 23.558 | 25 |
| 3 | 0.75 | 132.89 | 0.10552 | 29.626 | 0.73478 | 30.694 | 29.626 | 31.095 |
| 4 | 0.75 | 150.77 | -0.10767 | 34.022 | 0.84849 | 35.425 | 34.022 | 35.736 |
| 5 | 0.75 | 176.1 | 0.018419 | 38.317 | 0.79134 | 40.296 | 38.317 | 40.458 |
| 6 | 0.75 | 211.13 | 0.16825 | 42.913 | 0.60793 | 45.912 | 42.918 | 45.992 |
| 7 | 0.75 | 258.85 | 0.0037489 | 49.209 | 0.32339 | 53.385 | 49.21 | 53.4 |
| 8 | 0.75 | 323.49 | -0.33698 | 57.194 | 0.19678 | 63.009 | 57.194 | 62.945 |
| 9 | 0.75 | 410.96 | -0.50113 | 67.243 | 0.25339 | 75.439 | 67.243 | 75.232 |
| 10 | 0.75 | 529.51 | -0.54883 | 80.495 | 0.24574 | 91.732 | 80.495 | 91.44 |
| 2 | 1 | 110.32 | 0.56645 | 23.655 | 0.7752 | 25.379 | 23.655 | 25.508 |
| 3 | 1 | 116.71 | 0.17564 | 28.612 | 0.72988 | 30.279 | 28.612 | 30.394 |
| 4 | 1 | 124.61 | -0.14395 | 31.588 | 0.83798 | 33.312 | 31.588 | 33.457 |
| 5 | 1 | 136.25 | -0.17776 | 33.915 | 0.74308 | 35.869 | 33.915 | 35.968 |
| 6 | 1 | 152.2 | -0.055669 | 36.031 | 0.50949 | 38.571 | 36.03 | 38.606 |
| 7 | 1 | 173.12 | -0.19768 | 38.789 | 0.2655 | 41.922 | 38.789 | 41.897 |
| 8 | 1 | 199.99 | -0.52295 | 42.071 | 0.18693 | 45.963 | 42.071 | 45.884 |
| 9 | 1 | 234.14 | -0.75047 | 45.867 | 0.24102 | 50.89 | 45.867 | 50.665 |
| 10 | 1 | 277.35 | -0.81771 | 50.455 | 0.23565 | 56.798 | 50.455 | 56.471 |

BDS Statistic tabulated value (Brock et al, 1987):

| Significance Level 5% | Significance Level 1% |
|-----------------------|-----------------------|
| E/SD=0.5 | E/SD=1 | E/SD=0.5 | E/SD=1 |
| 2 | 2.35 | 1.86 | 3.71 | 2.79 |
| 3 | 2.59 | 1.91 | 4.04 | 2.92 |
| 4 | 3.02 | 1.98 | 4.85 | 2.96 |
| 5 | 3.88 | 2.1 | 6.44 | 3.06 |
Table 3. BDS Statistics test for The Pilipino Stock Exchange Index

| m | ε/σ | Index | Shuffle Index | Return | Shuffle Return | Linear Filter ARMA (119,1) | Nonlinear Filter GARCH (1,8) | Linear and nonlinear filter ARMA(119,1) & GARCH(6,7) |
|---|-----|-------|--------------|--------|----------------|----------------------------|-------------------------------|--------------------------------------------------|
| 2 | 0.25 | 1365.4 | 0.65277 11.919 | 0.37653 | 10.59 | 11.919 | 10.59 |
| 3 | 0.25 | 4851 | 1.1037 15.015 | 0.48061 | 13.951 | 15.013 | 13.952 |
| 4 | 0.25 | 20573 | 1.2441 17.966 | 0.36046 | 17.3 | 17.968 | 17.301 |
| 5 | 0.25 | 9846 | 3.4449 19.91 | 0.49485 | 20.033 | 19.912 | 20.034 |
| 6 | 0.25 | 510350 | 2.303 23.194 | 1.4617 | 23.755 | 23.196 | 23.755 |
| 7 | 0.25 | 2785700 | -0.23141 30.055 | 0.98529 | 30.842 | 30.058 | 30.843 |
| 8 | 0.25 | 15789000 | -1.902 35.693 | 2.4936 | 43.759 | 35.696 | 43.76 |
| 9 | 0.25 | 92031000 | -14.76 39.265 | -6.3098 | 55.881 | 39.268 | 55.883 |
| 10 | 0.25 | 548320000 | -12.228 30.655 | -5.1008 | 68.76 | 30.658 | 68.762 |
| 2 | 0.5 | 815.91 | -0.025424 13.691 | 0.17343 | 11.68 | 13.691 | 11.68 |
| 3 | 0.5 | 1772.5 | -0.039784 17.317 | 0.64612 | 15.386 | 17.317 | 15.386 |
| 4 | 0.5 | 4312 | -0.46183 | 20.699 | 0.55885 | 18.857 | 20.699 | 18.857 |
| 5 | 0.5 | 11557 | 0.12025 23.85 | 0.19192 | 22.043 | 23.85 | 22.043 |
| 6 | 0.5 | 33206 | 0.53569 28.232 | 0.26128 | 26.425 | 28.232 | 26.425 |
| 7 | 0.5 | 100280 | 0.89805 33.618 | 0.26984 | 31.625 | 33.619 | 31.624 |
| 8 | 0.5 | 314090 | 0.93919 39.912 | 0.314 | 37.375 | 39.913 | 37.375 |
| 9 | 0.5 | 1011200 | 1.9961 | 48.601 | 0.50089 | 48.843 | 48.602 | 48.842 |
| 10 | 0.5 | 3326400 | 2.5667 | 60.225 | 0.4354 | 55.12 | 60.226 | 55.119 |
| 2 | 0.75 | 616 | 0.16755 14.395 | 0.039572 | 12.496 | 14.396 | 12.496 |
| 3 | 0.75 | 1017.1 | 0.38888 18.275 | 0.80648 | 16.257 | 18.276 | 16.257 |
| 4 | 0.75 | 1802.7 | -0.14654 | 21.527 | 0.86633 | 19.618 | 21.527 | 19.618 |
| 5 | 0.75 | 3436.2 | -0.25281 | 24.442 | 0.55377 | 22.7 | 24.442 | 22.7 |
| 6 | 0.75 | 6938.9 | -0.2703 | 28.052 | 0.57363 | 26.526 | 28.052 | 26.526 |
| 7 | 0.75 | 14649 | -0.24326 | 32.208 | 0.52948 | 30.842 | 32.208 | 30.842 |
| 8 | 0.75 | 32000 | -0.32732 | 37.019 | 0.37663 | 35.572 | 37.02 | 35.572 |
| 9 | 0.75 | 71781 | -0.16152 | 42.66 | 0.25894 | 41.233 | 42.661 | 41.233 |
| 10 | 0.75 | 164420 | 0.083945 | 49.496 | 0.21561 | 48.002 | 49.496 | 48.002 |
| 2 | 1 | 491.02 | -0.29963 | 15.067 | 0.10756 | 13.133 | 15.067 | 13.134 |
| 3 | 1 | 688.22 | -0.0096641 | 18.886 | 0.93546 | 16.597 | 18.886 | 16.597 |
| 4 | 1 | 1009.3 | -0.44778 | 21.864 | 1.0646 | 19.608 | 21.865 | 19.608 |
| 5 | 1 | 1563.3 | -0.61617 | 24.451 | 0.76288 | 22.386 | 24.451 | 22.386 |
| 6 | 1 | 2535.6 | -0.68879 | 27.346 | 0.69811 | 25.416 | 27.347 | 25.417 |
| 7 | 1 | 4270.8 | -0.84812 | 30.569 | 0.59376 | 28.736 | 30.57 | 28.737 |
| 8 | 1 | 7415.4 | -1.0531 | 34.117 | 0.41756 | 32.268 | 34.118 | 32.268 |
| 9 | 1 | 13195 | -1.0615 | 38.096 | 0.20799 | 36.2 | 38.096 | 36.2 |
| 10 | 1 | 23953 | -1.085 | 42.655 | 0.087179 | 40.508 | 42.656 | 40.508 |

BDS Statistic tabulated value (Brock et al. 1987):

| Significance Level | Significance Level |
|--------------------|--------------------|
| 5%                 | 1%                 |
| 250                |                    |
| observations:      |                    |
| E/SD=0.5           | E/SD=1             |
| E/SD=0.5           | E/SD=1             |
| m:                 |                    |
| 2                  | 2.35               |
| 3                  | 2.59               |
| 4                  | 3.02               |
| 5                  | 3.88               |
| 6                  |                    |
| 7                  |                    |
| 8                  |                    |
| 9                  |                    |
| 10                 |                    |
| m   | $\varepsilon/\sigma$ | Index | Shuffle | Return | Shuffle | Linear Filter Return | Nonlinear Filter Return | Linear and nonlinear filter Return |
|-----|----------------------|-------|---------|--------|---------|----------------------|----------------------|-----------------------------------|
|     |                      | Index |         |        |         | ARMA(12,1) | GARCH(9,8) | ARMA(13,1) & GARCH(8,9)          |
| 2   | 0.25                 | 1235.8 | -0.48362 | 15.993 | 0.06586 | 17.997     | 15.993     | 17.997                           |
| 3   | 0.25                 | 4120.6 | -0.41997 | 19.217 | -0.14706 | 22.357     | 19.217     | 22.357                           |
| 4   | 0.25                 | 16280.0 | 0.14199 | 23.211 | -0.38644 | 26.558     | 23.211     | 26.558                           |
| 5   | 0.25                 | 72431.0 | 0.36058 | 27.973 | -0.50063 | 31.906     | 27.973     | 31.906                           |
| 6   | 0.25                 | 348030.0 | 2.1735  | 32.976 | -0.7366  | 38.124     | 32.976     | 38.124                           |
| 7   | 0.25                 | 1761000.0 | 7.5589  | 39.934 | -0.24227 | 47.135     | 39.934     | 47.135                           |
| 8   | 0.25                 | 9248900.0 | 12.691  | 47.258 | 0.25019  | 54.824     | 47.258     | 54.824                           |
| 9   | 0.25                 | 49954000.0 | 13.907  | 61.776 | 0.4457   | 71.962     | 61.776     | 71.962                           |
| 10  | 0.25                 | 275650000.0 | -11.107 | 84.709 | 1.1456   | 124.628    | 84.709     | 124.628                          |
| 2   | 0.5                  | 839.85 | 0.1051  | 18.139 | 0.1601   | 18.983     | 18.139     | 18.983                           |
| 3   | 0.5                  | 1721.9 | -0.19672| 22.143 | 0.025697 | 23.737     | 22.143     | 23.737                           |
| 4   | 0.5                  | 3918.7 | -0.63068| 26.299 | -0.25466 | 28.177     | 26.299     | 28.177                           |
| 5   | 0.5                  | 9779.2 | -0.39392| 30.664 | -0.21711 | 32.948     | 30.664     | 32.948                           |
| 6   | 0.5                  | 26110.0 | -1.0603 | 35.418 | -0.20709 | 38.215     | 35.418     | 38.215                           |
| 7   | 0.5                  | 73193.0 | -0.21739| 41.945 | 0.1055   | 45.253     | 41.945     | 45.253                           |
| 8   | 0.5                  | 212710.0 | -1.0135| 49.908 | 0.3209   | 53.86      | 49.908     | 53.86                            |
| 9   | 0.5                  | 635250.0 | 0.71513| 60.314 | 0.67551  | 64.933     | 60.314     | 64.933                           |
| 10  | 0.5                  | 1937800.0 | 1.616  | 72.888 | 1.1711   | 78.196     | 72.888     | 78.196                           |

Table 4. BDS Statistics test for the Straits Times Index

BDS Statistic tabulated value (Brock et al. 1987):

| Significance Level  | Significance Level  |
|---------------------|---------------------|
| 5%                  | 1%                  |

| m  | E/SD=0.5 | E/SD=1 | E/SD=0.5 | E/SD=1 |
|----|----------|--------|----------|--------|
| 2  | 2.35     | 1.86   | 3.71     | 2.79   |
| 3  | 2.59     | 1.91   | 4.04     | 2.92   |
| 4  | 3.02     | 1.98   | 4.85     | 2.96   |
| 5  | 3.88     | 2.1    | 6.44     | 3.06   |
Figure 5. R/S Analysis & V-Statistic JCI Index AR(1) Residual

Figure 6. R/S Analysis & V-Statistic JCI Return AR(1) Residual
Figure 9. R/S Analysis & V-Statistic PSEi Index Shuffle

Figure 10. R/S Analysis & V-Statistic PSEi Return Shuffle
Figure 11. R/S Analysis & V-Statistic PSEI Index AR(1) Residual

Figure 12. R/S Analysis & V-Statistic PSEI Return AR(1) Residual
Figure 13. R/S Analysis & V-Statistic STI Index

Figure 14. R/S Analysis & V-Statistic STI Return
Figure 15. R/S Analysis & V-Statistic STI Index Shuffle

Figure 16. R/S Analysis & V-Statistic STI Return Shuffle
Figure 17. R/S Analysis & V-Statistic STI Index AR(1) Residual

Figure 18. R/S Analysis & V-Statistic STI Return AR(1) Residual

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