WEAK-FORM MARKET EFFICIENCY, ESTIMATION INTERVAL AND THE NIGERIAN STOCK EXCHANGE: EMPIRICAL EVIDENCE

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Abstract

Given the desirability of efficient capital markets in aiding optimal resource mobilization and allocation in the financial system, this paper is an attempt to investigate the efficiency level of the Nigerian Stock Exchange (NSE) across different data estimation intervals with reference to the weak-form variant of the Efficient Market Hypothesis (EMH). The paper employed daily, weekly, monthly and quarterly aggregate stock price data using the NSE All Share Index series from 4th January, 1999 to 31st December, 2013 to test for the weak-form efficiency of the NSE using a combination of seven (7) statistical and parametric tools namely- Autocorrelation tests, the ADF and P-P unit root tests, Variance Ratio tests, the Normality/Random Walk tests, the Granger Causality test, the ARCH-GARCH test and Regression rest. The empirical results of the investigation indicate that on balance the NSE is weak-form inefficient when daily, weekly, monthly and quarterly prices are examined irrespective of the estimation interval and the parametric test employed in the tests. It is to be noted from the findings that the NSE is still weak-form inefficient despite the implementation of various capital market reforms undertaken in the recent past as well as the adoption of automation and ICT in the operations of the Exchange. It is therefore recommended that these salutary reforms and policies should be intensified and sustained to ensure efficiency of the NSE.

Keywords: *Weak-form efficiency, Efficient Market Hypothesis, Estimation Interval, Parametric Tests.*

INTRODUCTION

The financial system of any economy represents the set of financial assets, financial markets, financial institutions and the rules and regulations churned out from time to time that mutually interact in the process of bringing together surplus and deficit units in the economy resulting in the creation, custodianship and exchange of securities between suppliers and users of funds in the system (Okafor, 1983). Thus, in a well-functioning financial system, capital markets exist to provide not only the physical space but also all the facilities both virtual and non-virtual that aid the interaction between the surplus and deficit units. It is within the capital market segment of the financial markets that long term financial assets are created and exchanged thus providing the platform for diverse groups of savers and investors (surplus units) and issuers of financial assets (deficit units) to consummate their transactions in accordance with their risk-return preferences. However, the extent to which the capital market is able to perform these intermediation and allocation functions depend very much on how efficient the market is.

The literature of finance is very much replete with discussions on the meaning, desirability and tests of efficient capital markets given that efficient capital markets ensure that surplus funds are optimally mobilized and deployed to those who are willing and able to utilize them efficiently. In what has come to be popularly known as Efficient Market Hypothesis (EMH), Fama (1970) posits that market efficiency requires that in setting the prices of securities at any time t-1, the market correctly uses all available information. Another useful definition is provided by Jensen (1978) in which he asserts that a market is efficient with respect to a given information set if it is impossible to make profits by trading on the basis of that information set.

Empirical tests of the validity of the EMH have been carried out in many markets, both developed and emerging markets, by scholars in finance using different techniques of analysis and different types of data and estimation periods. Interestingly, these tests are still on-going given the observed fact that there is as yet no consensus in the reported findings of research in the subject area. For example and with respect to the Nigerian capital market, writers like Olowe (1974), Afego (2012) and Nwosa and Oseni (2012) found no evidence in their various studies to support the hypothesis of weak form efficiency of the NSE while scholars like Samuels and Yacout (1981), Ajao and Osayuwu (2012) find strong evidence to support the assertion that the NSE is weak form efficient.

Another problem related to the above is the absence of consistency in observed results of the tests of market efficiency across different estimation intervals as to when for example, daily, weekly, monthly, quarterly or annual data are employed in the studies. Such inconsistencies no doubt throw up the additional question of whether the NSE is efficient across different estimation intervals. This gap ought to be filled. Is the Nigerian stock market weak form efficient or not?

The NSE itself has come a long way and has grown tremendously over the years. From a modest listing of 19 securities in 1961 and 100 in 1986, the NSE has 346 listed securities as at the end of 2014. Market capitalization as at end of 1986 was N8.5 billion, in the year 2000 it was N466 billion and by 2013 it has jumped to N1.32 trillion. In 2014 it was well above N2 trillion. Value of transactions was N7.3 billion in 1986 and N2.099 billion by the year 2000 but has grown to

N17.3b in 2014. The observed phenomenal growth of the NSE is attributable in part, to the various policy reforms implemented since the introduction of the Structural Adjustment Programme (SAP) in 1986 and coupled with the adoption of information and communication technology (ICT) with its attendant salutary benefits of speed, accuracy and magnitude of relevant market information disseminated which enhances service delivery. These reforms include the introduction of electronic bonus for shareholders, automation of the bond market, review of minimum equity requirement for capital market operators, the introduction of NSE 30 Index and NSE 50 Index to complement the existing NSE All Share Index, the launching and coming into effect of Exchange Traded Funds (ETF), On-line trading as well as Remote trading and Dematerialization of dividends. In spite of this phenomenal growth, it is arguable whether there has been a commensurate increase in the efficiency level of the capital market. This again is a problem that ought to be examined.

In the light of the above problems therefore, the objective of this paper is to investigate empirically whether the NSE is weak form efficient across different data estimation intervals.

The rest of the research report is organized as follows. Section 2 contains the theoretical framework and empirical literature review. In section 3, the methodology adopted in carrying out the research and data are presented while section 4 presents the data analysis and findings. Section 5 presents the conclusion and recommendations.

Literature Review

Theoretical Framework: The theory of EMH is embedded within the broad confines of the theory of valuation and pricing of assets. Basically we can delineate four competing approaches to asset valuation namely- The Fundamental Approach, the Technical Approach, The Efficient Market Approach popularly referred to as the Efficient Market Hypothesis (EMH) and The Arbitrage Pricing Technique (APT).

The Fundamental approach is predicated on the assumptions that every security has an intrinsic value and that the intrinsic value of every security is reflected in the market price of that security. It is also assumed that the basic economic and fundamental facts and features about a firm or corporation determine the intrinsic value of securities issued by the firm or corporation. Thus according to the Fundamentalists, the task of the rational investor is to undertake rigorous fundamental analysis of the basic economic facts relating to assets to determine their intrinsic values as a prelude to identifying mis-priced assets in the market. Hence, armed with information on mis-priced securities the rational investor can formulate profitable trading rules. (Okafor, 1983), (Bodie, et al.,2008)

On the other hand, the Technical approach dismisses the quest to obtain knowledge of intrinsic value as irrelevant in the buy or sell decisions of investors in the capital market. The assumptions here are that the value of a security is determined by the forces of supply and demand and that prices of securities are observable, chartable and follow recurring patterns which can be used to formulate profitable trading rules in the market. For the Technicalists therefore, reliance on market prices and their patterns over time would provide signals for timing of market transactions to optimum advantage.(Francis, 1980).

The Efficient Market approach is anchored on the EMH which assumes that market prices of securities fully reflect all available and relevant information about such securities and changes in security prices are random and not systematic as propounded by the Technicalists. For the EMH approach therefore, there is no specific and recurring patterns in the behavior of stock prices which could provide the basis for formulating reliable and profitable trading rules. (Hirt and Block,1983) The culmination of the EMH is the single-factor CAPM according to which the expected return on an asset is postulated be an increasing function of the asset's beta coefficient. Although some authors like Roll () are of the view that the CAPM is untestable on account of the difficulty in finding a perfect proxy for the market portfolio, the work by Ogbulu (2012) demonstrates the use of an All-Asset Market Portfolio to test the validity of the single-factor CAPM.

Expectedly, the discussions and controversies that have been generated over the years on the proper meaning of the term "all available information" have given rise to the characterization of the EMH into three levels of market efficiency namely- the weak form, the semi-strong form and the strong form. (Bodie, et al, 2008), (Ogbulu, 2009). The weak form asserts that current market prices of securities in the capital market fully reflect the information implied by the historical sequence of prices of the securities. Hence, the weak form efficiency implies that knowledge of past prices of a security cannot be used to predict future prices of that asset nor consistently secure abnormally high rates of return. The semi-strong form says that all public information about the securities including historical information is already fully reflected in the current prices of the securities hence an investor cannot use fundamental analysis of the securities to determine whether an asset is mis-priced or not in order to produce abnormal returns. On the other hand, the strong form states that all, not just publicly available information about a security is fully reflected in security prices such that even those with privileged or what may be considered as insider information can utilize such information to earn superior returns in the market.

The Arbitrage Pricing Theory (APT) in contrast to the EMH single-factor CAPM, postulates a multifactor APT which generalizes the single-factor model to incorporate several other sources of systematic risk beyond the beta coefficient. (Ross,1976); (Chen, Roll and Ross, 1986).

Notwithstanding the apparent contradictions inherent in these theories, it should be noted that each approach has its adherents and in practice many practitioners are wont to use a combination of these approaches to arrive at optimal decisions. The current paper is based on the EMH as an approach to efficient pricing and selection of assets in the capital market.

Empirical Literature: As earlier pointed out, the literature of financial economics is replete with a good measure of the raging controversy on the validity of the EMH over the past three or four decades. Given that capital markets are dynamic and continually evolving, the debate over tests of market efficiency is evidently not about to subside. A brief survey of empirical literature is provided here.

In their seminal work, Niblock and Sloan (2007), investigated the weak form efficiency of the Chinese stock markets using daily data of the Shangai A, Shangai B, Shenzhen A, Shenzhen B, Hang Seng and the Dow Jones Industrial Average (DJIA) indices from 4th March, 2002 to 2005 with their sample divided into two groups - from 4th March, 2002- 31st December, 2003 and from 1st January, 2004 -31st December, 2005. The authors employed the Serial Correlation Coefficient test, the Runs test and the Variance Ratio test to examine the validity of the Random Walk Hypothesis (RWH) and then the existence of relationships between the market indices is undertaken using tests of Co-integration and Granger Causality. The results of the random walk tests conducted by the authors reveal return predictabilities for the Chinese share indices thus supporting the assertion that despite continual financial liberalization and unparalleled growth, China's stock markets are still not weak form efficient. In addition, the authors report that weekly return data did not show evidence of weak form inefficiency.

N'DRI (2015) examined the RWH in the regional stock market of the West African Economic and Monetary Union called the Bourse Regionale des Valeurs Mobilieres (BRVM) using the Lo and MacKinlay (1988), Chow and Denning (1993) and Wright (2000) rank-based variance ratio tests applied to daily stock price index over the period 2nd January, 2002 to 31st December, 2004. The findings show that all three tests demonstrate that the null hypothesis of random walk cannot be rejected in the BRVM thus suggesting that the BRVM is weak form efficient.

The study by the duo of Hameed and Ashraf (2006) investigated if volatility of returns is time-varying in the Pakistan stock market as well as testing for the existence of a viable risk-reward relationship in the market and finally to examine the impact of the Securities and Exchange Commission (SEC)'s reforms and the 9/11 incidence on the volatility of returns in Pakistan. To achieve the stated objective, the authors utilized the Generalized GARCH (p-q) technique to model volatility and test for weak form efficiency. Given the model, weak form efficiency is established if the coefficients of the ARIMA terms (the mean square equation) are statistically insignificant. On the other hand, the variance equation with significant coefficients suggests that investors are rewarded for taking additional risk over time. The authors' findings show that returns in the Pakistani stock market exhibit persistence and volatility clustering. In addition, the authors rejected the weak form hypothesis as it was found that past information helped in predicting future prices. Moreover, it was observed that the mean variance hypothesis does not hold also for the Pakistani stock market as no evidence is found that investors are rewarded for taking increased risk.

In his own paper, Gimba (2012), conducted a study to investigate the weak form EMH of the NSE by hypothesizing normal distribution and random walk of the return series using daily and weekly NSE All-Share Index (ASI) and five (5) most traded and oldest bank stocks of the NSE from January, 2007 to December, 2009 for the daily data and from June, 2005 to December, 2009 for the weekly data. The empirical results obtained using autocorrelation tests for the observed returns reject the null hypothesis of the existence of random walk for the market index and 4 out of the 5 selected individual stocks. The author therefore concluded that the NSE is weak form inefficient and hence recommended among others, minimizing institutional restrictions on trading of securities in the market.

In a study of the Indian stock market, Khan, Ikram and Mehtab (2011), carried out tests of market efficiency of the Indian capital markets in its weak form based on indices of two major stock exchanges in India- the NSE and the BSE using daily closing values of the indices over the period 1st April, 2000 to 31st March, 2010. The authors employed the Runs test and their findings indicate that the Indian capital markets are weak form inefficient and that prices do not follow a random walk.

In yet another work, Ananzeh (2014) conducted weak form efficiency test of the Amman Stock Exchange (ASE) using daily returns and employing parametric and non-parametric tests. The findings show that the Jarque-Berra (J-B) tests provide evidence of non-normality in the daily return distribution while the Runs test detect that the daily returns are inefficient in the weak form. Furthermore, the results show that the ADF and P-P unit root tests suggest weak form inefficiency in the return series. In the light of the findings, the author concluded that the Amman Stock Exchange is inefficient in the weak form.

In a related study of market efficiency across time using data from Nigeria, Emenike (2010) examined the weak form EMH for the NSE by hypothesizing normal distribution and random walk in periodic return series. The author examined monthly ASI of the NSE for three periods-January, 1985-December, 1992; January, 1993-December, 1999 and finally January, 2000-December, 2007. Normality test were conducted using Skewness, Kurtosis, Kolmorgonov-Sminov

(K-S) and the Q-Q normality chart while Random Walk was tested using the Runs test. The findings reveal that returns from the NSE do not follow normal distribution in all the periods. In addition, the Runs test rejects the randomness of the return series in all the periods. The author concluded that the NSE is not weak form efficient across all the time periods studied and recommended strengthening the regulatory capacities of the NSE and SEC to enforce market discipline.

Furthermore, Afego (2012) also examined the EMH for the NSE by testing for random walks in the monthly index returns of the NSE ASI over the period 1984-2009 using the Runs test. The results of the study show that the index returns display a predictable component and statistically significant deviations from randomness and therefore contradicting the weak form EMH. The author therefore recommended a range of policy strategies for improving the allocative capacity and quality of the information environment of the NSE.

In yet another work using data from the NSE, Ajao and Osayuwu (2012) investigated the weak form of the EMH using all securities traded on the NSE and monthly returns of the ASI from 2001-2010. The authors used serial correlation technique to test for independence of successive price movements while the Runs test is used to test for randomness of share price movements. The authors report that the serial correlation coefficients did not violate the two-standard error test (insignificant) and the Box-Ljung statistic shows that none of the serial correlation coefficients was significant. The findings also show that the pattern of the return distribution was approximately normal and based on the strength of these findings the authors concluded that the NSE is weak form efficient.

Another work worthy of mention is the study by the duo of Nwosa and Oseni (2011) in which the authors investigated the weak form EMH in the NSE using data for the period 1986-2010. Serial correlation coefficient and regression analysis were employed as tools of analysis just as the variables were also tested for stationarity using the ADF and P-P unit root tests. The findings from the unit root tests vividly demonstrate that the variables are integrated of order one. The results of the serial correlation test show that NSE is informational inefficient meaning that stock prices in the NSE do not exhibit random walk. In addition, findings from the regression analysis reveal that lagged values of stock returns are significant which implies that previous stock prices can successfully predict current prices which strongly contrast to the dictates of weak form efficiency prompting the authors to recommend that strong and adequate supervision be undertaken by the regulatory authorities.

Tests of EMH have also been carried out in the Asia Emerging markets over the past decade or two. For example, Worthington and Higgs (2006) investigated the weak form market efficiency of Asian equity markets using daily returns for ten (10) emerging markets (China, India, Indonesia, Korea, Malaysia, Pakistan, The

Phillipines, Sri Lanka, Taiwan and Thailand) and five (5) developed markets (Australia, Hong Kong, Japan New Zealand and Singapore) for random walks using serial correlation coefficients test, Runs test, ADF, P-P, Kwiatkaoski, Phillips, Schmidt and Shin unit root tests as well as the Variance Ratio tests. According to the authors, results of these tests indicate that the serial correlation and Runs tests report that all of the markets are weak form inefficient. The unit root tests suggest weak form efficiency in all the markets, with the exception of Australia and Taiwan. Continuing, the results from the more stringent variance ratio tests indicate that none of the emerging markets is characterized by random walks and hence are not weak form efficient while only the developed markets in Hong Kong, New Zealand and Japan are consistent with the most stringent random walk criteria.

Going farther to the East, the work by Abrosimova, Dissanike and Linowski (2005) examined the existence of weak form efficiency in the Russian stock markets for the period 1st September, 1995 to 1st May, 2001 using daily, weekly and monthly Russian Trading System Index (RTS) time series and employing different approaches to assess the predictability of the RTS index time series. The unit root, autocorrelation and variance ratio tests were employed and the findings demonstrate support for the null hypothesis of Random Walk for only the monthly data. However, further analysis conducted for the daily and weekly data using ARIMA and GARCH models provide insufficient evidence to support market predictability on the Russian stock market.

Considering capital markets in the Americas, Chen and Metghalchi (2012) investigated the predictive power of various trading rules with different combinations of the most popular indicators in the analysis for Brazilian stock index (BVESPA) over the period 5th January, 1996 to 3rd January, 2011. The empirical results indicate that all the buy-sell differences under the single, double and triple indicator combinations are insignificant in the t-test. In other words, technical trading rules cannot beat the buy-and-hold strategy. The authors therefore concluded that the results in general support strongly the weak form of market efficiency in the Brazilian stock market.

In the study by Akber and Muhammad (2014) the authors attempted to seek evidence for weak-form of market efficiency for KSE 100 Index using index returns for the period 1st January, 1992 to 30th April, 2013 with the return series divided into sub-periods. The paper has made use of primarily Non-Parametric tests as well as Parametric tests. Runs test was run on 20 companies return series for comparison with the results of index return series. In addition, from KSE 30 Index, 20 companies return series based on the free-float of shares were also analyzed through Runs test to check if increase in numbers of floating shares does increase the randomness in return series or not. Overall the findings show that KSE 100 Index is weak-form inefficient while companies return series from

KSE 30 Index are found to be more random than companies return series from KSE100 Index.

The study by Abdul Aziz Farid Saymeh (2013) empirically tested the Weak Efficient Form Hypothesis for two emerging stock markets, which are: Amman Stock Exchange, (ASE) and Turkish Stock Exchange (BORSA Istanbul) through examining their monthly indexes for the period 2000-2011. Thus it is an empirical test to study the effect of historical information in predicting the future stock prices of the two stock markets. Data used in the empirical analysis were collected from historical records of ASE and BORSA Istanbul markets for the period 2000-2011.Tests used by the author were: Ljung Box Autocorrelation, Runs , Dickey-Fuller Unit Root and Individual Variance Ratio tests and according to the author, the results of the study indicated debatable results. Runs test rejected the Random Walk characteristics while Augmented Dickey-Fuller tests indicated that both markets are weak form efficient. The Autocorrelation tests also rejected the Random Walk Hypothesis for both markets. However, with respect to the Variance Ratio tests, the findings revealed mixed results as they accepted BORSA Istanbul and rejected ASE as being Weak Form Efficient. Based on these test results, the author opined that there were not enough evidences to consider ASE and BORSA Istanbul as Weak Form Efficient markets.

In the study by Hernandez-Mejia et al (2014) to determine which model explains with greater precision the historical performance of the Mexican Stock Market Index (IPC), the authors employed the ARCH family models. They analyzed market volatility using daily returns of the IPC index during the period 2000-2008. To analyze market volatility, GARCH, EGARCH and TARCH models were compared according to traditional evaluation criteria and the report that in their findings that the EGARCH model (1.1) has the best predictive power with respect to the Mexican Stock Market.

Goudarzi (2013) investigated market efficiency in the Indian stock market through modeling one stylized facts of asset returns series. That is, mean reversion in the Indian stock market. To achieve this purpose, the author used ADF test and GARCH model and the results show that the underlying series is stationary and therefore mean reverting. Therefore, based on the results the study concluded that, the Indian stock market is informationally weak-inefficient.

In the light of the above survey, it is obvious that the controversy has not and perhaps cannot be settled one way or the other soon. The present study contributes to the debate by examining the weak form efficiency level of the NSE using seven different tests across four different data sets yielding (28) distinct decision cells.

Methodology and Data

Methodology. The methodology adopted for this study is the use of different parametric tools to test for the weak form efficiency of the NSE. This approach is informed by the desire of the researcher to generate findings based on an analytical process that is comprehensive enough such that the results can be relied upon to make an emphatic declaration on the weak form efficiency level of the NSE. This approach finds support from the earlier works of (Gimba,2012) and Afego (2012). To achieve this methodological objective, the study employed the following tests: The Autocorrelation test, Unit Root test, Variance Ratio test, Normality/Random Walk test, ARCH-GARCH test, Granger Causality test and Regression analysis.

The Autocorrelation Test. Autocorrelation, as aptly defined by Koutsoyiannis (1973), describes the relationship, not between two or more variables, but between successive values of the same variable. It is therefore a special case of correlation. Being a measure of the linear relationship between successive values of the same variable, it can be used to examine the relationship between past prices of securities and their current levels and hence the predictability of future prices given current or historical prices. In this way, the autocorrelation function (ACF) at lag k is used to test for weak form efficiency variant of the EMH under the assumption that prices of securities in an efficient market follow the random walk and are non-stationary. The sample autocorrelation function (ρ_k) is usually given as:

$\rho_k = \gamma_k / \gamma_0 =$ (covariance at lag k)/variance……………………………………....(1)

where $\gamma_k = \Sigma(P_{jt} - E(P_{jt}))\ (P_{t+k} - E(P_{jt}))/N\text{-}k$ and $\gamma_0 = \Sigma((P_{jt} - E(P_{jt}))^2/N\text{-}1$…….(2)

where Pjt = Stock market price at period t.
E(Pjt) = Sample mean of stock market price series
N = Sample size (See Gujarati and Porter, 2009)

The decision rule here is that for lags of k periods, accept the null hypothesis $\rho_k = 0$ if and only if the p-values are significantly different from zero at the chosen level of significance which supports the weak efficiency. If the p-values are not significantly different from zero at the chosen level of significance, the null hypothesis cannot be accepted thus confirming that the market is weak form inefficient and does not follow the random walk.

The Unit Root Test. Unit root test has become a popular test of the stationarity or otherwise of time series data in many econometric studies given the time-dependent nature of many economic variables. Two of the most popular tests for unit root are the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (P-P) test. The tests usually consist of estimating the regression:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{n} \alpha_i \Delta Y_{t-1} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where ε_t is a pure white noise error term and $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$, and so on with a number of lagged difference terms included so that the error term is serially uncorrelated to enable the researcher obtain an unbiased estimate of δ, the coefficient of lagged Y_{t-1} in equation (3) above (Gujarati and Porter, 2009). In testing for unit root, the null and alternative hypotheses are stated as Ho: $\eta = 0$ (unit root exists and series is non-stationary) as against H_1: $\eta = 0$ (No unit root, series is stationary). Acceptance of the null hypothesis means that stock market prices follow a random walk and weak form efficiency is supported. On the contrary, rejection of the null hypothesis indicates that there is no unit root in the series meaning that the series is stationary. This implies that stock market prices do not follow random walk and is thus weak form inefficient.

The Granger Causality Test. The Granger causality test according to Granger (1969) is used for testing the short run direction of causality between variables say Y and X. The test is based on estimating the following bivariate regressions.

$$Y_t = \sum_{i=1}^{n} \alpha_i X_{t-i} + \sum_{j=1}^{n} \beta_j Y_{t-j} + u_{1t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$X_t = \sum_{i=1}^{n} \delta_i Y_{t-i} + \sum_{j=1}^{n} \lambda_j X_{t-j} + u_{2t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where Y_t and X_t are the variables of interest while u_{1t} and u_{2t} are the disturbance terms assumed to be uncorrelated. In testing for weak form efficiency therefore the Granger causality test have been used by many scholars to investigate the lead-lag or predictability inherent in financial time series. The present study employed the Granger causality test to estimate the degree of causality between stock market prices and stock returns across the different estimation intervals under study. (Brooks, 2008)

The Variance Ratio Test. Although many variants of Variance Ratio tests are available like the Chow and Denning (1993) multiple variance ratio test, Wright (2000) test, and the Lo and Mackinlay (1988) variance ratio test, variance ratio technique tests the null hypothesis that a given time series is independent and identically distributed hence, if a series follows a random walk with uncorrelated changes in the series say (Pt), then the variance of its q- differences would be q times the variance of its first differences. The variance ratio is then given as:

$$Z(q) = Var(R(q)-1))/\sqrt{\theta(q)} \rightarrow N(0,1) \quad \text{……(6)}$$

and

$$Z^*(q) = Var(R(q)-1))/\sqrt{\theta^*(q)} \rightarrow N(0,1) \quad \text{……(7)}$$

Thus, under the null hypothesis of homoscesdasticity, Z(q) and Z*(q) have an asymptotic standard distribution with mean zero and standard deviation, one. If the computed variance ratio Z(q) or Z*(q) is greater than the critical value of a predetermined significance level, then the random walk hypothesis is rejected. That is, the market is weak form inefficient (N'dri, 2015).

The ARCH-GARCH Test. Credit for the emergence of the Autoregressive Conditional Heteroscedasticity (ARCH) model is usually attributed to Engle (1982) who developed the ARCH model to capture the effect of serially correlation of volatility in time series data according to which the ARCH model expresses conditional variance as a distributed lag of past squared innovations. (Goudarzi, 2013). In developing the ARCH model, the conditional return must be modeled first by stating the return relationship as an autoregressive AR(p) process with lags up to (p) stated as follows:

$$ASI_t = \alpha_o + \sum \alpha_t ASI_{t-1} + \varepsilon_t \quad \text{……(8)}$$

Where ASIt is current stock market price in period t. Equation (8) above implies that ASIt depends not only on (ASI_{t-1}) but also on previous prices (ASI_{t-p}). Given that the ARCH model assumes that the residuals (ε's) have no constant variance, the conditional variance is modeled to incorporate the ARCH process of (ε^2) in the conditional variance with (q) lagged values of the residuals (ε^2) as stated in equation (9).

$$\sigma_t^2 = \alpha_o + \alpha_1\varepsilon_{t-1}^2 + \ldots + \alpha_p \varepsilon_{t-p}^2 \quad \text{……(9)}$$

However, Bollerslev (1986) refined Engle (1982) linear ARCH (q) model as represented in equation (9) above to remove its long lag structure by including the lagged values of the conditional variance in his formulation which Bollerslev called the Generalized Conditional Heteroscedasticity (GARCH) model. That is, the GARCH (p,q) model specifies the conditional variance to be a linear combination of (q) lags of the squared residuals (ε^2_t) from the conditional return equation and (p) lags from the conditional variance (σ_{t-j}^2). The GARCH (p,q) model is then written as follows:

$$\sigma_t^2 = \alpha_o + \sum \alpha_i \varepsilon_{t-i}^2 + \sum \beta_j \sigma_{t-j}^2 \quad \text{.....................................(10)}$$

where α_i, $\beta_j > 0$ and α_i , $\beta_j < 1$ to avoid the possibility of negative conditional variance. From equation (10), it means that the current value of the conditional variance is a function of a constant and values of the squared residuals from the conditional return equation plus values of the previous conditional variance. (Goudarzi, 2013). Thus, given the standard GARCH (p,q) model, if both the ARCH and GARCH coefficients are significant then there is evidence of strong autocorrelation in the squared price series and weak form inefficiency is established. In addition, the GARCH model can be utilized to model volatility clustering. If the coefficients of the ARCH and GARCH terms sum up to 1, then there is volatility clustering and confirms the presence of ARCH and GARCH effects in the market.

Data

The data set for the study consists of daily, weekly, monthly and quarterly prices of the NSE All-Share Index (ASI) sourced from the official Daily Stock Market Price List of the NSE from 4th January, 1999-31st December, 2013. Thus, the sample consists of 3713 observations for the Daily price list, 783 for the Weekly prices, 180 for the Monthly prices and 60 for the Quarterly prices. The summary descriptive statistics for the data series are as presented in Table 3.1.

TABLE. 3.1

Summary Statistics for NSE ASI (1999-2013)

	ASI Daily	ASI Weekly	ASI Monthly	ASI Quarterly
Mean	23650.95	23788.91	23677.18	23805.59
Median	22984.14	23050.59	22997.05	22776.14
Maximum	66371.20	66121.93	65652.40	63147.04
Minimum	4792.03	4817.770	4890.800	4890.770
Std. Deviation	13671.60	13755.43	13604.79	13793.21
Skewness	0.906150	0.891077	0.881605	0.912048
Kurtosis	3.622438	3.564804	3.554743	3.542606
Jarque-Bera	568.0671	114.0269	25.62486	9.054363
Probability	0.00000	0.00000	0.00000	0.00000
No of Obs.	3713	783	180	60

Source: Author's Computation

Table 3.1 shows that for Daily price index, mean of the series is 23650.95 while the standard deviation is 13671.60. The index reached maximum value of 66371.20 and minimum value of 4792 within the sample period. The J-B statistic at a value of 568.0671 is significant even at 1% level of significance and shows that the Daily ASI series is not a normal distribution. The Weekly ASI also depicts a mean value of 23788.91, maximum value of 66121.93, minimum value of 4817.77 and standard deviation of 13755.43. The J-B value is 114.0269 and p-value of 0.00000 which is highly significant and confirms that the Weekly ASI series is not normally distributed. The Monthly ASI has mean of 23677.18, standard deviation of 13604.79, maximum and minimum values of 65652.40 and 4890.8 respectively and J-B value of 25.62486 which is significant at 1%. The Monthly ASI price series is also not a normal distribution. The Quarterly ASI with a sample size of 60 exhibits the same pattern as the other series. It has a mean of 23805.59, standard deviation of 13793.21 J-B value of 9.054363 and p-value of 0.00000. Thus, the Quarterly ASI series is also not normally distributed. The complete E-View 8 tables are in Appendixes 1A-1D.

RESULTS AND DISCUSSION

Results

The results of the analyses conducted using the different approaches enumerated in 3.1 are as presented in Table 4.1.

Autocorrelation Results. From Table 4.1 below, the summary of the individual autocorrelation (AC) at different lags form 1-36, including the ACF and their associated p-values show that autocorrelation coefficients between successive values of the price series are significantly different from zero for all the price series examined (daily, weekly, monthly and quarterly). Using the autocorrelation approach therefore indicates that the NSE is weak form inefficient across all the price series. The Correlogram of the ASI price series are in appendixes 2A-2D.

Unit Root Tests. The results of both the ADF and P-P unit root tests conducted are summarized in Table.4.1. From the results, it is evident that all the price series are integrated of order one. That is, they become stationary after the first differencing. Thus, at levels they are non-stationary (unit root exists) which supports the presence of predictability in all the level series. Hence, we say the market is weak form inefficient for all the series. The results of the Unit root tests are in Table 4.2.

TABLE 4.1
Summary of Results on Weak form Efficiency across Different Approaches.

Test Method	ASI Daily	ASI Weekly	ASI Monthly	ASI Quarterly
Autocorrelation AC/ACF L-B Test	AC and ACF sig at all lags. Weak form inefficient indicated.	AC and ACF sig at all lags. Weak form inefficient	AC and ACF sig at all lags. Weak form inefficient.	AC and ACF sig at all lags. Weak form inefficient.
Unit Root Test ADF and P-P tests	ADF and P-P are 1(1). Level series non-stationary. Weak form inefficient.	ADF and P-P are 1(1). Level series non-stationary. Weak form inefficient.	ADF and P-P are 1(1). Level series non-stationary. Weak form inefficient.	ADF and P-P are 1(1). Level series not stationary. Weak form inefficient.
Normality Test Using the J-B Test	J-B sig. Series not normally distributed. Weak form inefficient.	J-B sig. Series not normally distributed. Weak form inefficient.	J-B sig. Series not normally distributed. Weak form inefficient.	J-B Sig. Series not normally distributed. Weak form inefficient.
Granger Causality	Bi-directional. Weak form inefficient.	No causality. Weak form efficient.	Bidirectional. Weak form inefficient.	No causality. Weak form efficient
Variance Ratio Test	Joint Test for all lags sig. Series is nonrandom. Weak form inefficient.	Joint test for all lags sig. Series is nonrandom. Weak form inefficient.	Joint test for all lags sig. Series is nonrandom. Weak form inefficient.	Joint test for all lags not sig. Series indicate randomness. Weak form efficient.
ARCH-GARCH Tests	ARCH term sig. GARCH term sig. Weak form inefficient. Volatility clustering present.	ARCH term sig. GARCH term sig. Weak form inefficient. Volatility clustering present.	ARCH term insig. GARCH term insig. Weak form efficient.Volatility clustering not supported.	ARCH term insig. GARCH term insig. Weak form efficient. Volatilty clustering not supported.
Regression Test ASI = bo+b_1ASI(-1)	b_1 sig. Weak form inefficient	b_1 sig. Weak form inefficient.	b_1 sig. Weak form inefficient.	b_1 sig. Weak form inefficient.

Source: Author's computation.

TABLE 4.2
Summary Result of Unit Root Tests

Variable	ADF test statistic at level	ADF test statistic at 1st diff	Order of integration	P-P test statistic at level	P-P test statistic at 1st diff.	Order of integration
Daily ASI	-0.9455	-24.5921	1(1)	-0.95402	-33.2006	1(1)
Weekly ASI	-1.0344	-9.51354	1(1)	-1.32186	-28.9506	1(1)
Monthly ASI	-192820	-4.71846	1(1)	-1.53104	-12.3528	1(1)
Quarterly ASI	-1.8087	-5.06998	1(1)	-1.70611	-5.14495	1(1)

Source: Author's Computation

Normality Tests. The results of the Jarque-Bera (J-B) Normality tests from Table 4.1 indicate that in all the series we cannot accept the null hypothesis of normal distribution given their p-values. All the price series are therefore not normally distributed indicative that the price series do not follow a random walk. The market is therefore inefficient in the weak form. The individual results for the J-B test as well as the histogram of the price series are as presented in appendixes 1A-1D.

Granger Causality Tests. Results of the Granger Causality test as summarized in Table 4.1 vividly show mixed results. We observe significant bi-directional granger causality relationship between successive price changes for the Daily ASI and Quarterly ASI at lag 2 respectively and no significant granger causality relationship for the Weekly ASI and Monthly ASI respectively. While the bi-directional granger relationship in the Daily ASI and Quarterly ASI indicate weak form inefficiency, the absence of granger causality for the Weekly ASI and Monthly ASI respectively suggest weak form efficiency. The individual Granger Causality test results are in appendixes 3A-3D.

Variance Ratio Tests. The Variance ratio tests conducted with the aid of E-Views 8 also report mixed results. The joint variance ratio tests was conducted under the null hypothesis of ASI is a martingale process is rejected for all lags from 2-16 for the Daily ASI, Weekly ASI and Monthly ASI only. On the other hand, the null hypothesis is accepted in the case of the Quarterly ASI. Hence, the variance ratio tests for the Daily, Weekly and Monthly ASI indicate that the price series do not follow a martingale process and therefore weak form inefficient, while the test for Quarterly ASI indicates weak form efficiency. The test results are in appendixes 4A-4D.

The ARCH-GARCH Tests. The GARCH tests conducted also present us with mixed findings. The Daily ASI and Weekly ASI report GARCH equations with significant coefficients of the mean and variance equations thus supporting weak form inefficiency. However, with respect to the GARCH equations for the Monthly and Quarterly ASI, the coefficients of the mean and variance equations are statistically not significant suggesting weak form efficiency and that investors are not rewarded for taking additional risk over time. The results also indicate the presence of volatility clustering with respect to the Daily and Weekly ASI but no evidence to support volatility clustering in the case of Monthly and Quarterly ASI. The E-View results are in appendixes 5A-5D.

Regression Analysis. The findings here show that when the price series are regressed on their lagged values, the regression coefficients are significantly different from zero for all the price series suggesting that there is a significant relationship between the price series and their lagged values. In other words, historical prices can be used to predict current and future prices in the NSE. The results affirm weak form inefficiency in all the price series under study. The estimated regression models are in appendixes 6A-6D.

Discussion

The observed results of our investigation using different tests of the weak form efficiency level of the NSE aptly demonstrate that on balance the NSE is still inefficient in the weak form irrespective of the data testing techniques employed. This is despite all the capital market cum economic reforms undertaken in the last two or three decades by the regulatory authorities in Nigeria to enhance trading and operational activities of the Exchange and hence its efficiency. The empirical findings reported using the autocorrelation coefficients and L-B Q-statistic test are in consonance with the results of studies by Gimba (2012), Emenike (2010), Afego (2012) as well as Nwosa and Oseni (2011) who reported weak form inefficiency of the NSE. The unit test, Normality, Regression test as well as the ARCH-GARCH test results obtained in this study also find support in the works by Ajao and Osayuwu (2012), Worthington and Higgs (2006), Hameed and Ashraf (2006), N'DRI (2015) and Al-Raimony and El-Nader (2012).

However, the mixed results reported with respect to the Granger Causality, Variance Ratio and GARCH tests appear to suggest that the longer the data estimation interval, the more difficult it becomes to use historical prices to predict future prices. In other words, the more weak form efficient the market becomes the longer the time interval. For example, the variance ratio tests for the Daily, Weekly and Monthly market price index ASI reject the null hypothesis of random walk in these series and for the Quarterly data, the null hypothesis is accepted indicating that NSE is weak form efficient when quarterly data series are used. One reason for this phenomenon could be that quarterly data give the market long enough time to incorporate all available information embedded in past prices thus rendering predictability of prices (returns) impossible. This pattern is also evident in the results obtained with respect to the GARCH tests. This therefore calls for further investigation.

CONCLUSION AND RECOMMENDATIONS

This work set out to investigate the weak form efficiency level of the Nigerian Stock Exchange (NSE) over the period 1999-2013 using different data set namely daily, weekly, monthly and quarterly. The motivation for the investigation is anchored on the desire of the researcher to examine whether the plethora of reforms and deregulation policies undertaken by the regulatory authorities in Nigeria in recent times and the visible growth in the Nigerian stock market indices can be said to have been matched by a proportionate improvement in the efficiency level of the market. On another note, different statistical and parametric tests were employed to find out whether our results would be consistent across all testing techniques used or whether such results would be method-specific. In the light of the above, (7) seven testing techniques were employed to test four different data series (28 decision cells in all) for weak form efficiency in the NSE. The empirical results show that except in five cases, all the other 23 decision cells report that the NSE is weak form inefficient. In the five decision cells that report weak form efficiency, four cells relate to Monthly and Quarterly data and one cell is Weekly data. All the seven tests report weak form inefficiency with respect to Daily ASI data series. On balance therefore, the NSE is weak form inefficient. Secondly, the findings show a pattern with respect to the seven decision cells where weak form efficiency was reported perhaps suggesting that the longer the data estimation interval, the more weak-form efficient the market becomes. This however calls for further research.

Given the above findings, it is recommended that the regulatory authorities should intensify efforts aimed at increasing their supervisory and regulatory activities to enhance timely dissemination of relevant and adequate information to market participants. In addition, more reform policies to liberalize and deregulate further the market are sorely needed in order to increase the depth and breadth of the market.

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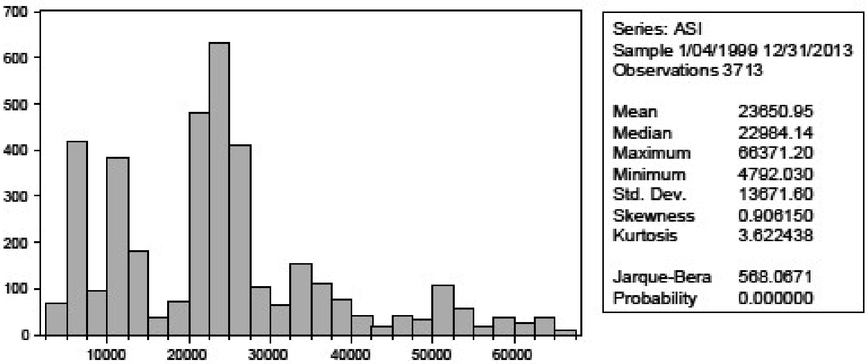
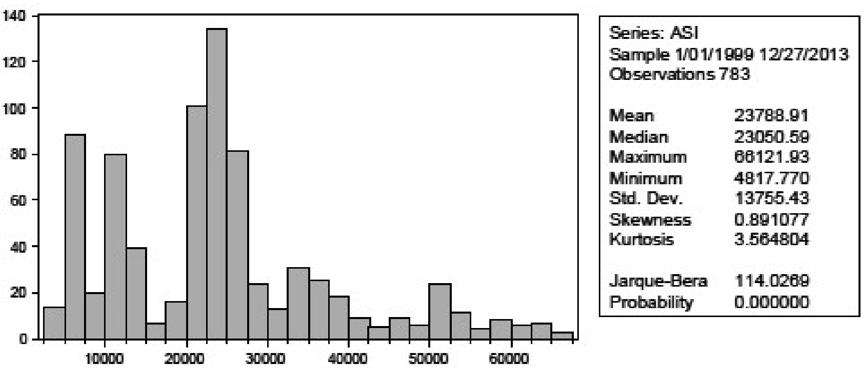
APPENDIXES (OPTIONAL)

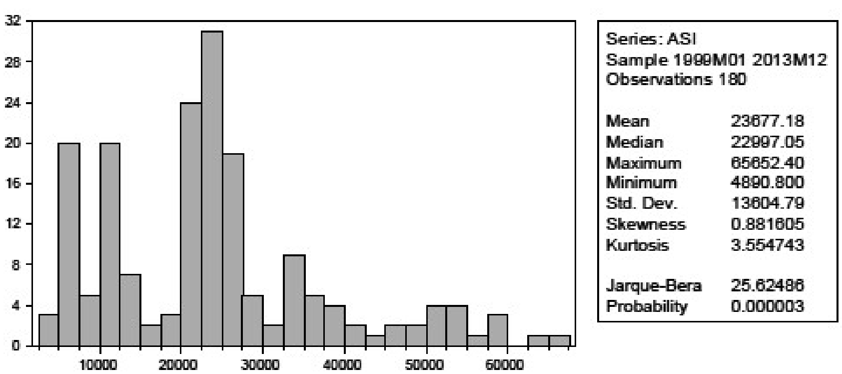
Appendix 1A: Descriptive Statistics Daily ASI.



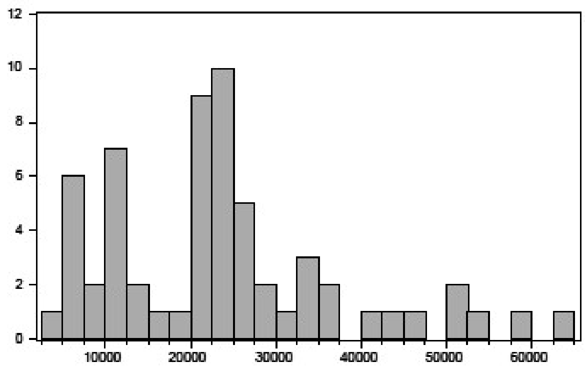
Appendix 1B: Descriptive Statistics Weekly ASI.



Appendix 1C: Descriptive Statistics Monthly ASI.



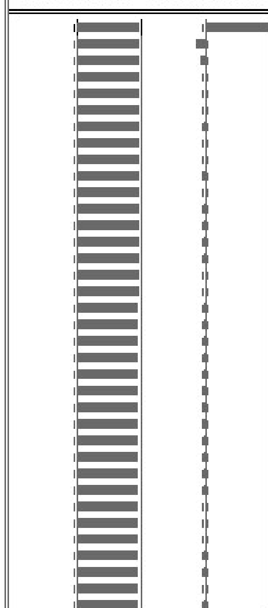
Appendix 1D: Quarterly ASI.



Series: ASI	
Sample 1999Q1 2013Q4	
Observations 60	
Mean	23805.59
Median	22776.14
Maximum	63147.04
Minimum	4890.770
Std. Dev.	13793.21
Skewness	0.912048
Kurtosis	3.542606
Jarque-Bera	9.054363
Probability	0.010811

Appendix 2A: Correlogram of Daily ASI.

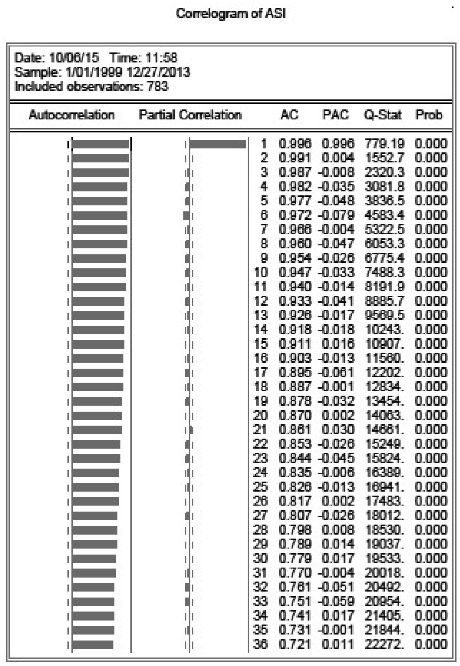
Correlogram of ASI



Date: 10/06/15 Time: 11:19
Sample: 1/04/1999 12/31/2013
Included observations: 3713

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.999	0.999	3711.1	0.000
		2	0.998	-0.143	7416.9	0.000
		3	0.998	-0.061	11117.	0.000
		4	0.997	0.005	14810.	0.000
		5	0.996	0.012	18497.	0.000
		6	0.995	0.016	22179.	0.000
		7	0.994	-0.000	25854.	0.000
		8	0.993	0.006	29524.	0.000
		9	0.992	0.004	33188.	0.000
		10	0.991	-0.025	36846.	0.000
		11	0.990	0.016	40498.	0.000
		12	0.989	-0.012	44144.	0.000
		13	0.988	-0.010	47784.	0.000
		14	0.987	-0.014	51418.	0.000
		15	0.986	-0.003	55045.	0.000
		16	0.985	0.007	58667.	0.000
		17	0.984	0.005	62282.	0.000
		18	0.983	-0.001	65891.	0.000
		19	0.982	-0.004	69494.	0.000
		20	0.981	-0.012	73090.	0.000
		21	0.980	-0.010	76680.	0.000
		22	0.979	-0.022	80264.	0.000
		23	0.978	-0.029	83840.	0.000
		24	0.977	-0.028	87409.	0.000
		25	0.976	-0.026	90971.	0.000
		26	0.975	-0.014	94524.	0.000
		27	0.973	-0.005	98070.	0.000
		28	0.972	-0.016	101607	0.000
		29	0.971	-0.000	105136	0.000
		30	0.970	0.006	108657	0.000
		31	0.968	0.006	112170	0.000
		32	0.967	0.003	115675	0.000
		33	0.966	-0.005	119171	0.000
		34	0.965	-0.016	122660	0.000
		35	0.963	0.003	126140	0.000
		36	0.962	-0.002	129612	0.000

Appendix 2B: Correlogram of Weekly ASI

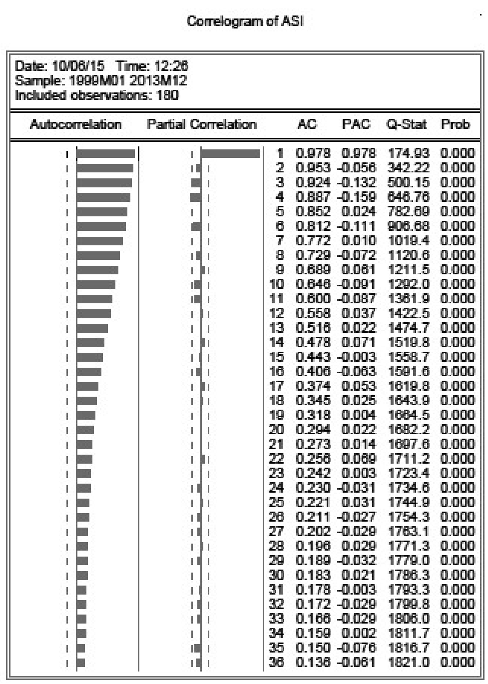


Correlogram of ASI

Date: 10/06/15 Time: 11:58
Sample: 1/01/1999 12/27/2013
Included observations: 783

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.996	0.996	779.19	0.000
		2	0.991	0.004	1552.7	0.000
		3	0.987	-0.008	2320.3	0.000
		4	0.982	-0.035	3081.8	0.000
		5	0.977	-0.048	3836.5	0.000
		6	0.972	-0.079	4583.4	0.000
		7	0.966	-0.004	5322.5	0.000
		8	0.960	-0.047	6053.3	0.000
		9	0.954	-0.026	6775.4	0.000
		10	0.947	-0.033	7488.3	0.000
		11	0.940	-0.014	8191.9	0.000
		12	0.933	-0.041	8885.7	0.000
		13	0.926	-0.017	9569.5	0.000
		14	0.918	-0.018	10243.	0.000
		15	0.911	0.016	10907.	0.000
		16	0.903	-0.013	11560.	0.000
		17	0.895	-0.061	12202.	0.000
		18	0.887	-0.001	12834.	0.000
		19	0.878	-0.032	13454.	0.000
		20	0.870	0.002	14063.	0.000
		21	0.861	0.030	14661.	0.000
		22	0.853	-0.026	15249.	0.000
		23	0.844	-0.045	15824.	0.000
		24	0.835	-0.006	16389.	0.000
		25	0.826	-0.013	16941.	0.000
		26	0.817	0.002	17483.	0.000
		27	0.807	-0.026	18012.	0.000
		28	0.798	0.008	18530.	0.000
		29	0.789	0.014	19037.	0.000
		30	0.779	0.017	19533.	0.000
		31	0.770	-0.004	20018.	0.000
		32	0.761	-0.051	20492.	0.000
		33	0.751	-0.059	20954.	0.000
		34	0.741	0.017	21405.	0.000
		35	0.731	-0.001	21844.	0.000
		36	0.721	0.011	22272.	0.000

Appendix 2C: Correlogram of Monthly ASI



Correlogram of ASI

Date: 10/06/15 Time: 12:26
Sample: 1999M01 2013M12
Included observations: 180

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.978	0.978	174.93	0.000
		2	0.953	-0.056	342.22	0.000
		3	0.924	-0.132	500.15	0.000
		4	0.887	-0.159	646.76	0.000
		5	0.852	0.024	782.69	0.000
		6	0.812	-0.111	906.68	0.000
		7	0.772	0.010	1019.4	0.000
		8	0.729	-0.072	1120.6	0.000
		9	0.689	0.061	1211.5	0.000
		10	0.646	-0.091	1292.0	0.000
		11	0.600	-0.087	1361.9	0.000
		12	0.558	0.037	1422.5	0.000
		13	0.516	0.022	1474.7	0.000
		14	0.478	0.071	1519.8	0.000
		15	0.443	-0.003	1558.7	0.000
		16	0.406	-0.063	1591.6	0.000
		17	0.374	0.053	1619.8	0.000
		18	0.345	0.025	1643.9	0.000
		19	0.318	0.004	1664.5	0.000
		20	0.294	0.022	1682.2	0.000
		21	0.273	0.014	1697.6	0.000
		22	0.256	0.069	1711.2	0.000
		23	0.242	0.003	1723.4	0.000
		24	0.230	-0.031	1734.6	0.000
		25	0.221	0.031	1744.9	0.000
		26	0.211	-0.027	1754.3	0.000
		27	0.202	-0.029	1763.1	0.000
		28	0.196	0.029	1771.3	0.000
		29	0.189	-0.032	1779.0	0.000
		30	0.183	0.021	1786.3	0.000
		31	0.178	-0.003	1793.3	0.000
		32	0.172	-0.029	1799.8	0.000
		33	0.166	-0.029	1806.0	0.000
		34	0.159	0.002	1811.7	0.000
		35	0.150	-0.076	1816.7	0.000
		36	0.136	-0.061	1821.0	0.000

Appendix 2D: Correlogram of Quarterly ASI

Correlogram of ASI

Date: 10/06/15 Time: 12:59
Sample: 1999Q1 2013Q4
Included observations: 60

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.924	0.924	53.840	0.000
		2	0.818	-0.243	96.797	0.000
		3	0.693	-0.166	128.11	0.000
		4	0.551	-0.156	148.25	0.000
		5	0.435	0.146	161.03	0.000
		6	0.337	0.013	168.87	0.000
		7	0.259	0.003	173.57	0.000
		8	0.212	0.072	176.79	0.000
		9	0.183	0.018	179.23	0.000
		10	0.160	-0.045	181.14	0.000
		11	0.140	-0.049	182.64	0.000
		12	0.113	-0.048	183.63	0.000
		13	0.068	-0.117	184.00	0.000
		14	0.027	0.060	184.06	0.000
		15	-0.013	0.005	184.07	0.000
		16	-0.064	-0.120	184.42	0.000
		17	-0.099	0.040	185.27	0.000
		18	-0.121	0.052	186.58	0.000
		19	-0.134	-0.005	188.22	0.000
		20	-0.111	0.148	189.37	0.000
		21	-0.090	-0.102	190.14	0.000
		22	-0.080	-0.113	190.76	0.000
		23	-0.092	-0.202	191.60	0.000
		24	-0.125	-0.019	193.22	0.000
		25	-0.169	0.002	196.25	0.000
		26	-0.206	0.070	200.91	0.000
		27	-0.248	-0.077	207.85	0.000
		28	-0.288	-0.064	217.48	0.000

Appendix 3A: Granger Causality Test of Daily ASI

Pairwise Granger Causality Tests
Date: 10/06/15 Time: 11:28
Sample: 1/04/1999 12/31/2013
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
ASI(-2) does not Granger Cause ASI	3709	20.2130	2.E-09
ASI does not Granger Cause ASI(-2)		8.6E+24	0.0000

Appendix 3B: Granger Causality Test of Weekly ASI

Pairwise Granger Causality Tests
Date: 10/06/15 Time: 12:06
Sample: 1/01/1999 12/27/2013
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
ASI(-2) does not Granger Cause ASI	779	0.53667	0.5849
ASI does not Granger Cause ASI(-2)		2.4E+27	0.0000

Appendix 3C: Granger Causality Test of Monthly ASI

Pairwise Granger Causality Tests
Date: 10/06/15 Time: 12:34
Sample: 1999M01 2013M12
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
ASI(-2) does not Granger Cause ASI	176	11.4650	2.E-05
ASI does not Granger Cause ASI(-2)		5.3E+28	0.0000

Appendix 3D: Granger Causality Test of Quarterly ASI

Pairwise Granger Causality Tests
Date: 10/06/15 Time: 13:05
Sample: 1999Q1 2013Q4
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
ASI(-2) does not Granger Cause ASI	56	1.70290	0.1923
ASI does not Granger Cause ASI(-2)		3.4E+29	0.0000

Appendix 4A: Variance Ratio Test of Daily ASI

Null Hypothesis: ASI is a martingale
Date: 10/06/15 Time: 11:34
Sample: 1/04/1999 12/31/2013
Included observations: 3712 (after adjustments)
Heteroskedasticity robust standard error estimates
Lags specified as grid: min=2, max=16, step=1

Joint Tests	Value	df	Probability
Max |z| (at period 4)*	15.81945	3712	0.0000

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	1.518653	0.038602	13.43607	0.0000
3	1.874273	0.056027	15.60439	0.0000
4	2.085955	0.068647	15.81945	0.0000
5	2.202986	0.078788	15.26865	0.0000
6	2.267712	0.087347	14.51350	0.0000
7	2.305087	0.094831	13.76226	0.0000
8	2.330350	0.101528	13.10328	0.0000
9	2.348081	0.107615	12.52692	0.0000
10	2.370384	0.113219	12.10383	0.0000
11	2.390999	0.118429	11.74541	0.0000
12	2.414145	0.123309	11.46828	0.0000
13	2.439153	0.127917	11.25069	0.0000
14	2.467834	0.132298	11.09489	0.0000
15	2.497348	0.136483	10.97093	0.0000
16	2.521866	0.140499	10.83187	0.0000

*Probability approximation using studentized maximum modulus with parameter value 15 and infinite degrees of freedom

Test Details (Mean = 9.60985721983)

Period	Variance	Var. Ratio	Obs.
1	75536.2	--	3712
2	114713.	1.51865	3711
3	141575.	1.87427	3710
4	157565.	2.08595	3709
5	166405.	2.20299	3708
6	171294.	2.26771	3707
7	174117.	2.30509	3706
8	176026.	2.33035	3705
9	177365.	2.34808	3704
10	179050.	2.37038	3703
11	180607.	2.39100	3702
12	182355.	2.41414	3701
13	184244.	2.43915	3700
14	186411.	2.46783	3699
15	188640.	2.49735	3698
16	190492.	2.52187	3697

Appendix 4B: Variance Ratio Test of Weekly ASI

Variance Ratio Test on ASI

Null Hypothesis: ASI is a martingale
Date: 10/06/15 Time: 12:00
Sample: 1/01/1999 12/27/2013
Included observations: 782 (after adjustments)
Heteroskedasticity robust standard error estimates
Lags specified as grid: min=2, max=16, step=1

Joint Tests	Value	df	Probability
Max |z| (at period 16)*	2.967331	782	0.0441

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	1.003736	0.090081	0.041470	0.9669
3	1.022537	0.127639	0.176566	0.8598
4	1.046827	0.152639	0.306780	0.7590
5	1.101687	0.171511	0.592890	0.5533
6	1.192335	0.186893	1.029115	0.3034
7	1.258849	0.200229	1.292765	0.1961
8	1.330713	0.212202	1.558479	0.1191
9	1.397491	0.223171	1.781103	0.0749
10	1.471606	0.233461	2.020063	0.0434
11	1.539318	0.243345	2.216270	0.0267
12	1.610145	0.252914	2.412460	0.0158
13	1.678904	0.262175	2.589509	0.0096
14	1.744289	0.271140	2.745032	0.0061
15	1.799446	0.279801	2.857198	0.0043
16	1.855010	0.288141	2.967331	0.0030

*Probability approximation using studentized maximum modulus with parameter value 15 and infinite degrees of freedom

Test Details (Mean = 44.2758439898)

Period	Variance	Var. Ratio	Obs.
1	875174.	--	782
2	878444.	1.00374	781
3	894898.	1.02254	780
4	916156.	1.04683	779
5	964168.	1.10169	778
6	1043500	1.19233	777
7	1101712	1.25885	776
8	1164606	1.33071	775
9	1223048	1.39749	774
10	1287912	1.47161	773
11	1347172	1.53932	772
12	1409157	1.61014	771
13	1469333	1.67890	770
14	1526557	1.74429	769
15	1574829	1.79945	768
16	1623457	1.85501	767

Appendix 4C: Variance Ratio Test of Monthly ASI

Variance Ratio Test on ASI

Null Hypothesis: ASI is a martingale
Date: 10/06/15 Time: 12:30
Sample: 1999M01 2013M12
Included observations: 179 (after adjustments)
Heteroskedasticity robust standard error estimates
Lags specified as grid: min=2, max=16, step=1

Joint Tests	Value	df	Probability
Max |z| (at period 13)*	3.288304	179	0.0150

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	1.128150	0.106656	1.201531	0.2295
3	1.338284	0.167458	2.020110	0.0434
4	1.593353	0.220834	2.686868	0.0072
5	1.741692	0.267125	2.776576	0.0055
6	1.915978	0.306349	2.989983	0.0028
7	2.042177	0.340273	3.062767	0.0022
8	2.162486	0.370786	3.135198	0.0017
9	2.255972	0.399421	3.144483	0.0017
10	2.358100	0.426576	3.183722	0.0015
11	2.475715	0.451996	3.264887	0.0011
12	2.558187	0.476062	3.273078	0.0011
13	2.640741	0.498963	3.288304	0.0010
14	2.687654	0.520547	3.242078	0.0012
15	2.722216	0.540813	3.184492	0.0015
16	2.761377	0.559923	3.145749	0.0017

*Probability approximation using studentized maximum modulus with parameter value 15 and infinite degrees of freedom

Test Details (Mean = 200.192178771)

Period	Variance	Var. Ratio	Obs.
1	4664917	--	179
2	5262728	1.12815	178
3	6242986	1.33828	177
4	7432859	1.59335	176
5	8124848	1.74169	175
6	8937880	1.91598	174
7	9526587	2.04218	173
8	1.0E+07	2.16249	172
9	1.1E+07	2.25597	171
10	1.1E+07	2.35810	170
11	1.2E+07	2.47571	169
12	1.2E+07	2.55819	168
13	1.2E+07	2.64074	167
14	1.3E+07	2.68765	166
15	1.3E+07	2.72222	165
16	1.3E+07	2.76138	164

Appendix 4D: Variance Ratio Test of Quarterly ASI

Variance Ratio Test on ASI

Null Hypothesis: ASI is a martingale
Date: 10/06/15 Time: 13:02
Sample: 1999Q1 2013Q4
Included observations: 59 (after adjustments)
Heteroskedasticity robust standard error estimates
Lags specified as grid: min=2, max=16, step=1

Joint Tests	Value	df	Probability
Max |z| (at period 4)*	2.244331	59	0.3140

Individual Tests

Period	Var. Ratio	Std. Error	z-Statistic	Probability
2	1.402779	0.255558	1.576074	0.1150
3	1.704803	0.369212	1.908939	0.0563
4	2.004330	0.447496	2.244331	0.0248
5	2.123840	0.506598	2.218405	0.0265
6	2.163722	0.554268	2.099566	0.0358
7	2.155089	0.594694	1.942326	0.0521
8	2.066757	0.630725	1.691317	0.0908
9	1.961070	0.663666	1.448124	0.1476
10	1.872873	0.693679	1.258324	0.2083
11	1.791570	0.721018	1.097851	0.2723
12	1.749406	0.746041	1.004511	0.3151
13	1.765781	0.768980	0.995839	0.3193
14	1.787120	0.790020	0.996329	0.3191
15	1.807158	0.809368	0.997270	0.3186
16	1.856295	0.827261	1.035096	0.3006

*Probability approximation using studentized maximum modulus with parameter value 15 and infinite degrees of freedom

Test Details (Mean = 588.875084746)

Period	Variance	Var. Ratio	Obs.
1	1.9E+07	--	59
2	2.6E+07	1.40278	58
3	3.2E+07	1.70480	57
4	3.7E+07	2.00433	56
5	3.9E+07	2.12384	55
6	4.0E+07	2.16372	54
7	4.0E+07	2.15509	53
8	3.8E+07	2.06676	52
9	3.6E+07	1.96107	51
10	3.5E+07	1.87287	50
11	3.3E+07	1.79157	49
12	3.3E+07	1.74941	48
13	3.3E+07	1.76578	47
14	3.3E+07	1.78712	46
15	3.4E+07	1.80716	45
16	3.5E+07	1.85629	44

Appendix 5A: ARCH-GARCH Test of Daily ASI

Dependent Variable: ASI
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 10/06/15 Time: 11:38
Sample (adjusted): 1/05/1999 12/31/2013
Included observations: 3712 after adjustments
Convergence achieved after 85 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-2.992298	1.770550	-1.690039	0.0910
ASI(-1)	1.000562	0.000144	6950.151	0.0000
	Variance Equation			
C	15.14322	6.556309	2.309717	0.0209
RESID(-1)^2	0.211398	0.008123	26.02580	0.0000
GARCH(-1)	0.832708	0.004794	173.7151	0.0000

R-squared	0.999595	Mean dependent var	23655.79
Adjusted R-squared	0.999595	S.D. dependent var	13670.25
S.E. of regression	275.0641	Akaike info criterion	13.03238
Sum squared resid	2.81E+08	Schwarz criterion	13.04075
Log likelihood	-24183.09	Hannan-Quinn criter.	13.03536
Durbin-Watson stat	0.958428		

Appendix 5B: ARCH-GARCH Test of Weekly ASI

Dependent Variable: ASI
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 10/06/15 Time: 12:10
Sample (adjusted): 1/08/1999 12/27/2013
Included observations: 782 after adjustments
Convergence achieved after 285 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	19.55921	18.41875	1.061919	0.2883
ASI(-1)	0.999052	0.001284	778.2690	0.0000
	Variance Equation			
C	1211.404	374.0589	3.238539	0.0012
RESID(-1)^2	0.316075	0.035405	8.927340	0.0000
GARCH(-1)	0.795665	0.015846	50.21180	0.0000

R-squared	0.995362	Mean dependent var	23812.16
Adjusted R-squared	0.995356	S.D. dependent var	13748.83
S.E. of regression	936.9103	Akaike info criterion	15.66442
Sum squared resid	6.85E+08	Schwarz criterion	15.69423
Log likelihood	-6119.790	Hannan-Quinn criter.	15.67589
Durbin-Watson stat	1.991187		

Appendix 5C: ARCH-GARCH Test of Monthly ASI

Dependent Variable: ASI
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 10/06/15 Time: 12:36
Sample (adjusted): 1999M02 2013M12
Included observations: 179 after adjustments
Convergence not achieved after 500 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-6.254968	448.5608	-0.013945	0.9889
ASI(-1)	1.019319	0.012351	82.52845	0.0000
Variance Equation				
C	1964210.	423719.9	4.635633	0.0000
RESID(-1)^2	0.747081	0.292543	2.553748	0.0107
GARCH(-1)	0.141709	0.083483	1.697463	0.0896

R-squared	0.973471	Mean dependent var	23778.75
Adjusted R-squared	0.973321	S.D. dependent var	13574.34
S.E. of regression	2217.189	Akaike info criterion	17.81106
Sum squared resid	8.70E+08	Schwarz criterion	17.90010
Log likelihood	-1589.090	Hannan-Quinn criter.	17.84717
Durbin-Watson stat	1.709251		

Appendix 5D: ARCH-GARCH Test of Quarterly ASI

Dependent Variable: ASI
Method: ML - ARCH (Marquardt) - Normal distribution
Date: 10/06/15 Time: 13:08
Sample (adjusted): 1999Q2 2013Q4
Included observations: 59 after adjustments
Convergence not achieved after 500 iterations
Presample variance: backcast (parameter = 0.7)
GARCH = C(3) + C(4)*RESID(-1)^2 + C(5)*GARCH(-1)

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	535.2013	1003.176	0.533507	0.5937
ASI(-1)	1.012235	0.029749	34.02562	0.0000
Variance Equation				
C	3169474.	2029383.	1.561792	0.1183
RESID(-1)^2	0.643613	0.481642	1.336288	0.1815
GARCH(-1)	0.305612	0.257668	1.186070	0.2356

R-squared	0.899156	Mean dependent var	24116.06
Adjusted R-squared	0.897386	S.D. dependent var	13698.53
S.E. of regression	4388.100	Akaike info criterion	19.14956
Sum squared resid	1.10E+09	Schwarz criterion	19.32562
Log likelihood	-559.9119	Hannan-Quinn criter.	19.21828
Durbin-Watson stat	1.260319		

Appendix 6A: Regression Test of Daily ASI

Dependent Variable: ASI
Method: Least Squares
Date: 10/06/15 Time: 11:41
Sample (adjusted): 1/05/1999 12/31/2013
Included observations: 3712 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	14.58054	9.014622	1.617432	0.1059
ASI(-1)	0.999790	0.000330	3029.159	0.0000

R-squared	0.999596	Mean dependent var	23655.79
Adjusted R-squared	0.999596	S.D. dependent var	13670.25
S.E. of regression	274.8605	Akaike info criterion	14.07094
Sum squared resid	2.80E+08	Schwarz criterion	14.07429
Log likelihood	-26113.67	Hannan-Quinn criter.	14.07214
F-statistic	9175802.	Durbin-Watson stat	0.959110
Prob(F-statistic)	0.000000		

Appendix 6B: Regression Test of Weekly ASI

Dependent Variable: ASI
Method: Least Squares
Date: 10/06/15 Time: 12:15
Sample (adjusted): 1/08/1999 12/27/2013
Included observations: 782 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	104.1225	66.82973	1.558026	0.1196
ASI(-1)	0.997482	0.002434	409.7860	0.0000

R-squared	0.995377	Mean dependent var	23812.16
Adjusted R-squared	0.995371	S.D. dependent var	13748.83
S.E. of regression	935.4655	Akaike info criterion	16.52252
Sum squared resid	6.83E+08	Schwarz criterion	16.53444
Log likelihood	-6458.305	Hannan-Quinn criter.	16.52711
F-statistic	167924.5	Durbin-Watson stat	1.994211
Prob(F-statistic)	0.000000		

Appendix 6C: Regression Test of Monthly ASI

Dependent Variable: ASI
Method: Least Squares
Date: 10/06/15 Time: 12:38
Sample (adjusted): 1999M02 2013M12
Included observations: 179 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	505.3492	324.0074	1.559684	0.1206
ASI(-1)	0.987058	0.011916	82.83133	0.0000

R-squared	0.974851	Mean dependent var	23778.75
Adjusted R-squared	0.974709	S.D. dependent var	13574.34
S.E. of regression	2158.753	Akaike info criterion	18.20356
Sum squared resid	8.25E+08	Schwarz criterion	18.23917
Log likelihood	-1627.219	Hannan-Quinn criter.	18.21800
F-statistic	6861.030	Durbin-Watson stat	1.745999
Prob(F-statistic)	0.000000		

Appendix 6D: Regression Test of Quarterly ASI

Dependent Variable: ASI
Method: Least Squares
Date: 10/06/15 Time: 13:06
Sample (adjusted): 1999Q2 2013Q4
Included observations: 59 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	1819.426	1114.381	1.632678	0.1080
ASI(-1)	0.947697	0.040990	23.12044	0.0000

R-squared	0.903644	Mean dependent var	24116.06
Adjusted R-squared	0.901953	S.D. dependent var	13698.53
S.E. of regression	4289.341	Akaike info criterion	19.59896
Sum squared resid	1.05E+09	Schwarz criterion	19.66939
Log likelihood	-576.1694	Hannan-Quinn criter.	19.62646
F-statistic	534.5549	Durbin-Watson stat	1.238605
Prob(F-statistic)	0.000000		