



STOCK RETURNS PREDICTABILITY AND THE ADAPTIVE MARKET HYPOTHESIS IN EMERGING MARKETS: EVIDENCE FROM THE NIGERIAN CAPITAL MARKET. (1986-2016)



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ABSTRACT

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This paper explores the Adaptive Market Hypothesis using daily data from the Nigerian stock markets for the period of 1987 to 2016. Using different four subsamples, the results are as follows; all four linear tests for the ASI suggest that the market is adaptive, the different tests disagree in relation to which subsamples are efficient and inefficient. Each of the nonlinear tests suggests that each market exhibits strong and significant nonlinear dependence, indicating inefficiency. These results indicate on evidence on the linear dependence of the ASI markets, however, it exhibits strong nonlinear dependence and in that sense they are inefficient for every subsample. There is also very little evidence of a switch to efficiency. In summary the evidence from the linear tests seems to be very supportive of the AMH whereas the nonlinear tests indicate continuing, although time varying, inefficiency. This results have some important policy implications.

1. INTRODUCTION

The Efficient Market Hypothesis (EMH) has been argued and discussed extensively in the finance literature. EMH theoretically proposed that a market is efficient if its price reflects all relevant information immediately, Fama (1965). Thus, it is impossible to exploit any information set to predict future price changes. Empirically, the weak-form version of market efficiency has become the most commonly tested form of the hypothesis in the literature. Evidence from the weak-form asserts that prices already reflect all information that can be derived by examining past market trading data such as the history of past prices, trading volume etc. In a situation where prices were predictable and profits could be ascertained by through historical data, arbitrage would eliminate these profits in an efficiently operating market. Therefore there should be no predictability in security prices.

Previous studies have shown that stock returns do not follow random walks (see, for example (Fama and French, 1988; Lo and MacKinlay, 1988; Brock *et al.*, 1992; Jegadeesh and Titman, 1993)). This has paved way for contemporary scholars examining the reliability of the EMH in different economy (see, for example, (Opong *et al.*, 1999; Lim *et al.*, 2008; Borges, 2010)). Nevertheless, the majority of these studies have one major shortcoming. They use statistical tests to evaluate whether a market is efficient over the whole of some predefined period. This

means that market efficiency is treated as an all-or-nothing condition. However it is reasonable to expect market efficiency to evolve over time due to varying underlying market factors, such as institutional, regulatory and technological changes and possibly the demography behaviour of market participants.

Studies on EMH are extended by introducing to accommodate the idea of a changing degree of market efficiency over time. Lo (2004) proposes a new version of the EMH derived from evolutionary principles. The author argues that valuable insights can be derived from the biological perspective and calls for an evolutionary alternative to market efficiency. This paradigm is called the Adaptive Market Hypothesis (AMH) under which the EMH and market inefficiency can co-exist in an intellectually consistent manner.

In another empirical literature, AMH provides a number of practical implications within finance. Firstly, the risk premium varies over time according to the stock market environment and the demographics of investors in that environment. The second implication is that arbitrage opportunities do exist from time to time in the market. Thus from an evolutionary viewpoint, active liquid financial markets imply that profit opportunities must exist. However as they are exploited, they disappear. But new opportunities are continually being created as certain species/ traders die out and rather than move towards a higher degree of efficiency the AMH implies that complex market dynamics such as trends panics, bubbles and crashes are continually witnessed in natural market ecologies. The third implication is that investment strategies are successful or unsuccessful, depending on the particular market environment.

Contrary to the EMH, the AMH implies that investment strategies may decline for a time, and then return to profitability when environmental conditions become more conducive to such strategies. A consequence of this implication is that market efficiency is not an all-or-nothing condition, but is a characteristic that varies continuously over time and across markets. Lo (2005) is the view that convergence to equilibrium is neither guaranteed nor likely to occur and that it is incorrect to assume that the market must move towards some ideal state of efficiency. Lim and Brooks (2006) examine the evolving efficiency of developed and developing stock markets through the portmanteau bi-correlation test statistic. Using a rolling sample approach, they find that the degree of market efficiency varies through time in a cyclical fashion. Todea *et al.* (2009) study the profitability of the moving average strategy over windows using linear and nonlinear tests. They report that returns are not constant over time, but rather episodic.

Using two methods; autocorrelation and regression analysis, Ito and Sugiyama (2009) examine the monthly S&P500 returns. They document that the degree of market efficiency varies over time, with the market being most inefficient during the late 1980s and most efficient around the year 2000. Applying two autocorrelation on AMH return predictability of the daily and weekly DJIA from 1900 to 2009, Kim *et al.* (2011) found strong evidence that return predictability fluctuates over time in a similar way to that described by Lo and that the US market has become more efficient after 1980. Also they revealed how the return predictability over time is related to changing market and economic conditions. They found that there is no return predictability during market crashes, while economic and political crises are associated with a high degree of return predictability.

On cross country analysis, Smith (2012) investigates the adaptive nature of fifteen European emerging stock markets, along with the developed markets of Greece, Portugal and the UK. Applying the rolling window variance ratio tests for the period February 2000 to December 2009 they found that the most efficient markets were the Turkish, UK Hungarian and Polish markets, while the least efficient were the Ukrainian, Maltese and Estonian. Each of the eighteen markets provides evidence of the time-varying nature of return predictability which is consistent with the adaptive market hypothesis. Lim *et al.* (2013) show that the three largest US indices have time-varying properties using a rolling window AR and WBAVR test. They argued that markets must go through periods of efficiency and inefficiency.

The purpose of this paper is to extend the literature on the AMH by examining the changing efficiency of the Nigeria stock markets using tests for independence to determine whether the AMH is appropriate to explain the

behaviour of the stock returns of these three countries. We contribute to the literature in several ways. First, the data covers a very long time span of the most important markets in Nigeria. Second, this study uses a range of linear and nonlinear tests, thus capturing the main dynamics of stock returns in several dimensions and also reducing the risk that a spurious result from one test may affect the conclusions. Third, this study uses subsample analysis which gives a clear picture of the changing efficiency of the Nigeria stock market and will not be distorted by long memory as is the case with rolling subsample analysis. Rolling subsample analysis has the major flaw of one extreme event affecting and skewing the results for many subsamples. The remainder of the paper is organized as follows. The next section explains the methodology of the different statistical tools used to detect departures from the EMH. Section 3 presents the data while Section 4 presents the empirical results. Section 5 summarizes the findings and provides conclusions.

2. METHODOLOGY

Weak-form market efficiency states that analysis of past prices is futile when predicting prices which mean that stock prices move in a random walk. To examine whether prices follow a random walk, stock returns are examined using five tests for independence. The first three tests examine linear dependence in returns, while the last two tests examine nonlinear dependence in returns. A five-yearly subsample method is favoured to capture the changing efficiency of the three markets. We suggest that stock market return behaviour over subsample periods can be categorised into five types depending on the independence of the returns over time. The five types are: efficient, moving towards efficiency, switching to efficiency/inefficiency, adaptive or inefficient. A market is efficient if returns are independent with no dependence throughout the sample. A market is moving towards efficiency if returns had dependence but over time the dependence in returns has trended to reduce. A market has switched to efficiency/inefficiency if returns were independent (dependent) but become dependent (independent), although this could be evidence of an early stage adaptive market. A market is deemed adaptive if returns have gone through at least three different stages of dependence (e.g. dependent, independent, dependent). Finally, a market is inefficient if it has no independence in returns throughout the sample. Thus this classification incorporates all possible types of returns behaviour. In this paper, for simplicity and clarity, we examine dependency primarily from a statistical viewpoint. As Fama (1965) points out however, dependence from a statistical viewpoint may not be of paramount importance for investors, since the magnitude of dependence may be so small that trading on it may be unprofitable given trading costs. The extent to which investors may have been able to profitably trade on the levels of dependence is left beyond the scope of the current paper given the considerable difficulties of estimating realistic historic trading costs over such long investigation periods.

2.1. Linear Tests

2.1.1. Autocorrelation Test

Autocorrelation estimates are used to test the hypothesis that the process generating the observed return is a series of independent and identical distribution (iid) of random variables. It helps to evaluate whether successive values of serial correlation are different from zero. To test the joint hypothesis that all autocorrelation coefficients ρ_k are simultaneously equal to zero, we use Ljung and Box (1978) portmanteau Q statistic. The test statistic is

$$LB = n(n+2) \sum_{k=1}^m \left(\frac{\rho_k^2}{n-k} \right) \quad (1)$$

where n is the number of observations, m lag length. The test follows a chi-square (χ^2) distribution.

2.1.2. Runs Test

The runs test is a non-parametric test which also investigates the randomness of a series of stock returns. However, unlike the autocorrelation test, it does not require returns to be normally distributed. The runs test is usually deemed a linear test however it can also detect nonlinearity in a returns series. Thus the results may be somewhat different to the linear autocorrelation test. If an uninterrupted series of data is random, in the runs test the actual number of runs in the series should be close to the expected number of runs, irrespective of signs. A run is a succession of identical symbols (positive or negative returns in our case) which are followed or preceded by different symbols. So a run is a sequence of positive or negative returns. The number of positive runs is denoted by P, while the number of negative runs is denoted by N. The formula to calculate the expected number of runs is;

$$ER = \frac{X(X-1) - \sum_{i=1}^3 c_i^2}{X} \quad (2)$$

where X is the total number of runs, c_i is the number of returns changes of each category of sign ($i = 1, 2, 3$). The ER in Equation (2) has an approximate normal distribution for large X. Hence, to test the null hypothesis, we use standard Z statistic.

If the z-value is greater than the critical values, we reject the null hypothesis of independence of the series. Otherwise, we conclude that the returns are independent. Furthermore, the sample will not be independent if it consists of too many or too few runs. Hence, the independence of returns can be assessed by analysing the distribution of the duration of runs. If the actual number of runs exceeds (falls below) the expected runs, a positive (negative) z-value is obtained.

2.1.3. Variance Ratio Test

Since the seminal work of [Lo and MacKinlay \(1988\)](#) the variance ratio test has emerged as a primary tool in examining whether stock returns are serially uncorrelated, with [Hoque et al. \(2007\)](#) stating that it has become the most commonly used econometric tool for testing the random walk hypothesis. The variance ratio test is based on the statistical property that if a stock price follows a random walk, then the variance of the k-period return is equal to k times the variance of the one period return. That is, the variance of its 10 day returns is equal to 10 times the variance of its daily return. [Lo and MacKinlay \(1988\)](#) provide a test for this hypothesis using the single variance ratio, denoted by VR(k). Let r_t denote an asset return at time t, where $t = 1, 2, 3 \dots T$. Then the variance ratio for r_t , with holding period k is;

$$VR(2) = 1 + \rho(1)$$

(3)

where $\rho(j)$ is the autocorrelation of r_t of order j. That is, the variance ratio is one plus a weighted sum of autocorrelation coefficients for the asset returns with positive and declining weights. The variance ratio tests the null hypothesis that the variance ratio equals 1 for all ks since returns are serially uncorrelated with $\rho(j) = 0$. Alternatively, values for VR(k) greater than 1 imply positive serial correlations while values less than 1 imply negative serial correlations or mean reversion.

2.2. Nonlinear Tests

The previous tests examined the linear dependence in the stock market returns, but nonlinear dependence may not be detected. Nonlinear dependence in stock returns has gained much attention in recent times as it indicates possible dependence when linear tests indicate independence ([Hiremath and Kamaiah, 2010](#); [Alagidede, 2011](#); [Caraiani, 2012](#); [Lim and Hooy, 2012](#)). Persistent nonlinear dependencies could potentially be exploited using a variety of trading strategies. To the extent that good estimates for future price levels are possible conventional

long/short investment strategies using stocks may be appropriate. Other moments or other features of the underlying price distribution may also be predictable and this information can be potentially exploited using appropriate derivatives strategies (see, Hull (2012) chapter 11 for an outline of options trading strategies). A very simple example would be if variance was expected to increase substantially it might prove profitable to go long on options as their price is positively related to variance (both empirically and theoretically under the Black-Scholes model). As for the linear case the issue of trading costs is still critical as far as the economic profitability of strategies is concerned. Many statistical tests for nonlinear dependence have been proposed in the recent literature. Instead of only using a single statistical test, we employ a battery of nonlinear tests to enable a deeper and more detailed insight into the series while minimising the probability of missing something and thus drawing the wrong conclusions. If the tests display a unanimous consensus in favour of a specific result, this result is more likely to be correct. Initially the linear structure is removed from the data through a pre-whitening model. An AR(p) model is fitted to the data with the optimal length determined when the standardised residuals are no longer correlated through the Ljung-Box Q-statistic up to 20 lags.² The AR(p) model in which the Q-statistic at 20 lags is not significant at the 10% level of significance will be chosen. The residuals of the pre-whitened model will be tested through a battery of nonlinear tests, namely the McLeod and Li (1983); Engle (1982) and Brock *et al.* (1996) tests.

2.2.1. McLeod Li Test

The McLeod and Li (1983) is a portmanteau test of nonlinearity. To test for nonlinear effects in a time series, they propose the following statistic;

$$Q_{(m)} = \frac{n(n+2)}{n-k} \sum_{k=1}^m r_a^2(k) \quad (4)$$

where r_a^2 is the autocorrelations of the squared residuals. If the series e_t is independently and identically distributed then the asymptotic distribution of $Q(m)$ is χ^2 with m degrees of freedom. The null hypothesis is independence of returns and if it is rejected, it indicates the presence of ARCH/GARCH nonlinear effects in the data.

2.2.2. Engle LM Test

The Engle LM test was suggested by Engle in 1982 to detect ARCH disturbances. The residuals of the AR(p) model are tested for heteroskedasticity. The Engle LM statistic is computed from an auxiliary test regression, which is;

$$e_t^2 = a_0 + \sum_{i=1}^p a_i e_{t-i}^2 + v_t \quad (5)$$

where e is the residual from the pre-whitened AR(p) model. The F-statistic is an omitted variable test for the joint significance of all lagged squared residuals, but the NR^2 is Engle's LM test statistic, computed as the number of observations times the R^2 from the test regression. Under the null hypothesis of a linear generating mechanism for e_t , NR^2 for this regression is asymptotically $\chi^2(p)$. If the null hypothesis is rejected, there is evidence of ARCH/GARCH effects in the data.

2.2.3. BDS Test

The BDS test is a powerful and frequently used (Chen and Yeh, 2002) non-parametric test for serial dependence (or alternatively a nonlinear structure) in time series analysis, which was set out by Brock *et al.* (1987)

although the version used is based on Brock *et al.* (1996). However, the BDS test gives no information as to which data generating mechanism would be appropriate to model the data, thus other tests are also appropriate. The null hypothesis is that the data generating processes are independent and identically distributed (iid), while the alternative hypothesis is ‘an indication that the model is misspecified’ (Brock *et al.*, 1996). The failure to accept the null hypothesis dismisses market efficiency as the test is a measure of nonlinear predictability of the sample. The correlation integral is the probability that any two points are within a certain length ‘ ϵ ’ apart in phase space. As we increase ‘ ϵ ’, the probability scales according to the fractional dimension of the phase space. The correlation integrals are calculated according to;

$$C_m(n, \epsilon) = \frac{2}{(n-m)(n-m+1)} \sum_{s=1}^{n-m} \sum_{i=s+1}^{n-m+1} I_m(x_s, x_t, \epsilon) \quad (6)$$

where n is sample size, m is embedding dimension and ϵ is the maximum difference between pairs of observations counted in estimating the correlation integral.

3. THE DATA

The data used in this study are complete historical record of the daily prices of All share index (ASI). This index represents the most important and well established stock markets and provide enough data to examine how efficiency has changed over the very long term. The sample periods are from January 1987 to December 2016. Summary statistics for the stock index for the full sample and subsamples are presented in Table 1. The daily return for each index is calculated by;

$$r_t = \ln(P_t) - \ln(P_{t-1}) \quad (7)$$

where $\ln(pt)$ is the natural logarithm of the index at time t . The daily returns are mostly negatively skewed for each subsample, which means that the magnitude of the extreme negative returns tends to be greater than that of extreme positive returns. The kurtosis is greater than 3 for each subsample indicating a leptokurtic distribution. The Jarque–Bera statistic rejects the hypothesis of a normal distribution of daily returns in all subsamples at a significance level of 1%.

4. EMPIRICAL RESULTS AND DISCUSSION OF FINDINGS

This section discusses the empirical results of both linear and nonlinear tests carried out in the present paper. Table 1 reports the descriptive statistics for ASI returns. The mean returns are positive during the full sample period and the sub-sample average returns were highest during 2007-16. The standard deviation of full sample returns is the highest and show evidence of high volatility. The skewness is negative for the full sample and subsamples implying that returns are flatter to the left compared to the normal distribution, except sample for the 1987-96. Moreover, it indicates that the negative returns have greater magnitude than the positive. The kurtosis indicates that return distribution has sharp peaks compared to a normal distribution. Further, Jarque and Bera (1980) statistic confirm that index returns are normally distributed

Table-1. Descriptive statistics

Sample period	Mean	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarq-Be	Prob	Obs
Full sample	8.8037	11.0921	5.0383	1.7204	-0.7983	2.3684	44.2224	0.0000	360
Jan 1987-Dec 1996	6.7049	8.8525	5.0383	1.1510	0.2960	1.9341	7.4325	0.0243	120
Jan 1997-Dec 2006	8.9256	11.0921	5.0421	1.6412	-0.9449	2.7463	18.1795	0.0001	120
Jan 2007-Dec 2016	9.0150	11.0512	5.1132	1.6584	-0.7718	2.4068	13.6721	0.0011	120

Source: various computation from review9

4.2. Linear Results

4.2.1. Ljung-Box and Runs Test

The present study employs Ljung-Box test to check whether all autocorrelation are simultaneously equal to zero. The autocorrelation and runs test results are documented in Table 2. The results show that the full sample of all three sub-sample indices possess a first order autocorrelation that is significant and positive, indicating that stock returns are not independent on the basis of their full past price history. Table 2 also documents the autocorrelation coefficient for the subsamples of all three indices. However, lag 10 and lag 20 in sub-sample 1997-2006 shows no evidence of autocorrelation.

Considering the runs test, we find evidence of autocorrelation. We found linear autocorrelations during those periods. However, autocorrelation and runs test results indicate that the Nigerian stock market is switching between efficiency and inefficiency. In other words, these results seem to support the view that Nigeria stock market is adaptive.

Table-2. Ljung-Box Q and runs tests statistics

Sample period	LB(5)	LB(10)	LB(20)	Runs test
Full sample	0.175***	0.122***	0.021***	122***
1987-1996	0.229*	0.031*	0.078*	38***
1997-2006	0.108*	0.058	0.014	41***
2007-2016	0.096*	0.115*	0.094*	51*

The autocorrelation coefficient are given in the table at lags 5, 15 and 20 for the full sample and subsample period. The null of LB is zero autocorrelation. The last column furnishes the Runs Z statistics. *Represent significance at 10%. **Represent significance at 5%. ***Represent significance at 1%.

4.2.2. Lo and Mackinlay Variance Ratios

The ASI results for the variance ratio test full sample show that there is mean reversion between returns for all four tested k's since the variance-ratio statistic is significantly less than 1 and statistically significant at 1%. The results for the subsample analysis in Table 3 shows that only the period 1987–1996 has no significant positive variance ratio statistic for the tested k's. However, some subsamples have certain k's which provide significant positive variance ratio statistics. Thus the ASI variance ratio test results indicate that returns do conform to the AMH. This suggests that there is evidence of a switch to efficiency, but similarly to autocorrelation and runs test results, it could also be the first stage of the AMH.

Table-3. Variance ratios

Sample period	2	4	8	16
Full sample	0.4852***	0.3132***	0.1365***	0.0739***
1987-1996	0.4358*	0.3169	0.136	0.0509
1997-2006	0.5976**	0.3080**	0.1508**	0.0875**
2007-2016	0.4657**	0.3260**	0.145**	0.0941

Note: The Lo-MacKinlay variance ratios VR (q) are reported in the main rows and variance test $[Z^*(q)]$ statistics. Under the null of random walk, the variance ratio value is expected to equal one. *, ** and *** denote significance at 1%, 5% and 10% respectively.

4.3. Nonlinearity in Stock Returns

The linear tests such as autocorrelation, variance ratio, and runs tests are incapable to capture nonlinear patterns in the return series. The failure to reject linear dependence is insufficient to prove independence in view of non-normality of the series (Hsieh, 1989) and not necessarily imply independence (Granger and Andersen, 1978). The presence of nonlinearity indicates predictability and potential excess profits to agents. The use of linear models in such conditions may give the wrong inference of unpredictability. Moreover, the presence of nonlinearity in stock returns contradicts EMH. In this study, we employed a set of nonlinear tests to investigate the presence of nonlinear dependence.

4.3.1. Engle LM Tests

The Engle LM tests indicate unpredictability of returns during the last subsample (1997–2006). Overall, the results presented in Tables 4 shows a significant presence of nonlinearity in returns. This implies that Nigerian stock market was weakly inefficient throughout the sample period.

Table-4. Engle LM tests

Sample period	Lag 5	Lag 15	Lag 20
Full sample	52.69***	66.78***	66.86***
1987-1996	35.84**	31.38**	29.86*
1997-2006	4.5432	7.4837	9.6888
2007-2016	22.16***	28.69*	31.268*

*, ** and *** denote significance at 1%, 5% and 10% respectively

4.3.2. BDS Test Statistics

The BDS statistics support evidence of nonlinear dependence during the subsamples and full sample for both the indices (Table 6). The rejection for residuals from AR (ρ) indicates presence of nonlinear dependence and implies the possible predictability of future returns using the history of returns.

Table-5. BDS test statistics

	$m=2, \epsilon=0.75 s$	$m=4, \epsilon=1 s$	$m=8, \epsilon=1.25 s$	$m=10, \epsilon=1.50 s$
Full sample	0.034**	0.0004***	0.0008**	0.1161***
1987-1996	0.083***	0.150***	0.204***	0.2451***
1997-2006	0.0435***	0.039***	0.01	0.0133
2007-2016	0.0064	0.0234*	0.0016**	0.0392*

Here, 'm' and 'ε' denote the embedding dimension and distance, respectively and 'ε' equal to various multiples (0.75, 1, 1.25 and 1.5) of standard deviation (scp of the data). The value in the first row of each cell is a BDS test. The asymptotic null distribution of test statistics is N (0,1). Asterisked values indicate *, ** and *** denote significance at 1%, 5% and 10% respectively of significance.

5. SUMMARY AND CONCLUSION

This paper has tested the Adaptive Market Hypothesis using very long run historic data for the Nigeria stock markets using a fixed subsample size of 30 years. Table 1 provides a summary of the results for the tests conducted. The autocorrelation test and the runs test for the ASI shows that returns have gone through periods of independence and dependence, providing evidence consistent with the AMH. Further, the variance ratio test also shows that the ASI has gone through periods of dependence and independence, again advocating the AMH. Thus the linear ASI results suggest that the Nigerian market is adaptive, although the tests disagree in relation to which subsamples are efficient and inefficient. The sub-sample results show mixed evidence with the autocorrelation and variance ratio tests providing strong evidence of the AMH, however the nonparametric runs test provides evidence consistent with a switch to efficiency. This could be evidence of the AMH, but at this point can only be deemed as a switch to efficiency. If the efficiency had moved through 3 different stages of efficiency it could have been deemed adaptive. All three linear tests for the ASI suggest that the market is adaptive, the different tests disagree in relation to which subsamples are efficient and inefficient. Each of the nonlinear tests suggests that each market exhibits strong significant nonlinear dependence, indicating inefficiency. These results indicate that although no concrete conclusions can be made on the linear dependence of the ASI markets, it is clear that it exhibits strong nonlinear dependence and in that sense are inefficient for every subsample. Although the results for linear tests of dependence may be adaptive, the nonlinear tests show strong dependence for each market. There is also very little evidence of a switch to efficiency. On the evidence of the linear tests the markets have generally gone through periods of efficiency and inefficiency. In respect of the nonlinear tests the markets have generally been inefficient at conventional levels of statistical significance and this inefficiency has not declined over time. In summary the evidence from the linear tests seems to be very supportive of the AMH whereas the nonlinear tests indicate continuing, albeit time varying, inefficiency.

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