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The market efficiency of the Tanzania stock market

Abstract

The purpose of this article is to examine the efficiency of the Tanzania stock market. The study attempts to answer whether the Tanzania stock market is weak-form efficient. The study applies a battery of tests: the serial correlation test, unit root tests, runs test and the variance ratio test using daily and weekly data with a sample spanning from November 2006 to August 2015 for the Dar es Salaam Stock Exchange (DSE) all share index and from January 2009 to August 2015 for the DSE share index. Overall, the results of the market efficiency are mixed. The serial correlation test, unit root test and the runs test do not support weak-form efficiency, while the more robust variance ratio test supports weak-form efficiency for the DSE. The main contribution of the study is that the market efficiency of the Tanzania stock market has increased over the sample period.

Keywords: adaptive market hypothesis, efficiency market hypothesis, serial correlations test, unit root test, runs test, variance ratio test, Dar es Salaam Stock Exchange.
JEL Classification: G14, G15.

Introduction

The efficiency of financial markets has been widely debated by scholars from many years (Verheyden, De Moor and Van den Bossche, 2015). One side of the debate supports the efficient market hypothesis (EMH) and the assumption that markets are able to efficiently incorporate past information. The other side of the debate, behaviorists argue that investors suffer from psychological anomalies, which introduce irrationality and push market prices away from the rational and efficient underlying fundamental value. The authors add that one of the reasons the debate has not been settled is due to the lack of a theoretical alternative for the EMH. The study, therefore, finds that Lo's (2004, 2005) adaptive market hypothesis (AMH) seeks to address this lack by reconciling both the EMH and behavioral finance, drawing from concepts of evolutionary biology. There appears to be an evolution in the degree to which markets are efficient in incorporating past price information. Thereby, markets are not efficient all the time. Hence, the discussion on absolute efficiency which focuses on whether a market is efficient or not appears to be decreasing in its significance. Rather, the discussion should shift to the fact that the level of market efficiency changes over time (Verheyden et al., 2015).

The number of African stock markets grew from eight stock exchanges in 1989 (five in sub-Saharan Africa and three in North Africa) to over 20 stock exchanges by the year 2010 (Watundu, Kaberuka, Mwelu and Tibesigwa, 2015). Even though there is an increase in the number of stock exchanges, they still lack the depth, breath and liquidity levels are low. Few studies on market efficiency have been conducted on frontier markets. These markets are characterized by political instability, poor liquidity, thin trading, inadequate regulation, weak accounting standards and publication rules (Charfeddine and Khediri, 2016).

This study will investigate the efficiency of the Tanzania stock market, a frontier market. The Dar es Salaam Stock Exchange was incorporated in 1996 which was a key milestone in the development of a functioning capital market for the mobilization and allocation of long-term capital to the private sector in Tanzania (Ziorklui, 2001). The author finds that regional integration and globalization of the Tanzania capital market would be valuable in attracting foreign capital, efficiency of utilization of capital and corporate governance. A study on the challenges faced by the Dar es Salaam stock exchange indicates that the stock market lacks desirable characteristics such as liquidity, availability of information which leads to market efficiency, narrow price spread and high price sensitivity to new information (Massele, Darroux, Jonathan and Fengju, 2013). Other challenges observed in the study include: lack of public awareness and knowledge about capital markets, few market participants, lack of information and communication technology, and advanced technology in trading securities, macro-economic instability and lack of competent experts in financial markets. Mensah (2003) adds that the low market professionalism leads to market inefficiencies and low returns which are realized to active management.

In this study, the question of weak-form efficiency is investigated using the serial correlation test, runs test, unit root tests and variance ratio test. The indexes that are used are the DSE all share index and the DSE share index over a period spanning November 2006 to August 2015. The novelty of this study lies in showing the change in market efficiency of the DSE over the sample period using the variance ratio test.

The remainder of this paper is organized as follows. Section 1 presents the literature review on market efficiency. Section 2 presents the empirical methodology. Section 3 presents the data and the discussion of the empirical results. Final section summarizes the findings and provides conclusions.

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1. Literature review

A financial market is deemed weak-form efficient if it is not possible to identify any deterministic pattern in its time series behavior, that is, through arbitrage, market participants are not able to obtain systematic abnormal profits using historical information. In other words, financial returns have no memory and are independent in time (Ferreira and Dionísio, 2016).

The equity markets of Brazil, Russia, India and China (BRIC) are investigated to determine whether they may be considered weak-form efficient in recent years with a sample spanning from September 1995 to March 2010 (Mobarek and Fiorante, 2014). The findings show that these markets appear to be evolving in the right direction, especially during the last five to ten years, but the earlier sub-periods these markets experienced significant positive autocorrelation (persistence) in returns. However, results of the last sub-periods, including the subprime crisis, support the presumption that the BRIC markets may have been approaching a state of being fairly weak-form efficient. A key implication of the study is the relative increase in efficiency which is an important ingredient for these markets if they wish to foster their growth and welfare.

The efficiency of the Gulf Cooperation Council (GCC) stock markets of Saudi Arabia, the United Arab Emirates, Kuwait, Oman, Qatar and Bahrain is investigated (Jamaani and Roca, 2015). The study tests whether GCC stock markets are weak-form efficient individually or as a group by applying a battery of parametric and nonparametric unit root and Johansen cointegration tests to daily index prices denominated in local currencies covering the duration December 2003 to January 2013. The author find that the GCC stock markets are not individually weak-form efficient, that is, current prices of each GCC stock markets can be predicted from past price changes in that market. In addition, collectively, the GCC stock markets are not weak-form efficient in that past price changes can be used to predict the current price changes of another GCC stock market. This inefficiency can be attributed to the high concentration in the banking and financial sectors and the low degree of foreign participation.

AMH is based on an evolutionary approach to economic interactions (Lo, 2004). By using the moving window method, Lo calculates the time-varying first-order autocorrelations and shows that efficient and inefficient periods exist in stock markets. AMH considers that the degree of market efficiency changes over time and reflects evolving market conditions such as deregulation, legal reforms, technological innovations, market crushes and bubbles. Zhou and Lee (2013) investigate two implications for real estate investment trust (REIT) market efficiency from the AMH. Firstly, the authors find strong evidence of time variations in the degree of REIT return predictability. Moreover, the degree of predictability decreases over time for the REIT market, hence, it is becoming more efficient. Secondly, REIT returns predictability is shown to be influenced by market conditions with the degree of predictability being primarily influenced by the level of market development. Significantly, the authors find that regulatory changes have greatly improved the REIT market efficiency.

The existence of the AMH as an evolutionary alternative to the EMH is evaluated for the Tehran stock exchange in Iran by applying daily returns on the TEPIX index (Ghazani and Araghi, 2014). The data consist of daily returns over the period 1999 to 2013. The finding of the study obtained from linear (automatic variance ratio and automatic portmanteau) and nonlinear (generalized spectral and McLeod-Li) tests which represent the oscillatory manner of returns about dependency and independency in line with the AMH. Noda (2016) investigates the AMH in Japanese stock markets (TOPIX and TSE2) by using the time-varying model approach to measure the degree of market efficiency. The study finds that the degree of market efficiency changes over time in the two markets, in addition, the level of market efficiency of the TOPIX is higher than that of the TSE2 in most periods. Finally, the market efficiency of the TOPIX has evolved, however, that of the TSE2 has not, concluding that the findings support the AMH for the TOPIX stock market in Japan.

The market efficiency and trading rule profitability of the Ugandan foreign exchange market is investigated for the period January 1994 to June 2012 using a battery of variance ratio tests (Katusiime, Shamsuddin and Agbola, 2015). The findings indicate the market is epitomized by pricing inefficiency, except for few short periods of efficiency, concluding the market is not weak-form efficient. The authors find that market participants are unable to consistently exploit pricing inefficiencies due to transaction costs and time variation in the inefficiency under changing market conditions. The finding of time variation in market efficiency is consistent with the AMH.

2. Methodology

2.1. Serial correlation test. Urquhart and Hudson (2013) state that autocorrelations (ρ_k) occur when the covariances and correlations between different disturbances are not all non-zero (i.e., $Cov\ (\varepsilon_i, \varepsilon_j) = \sigma_{ij}$ for all $i \neq j$, where ε_t is the value of the disturbance in the ith observation).

$$\rho_k = \frac{\gamma_k}{\gamma_0}, \quad (1)$$

where y_1 is the covariance at lag k and y_0 is the variance. The first order autoregressive process contains values of ε_t lagged by one period, showing that the disturbance in period t is impacted by the disturbance in the previous period ε_{t-1}.

2.2. Unit root tests. The unit root test is designed to test for stationarity of time series, since the presence of non-stationarity depicts the existence of randomness that supports weak-form efficiency (Azad, 2009). Both the Augmented Dickey Fuller (ADF) and the Phillips Perron (PP) tests will be analyzed in this study. The following models are used, including an intercept (equation 2) and an intercept and trend (equation 3), as shown below:

$$\Delta y_{t\text{-}1} = c_0 + \delta y_{t\text{-}1} + \beta \sum_{i-1}^{\rho} \Delta y_{t\text{-}1} + \mu_t, \quad (2)$$

$$\Delta y_t = c_0 + c_1 t \delta y_{t\text{-}1} + \beta \sum_{i-1}^{\rho} \Delta y_{t\text{-}1} + \mu_t, \quad (3)$$

where y_t is a series that follows an autoregressive process. c_0 and c_1 are optional exogenous regressors, δ and β are parameters to be estimated. μ_t is assumed to be white noise. The presence of a unit root is the null hypothesis. Therefore, not rejecting the null hypothesis indicates the series follows a random walk.

The PP test is a non-parametric method to test unit root and is similar to the Dickey-Fuller test (Liu, 2011). It is also a controlling test for serial correlation (Jamaani and Roca, 2015). The distinction between the PP and ADF tests is the manner in which heteroskedasticity and serial correlation in errors are dealt with. The PP test's aim is to use non-ADF regression, then, make adjustment for bias which may exist because of correlation in innovation terms. The PP test's specifications are shown below (Jamaani and Roca, 2015):

$$P_t = \mu + \delta P_{t\text{-}1} + \varepsilon_t, \quad (4)$$

$$P_t = \mu + \beta (t - \frac{1}{2} T) + \alpha P_{t\text{-}1} + \varepsilon_t, \quad (5)$$

where P_t is natural price index logarithm during time t, while μ represents a constant. In addition, β and α are parameters which need to be estimated, and ε_t is an error term.

2.3. Runs test. The runs test is a non-parametric test that examines the randomness of a series of stock returns. However, unlike the serial correlation test, it does not require returns to be normally distributed (Urquhart and Hudson, 2013). It is also considered to be a linear test, but it can also detect nonlinearity in a returns series. The calculation of the expected number of runs can be achieved by applying equation 6, m as (Jamaani and Roca, 2015):

$$m = \frac{N(N+1) - \sum_{i=1}^{3} n_i^{\ 2}}{N}, \quad (6)$$

where m is the total expected number of runs, N is total number of observations, and $n_i$is the number of observations in each category i. For a large number of observations (N > 30), the sampling distribution of m is approximately normal and the standard error of m is given by:

$$\sigma_m = \left[\frac{\sum_{i=1}^{3} [n_i^{\ 2} + N(N+1)] - 2N \sum_{i=1}^{3} n_i^{\ 3} - N^3}{N^2(N-1)} \right]^{1/2}, \quad (7)$$

where the standard normal distribution for conducting runs test can be determined from the following equation:

$$Z = \frac{R - m \pm 0.5}{\sigma_m} \sim N(0,1), \quad (8)$$

where R = actual number of runs, m = expected number of runs and 0.5 = continuity adjustment (Patel, Radadia and Dhawan, 2012).

2.4. Variance ratio test. The variance ratio test by Lo and MacKinlay (1988) compares the variance of returns measured over two holding periods. The rationale behind the test is that when the random walk hypothesis (RWH) is true, the variance of a multi-period return is the sum of the single period variances (Katusiime et al., 2015). Given the return S_t at time t, the variance ratio, VR (q) is defined as:

$$VR_{(q)} = \frac{\sigma^2(q)}{\sigma^2(1)}. \quad (9)$$

The standard normal $Z(q)$ and $Z^*(q)$ test statistics are computed as follows (Abedini, 2009):

$$Z(q) = \frac{VR(q) - 1}{[\varnothing(q)]^{1/2}} \approx \text{N}(0,1), \quad (10)$$

$$Z^*(q) = \frac{VR(q) - 1}{[\varnothing^*(q)]^{1/2}} \approx \text{N}(0,1), \quad (11)$$

where ∅ (q) and ∅* (q) are the asymptotic variance of the variance ratio under the assumption of homoscedaticity and the heteroscedasticity, respectively:

$$\varnothing(q) = \frac{2(2q-1)(q-1)}{3q(nq)}, \quad (12)$$

$$\varnothing^*(q) = \sum_{j=1}^{q-1}\left[\frac{2(q-j)}{q}\right]^2_{\partial(j)}, \quad (13)$$

where ∂ (j) is the heteroscedasticity - consistent estimator and computed as follows:

$$\partial(j) = \frac{\sum_{t=j+1}^{nq}(p_t - p_{t-1} - \mu)^2(p_{t\text{-}j} - p_{t\text{-}j\text{-}1} - \mu)^2}{\sum_{t=1}^{nq}(p_t - p_{t-1-\hat{\mu}})^2}. \quad (14)$$

Note that both standard normal Z-statistics and Z*-statistics are approaching N (0, 1).

3. Data and sample

The source of the data is Bloomberg. The time series that are used are the DSE ALSI index and the DSE share index using both daily and weekly data, respectively. The time period for the DSE ALSI: daily data is from November 2006 until August 2015. For the DSE ALSI, weekly data is from December 2006 until August 2015. While for the DSE share index, both daily and weekly data is from January 2009 until August 2015. The currency base denominated is in Tanzania Shillings (TZS). The data that were analyzed consisted of index returns that are transformed to natural logs of both the daily and weekly prices of the index.

$$r_t = Ln\left(\frac{P_t - P_{t-1}}{P_{t-1}}\right)\times 100. \quad (15)$$

The price returns (r_t) are expressed in percentage terms were calculated as the ending index price minus the beginning index price divided by the beginning index price multiplied by 100.

Table 1 below presents a summary of the descriptive statistics of the daily and weekly return series of the Tanzania stock market. Average returns are negative for the four time series. Returns on the DSE share index: daily data time series is positively skewed, all the other time series are negatively skewed. The kurtosis of all four time series is greater than 3, this means the tail of the graph of the density function is short/fat, thus, leptokurtic. A normality test of the time series is carried out before estimation of the tests, to check if the times series are normally distributed, the Jarque-Bera test was used to test that the series are normally distributed (Watundu et al., 2015). All four time series have Jarque-Bera statistics that are significantly higher than the 0.05 critical value of 5.99. This is greater evidence that returns of the four time series are not normally distributed. This is expected for financial time series data. Results of the descriptive statistics are reported in Table 1 below.

Table 1. Results of the descriptive statistics

Series (observations)	Mean	Median	Maximum	Minimum	SD	Skewness	Kurtosis	Jarque-Bera Statistic	Probability
DSE All Share Index daily data	- 5.91e-05	0.000000	0.016259	- 0.017877	0.001018	- 3.751745	127.9613	1364738.	0.000000
DSE All Share Index weekly data	- 0.000285	- 3.31e-05	0.015980	- 0.019235	0.002085	- 1.749006	32.69485	16837.38	0.000000
DSE Share Index daily data	- 9.32e-05	0.000000	0.039748	- 0.037807	0.002231	0.637120	243.9216	5035390.	0.000000
DSE Share Index weekly data	- 0.000443	0.000000	0.013092	- 0.017127	0.002069	- 2.195610	22.91400	7779.865	0.000000

4. Empirical results and analysis

4.1. Serial correlation test. The results of the correlogram test show that auto correlation (AC) test of all four time series are not equal to 0, therefore, the time series are stationary. The p-values of all four time series are equal to 0. The Q-statistics should be significant with p-values that are close to 0 and less than 0.05. The null hypothesis will be rejected meaning the price changes are not independent and will violate the RWH. Results of the serial correlation test are reported in Table 2 below.

4.2. Unit root tests. The unit root tests were conducted to test for the stationarity status of the times series for both the daily and weekly data. Two unit root tests were examined for this study, the ADF unit root test and the PP test.

For the ADF unit root test, the test statistics are significant at 10%, 5% and 1% levels, respectively. The null hypothesis will, therefore, be rejected which leads to acceptance of the alternative hypothesis, that the time series are stationary and have no unit root. The time series, therefore, do not follow a random walk.

Similar results are applicable for the PP unit root test. The test statistics are significant at 10%, 5% and 1% levels, respectively. The null hypothesis will be rejected leading to acceptance of the alternative hypothesis, that the time series are stationary and have no unit root, thus, confirming the time series do not follow a random walk. Results of the stationarity tests are reported in Table 3 below.

Table 2. Results of the serial correlation test

	DSE All Share Index daily data				DSE All Share Index weekly data				DSE Share Index daily data				DSE Share Index weekly data			
Lags	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
1	0.369	0.369	478.62	0.000	0.168	0.168	20.687	0.000	0.506	0.506	445.48	0.000	0.206	0.206	15.492	0.000
2	0.246	0.128	692.60	0.000	0.078	0.052	25.212	0.000	0.275	0.026	577.04	0.000	0.062	0.020	16.891	0.000
3	0.119	-0.009	742.41	0.000	0.055	0.035	27.447	0.000	0.122	-0.035	603.05	0.000	-0.010	0.027	16.924	0.001
4	0.031	-0.043	745.80	0.000	-0.018	0.038	27.694	0.000	-0.015	-0.094	603.47	0.000	-0.103	0.101	20.808	0.000
5	0.022	0.012	747.49	0.000	-0.008	-0.005	27.743	0.000	-0.043	0.005	606.68	0.000	0.055	0.103	21.931	0.001
6	-0.032	-0.044	751.20	0.000	0.083	0.089	32.838	0.000	-0.035	0.012	608.88	0.000	0.171	0.159	32.741	0.000
7	-0.017	0.005	752.28	0.000	0.119	0.100	43.373	0.000	-0.033	-0.010	610.80	0.000	0.132	0.062	39.185	0.000
8	-0.009	0.009	752.59	0.000	0.015	-0.031	43.536	0.000	-0.018	-0.001	611.36	0.000	0.077	0.012	41.373	0.000
9	0.031	0.045	755.99	0.000	0.024	0.004	43.971	0.000	0.014	0.029	611.70	0.000	-0.003	-0.015	41.377	0.000
10	0.030	0.007	759.12	0.000	0.019	0.011	44.228	0.000	0.017	-0.002	612.19	0.000	-0.022	0.011	41.561	0.000
11	0.028	0.003	761.82	0.000	0.018	0.024	44.460	0.000	0.017	0.000	612.70	0.000	0.061	0.074	42.950	0.000
12	0.026	0.005	764.22	0.000	0.069	0.060	47.972	0.000	0.023	0.012	613.64	0.000	0.145	0.106	50.857	0.000
13	0.022	0.008	765.99	0.000	0.064	0.026	51.071	0.000	0.025	0.014	614.75	0.000	0.081	-0.009	53.298	0.000
14	0.041	0.029	771.80	0.000	0.011	-0.023	51.165	0.000	0.007	-0.015	614.85	0.000	0.007	-0.049	53.316	0.000
15	0.032	0.011	775.50	0.000	0.067	0.063	54.523	0.000	-0.030	-0.044	616.44	0.000	0.004	0.021	53.323	0.000
16	0.024	0.001	777.53	0.000	0.040	0.020	55.703	0.000	-0.040	-0.008	619.31	0.000	-0.076	-0.054	55.512	0.000
17	0.012	-0.005	778.03	0.000	0.072	0.062	59.644	0.000	-0.055	-0.022	624.59	0.000	-0.020	-0.017	55.671	0.000
18	-0.008	-0.018	778.28	0.000	0.058	0.019	62.144	0.000	-0.042	0.005	627.70	0.000	0.127	0.096	61.806	0.000
19	-0.025	-0.022	780.41	0.000	0.052	0.015	64.189	0.000	-0.027	-0.003	629.00	0.000	0.062	-0.010	63.264	0.000
20	-0.023	-0.003	782.35	0.000	0.018	-0.004	64.438	0.000	-0.015	-0.001	629.42	0.000	0.015	-0.038	63.347	0.000
21	-0.028	-0.010	785.11	0.000	0.014	0.006	64.586	0.000	-0.038	-0.046	631.91	0.000	-0.067	-0.071	65.061	0.000
22	-0.015	0.005	785.92	0.000	0.031	0.015	65.338	0.000	-0.031	-0.002	633.65	0.000	-0.005	0.076	65.071	0.000
23	-0.012	-0.004	786.45	0.000	-0.020	-0.040	65.630	0.000	-0.006	0.024	633.71	0.000	-0.004	-0.007	65.078	0.000
24	-0.011	-0.008	786.90	0.000	0.054	0.040	67.840	0.000	0.046	0.064	637.44	0.000	0.031	-0.015	65.456	0.000
25	0.005	0.010	786.97	0.000	0.059	0.033	70.473	0.000	0.079	0.035	648.40	0.000	0.068	0.022	67.254	0.000
26	0.022	0.022	788.73	0.000	0.035	0.014	71.432	0.000	0.099	0.035	665.60	0.000	0.026	0.011	67.517	0.000
27	0.029	0.014	791.73	0.000	0.009	-0.018	71.489	0.000	0.110	0.040	686.85	0.000	0.050	0.071	68.508	0.000
28	0.060	0.046	804.65	0.000	0.015	-0.003	71.669	0.000	0.092	0.017	701.73	0.000	-0.011	-0.006	68.556	0.000
29	0.049	0.010	813.02	0.000	0.047	0.044	73.335	0.000	0.065	0.006	709.10	0.000	0.076	0.095	70.852	0.000
30	0.062	0.030	826.81	0.000	0.008	-0.012	73.383	0.000	0.043	0.011	712.36	0.000	0.099	0.038	74.703	0.000
31	0.030	-0.014	829.99	0.000	0.004	-0.025	73.397	0.000	0.024	0.008	713.38	0.000	0.039	-0.007	75.319	0.000
32	0.017	-0.001	831.07	0.000	0.010	-0.012	73.481	0.000	0.018	0.010	713.93	0.000	0.032	0.015	75.720	0.000
33	0.017	0.012	832.08	0.000	-0.070	-0.080	77.238	0.000	0.032	0.028	715.76	0.000	-0.101	-0.120	79.786	0.000
34	0.029	0.031	835.06	0.000	-0.048	-0.035	79.017	0.000	0.034	0.010	717.77	0.000	-0.103	-0.064	84.071	0.000

Table 2 (cont.). Results of the serial correlation test

DSE All Share Index daily data					DSE All Share Index weekly data				DSE Share Index daily data				DSE Share Index weekly data			
Lags	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
35	0.033	0.016	838.84	0.000	0.026	0.038	79.557	0.000	0.041	0.020	720.74	0.000	0.006	0.029	84.084	0.000
36	0.020	-0.002	840.32	0.000	-0.013	-0.030	79.691	0.000	0.048	0.015	724.88	0.000	-0.035	-0.080	84.567	0.000

Table 3. Results of stationarity tests

	ADF In levels $H0$: $Y_t \sim I(1)$ $H1$: $Y_t \sim I(0)$		Phillips-Perron In levels $H0$: $Y_t \sim I(1)$ $H1$: $Y_t \sim I(0)$	
Series (observations)	Intercept	Trend + Intercept	Intercept	Trend + Intercept
DSE All Share Index daily data	- 55.40457***	- 55.43755***	- 55.57205***	- 55.62586***
DSE All Share Index weekly data	- 24.75244***	- 24.84206***	- 24.76660***	- 24.85846***
DSE Share Index daily data	- 37.17386***	- 37.51465***	- 83.94640***	- 82.90606***
DSE Share Index weekly data	- 10.72541***	- 11.22141***	- 20.35912***	- 20.35575***

Notes: *, **, *** significant at 10, 5 and 1% levels, respectively.

4.3. Runs test. This test is especially suitable for this data set, as it is suitable for testing data that are not normally distributed. All four time series have actual number of runs that are less than the expected number of runs, i.e., $R \leq m$ and the Z value of all four time series are negative suggesting positive serial correlation. This means that there is positive dependence of all four times series, thus, violating the RWH. Results of the runs test are reported in Table 4 below.

Table 4. Results of the runs test

Series (observations)	No. of runs (R)	Total cases (m)	Z statistic
DSE 20 All Share Index daily data	1 327	3 521	- 14.647
DSE 20 All Share Index weekly data	297	732	- 5.178
DSE Share Index daily data	626	1 738	- 11.709
DSE ASI Share Index weekly data	154	361	- 2.899

4.4. Variance ratio test. Two results are provided in the variance ratio test, the joint tests and individual tests. The joint tests provide the tests of the joint null hypothesis for all test periods, while the individual tests apply to the individual test periods that have been specified. The DSE ALSI daily data has a test period that has aminimum of 100 and a maximum of 2 100 with a step of 100 (i.e.,100 observations). The joint test of the DSE ALSI daily data shows that the p-value is 0.9998 which is greater than 0.05. Therefore, we fail to reject the null hypothesis and, instead, accept the null hypothesis. Results of the variance ratio test, DSE ALSI daily data are reported in Table 5 and Figure 1 below.

Table 5. Results of the variance ratio test DSE ALSI daily data

Joint tests		Value	df	Probability
Max lzl (at period 100)*		0.939403	191	0.9998
Wald (Chi-Square)		186.3157	21	0.0000
Individual tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
100	0.221007	0.829243	-0.939403	0.3475
200	0.408380	1.177160	-0.502582	0.6153
300	0.578005	1.443531	-0.292335	0.7700
400	0.639050	1.667890	-0.216411	0.8287
500	0.839063	1.865459	-0.086272	0.9313
600	0.649840	2.044020	-0.171309	0.8640
700	0.877735	2.208188	-0.055369	0.9558
800	0.762570	2.360969	-0.100565	0.9199
900	0.854164	2.504447	-0.058231	0.9536
1000	1.102218	2.640139	0.038717	0.9691
1100	1.010881	2.769190	0.003929	0.9969
1200	1.484479	2.892489	0.167495	0.8670
1300	1.356551	3.010743	0.118426	0.9057
1400	1.289548	3.124525	0.092669	0.9262
1500	1.026881	3.234306	0.008311	0.9934
1600	1.012775	3.340481	0.003824	0.9969
1700	0.836138	3.443384	-0.047587	0.9620
1800	0.632495	3.543300	-0.103718	0.9174

Table 5 (cont.). Results of the variance ratio test DSE ALSI daily data

Joint tests		Value	df	Probability
1900	0.438337	3.640475	-0.154283	0.8774
2000	0.285379	3.735122	-0.191325	0.8483
2100	NA	3.827429	NA	NA

Source: * Probability approximation using studentized maximum modulus with parameter value 21 and infinite degrees of freedom.

Figure 1 below shows a graph of the level of efficiency of the DSE ALSI daily data. It shows the level of efficiency of the DSE ALSI daily data has increased as the test periods increased. However, the level of efficiency has dropped slightly towards the end of the test period.

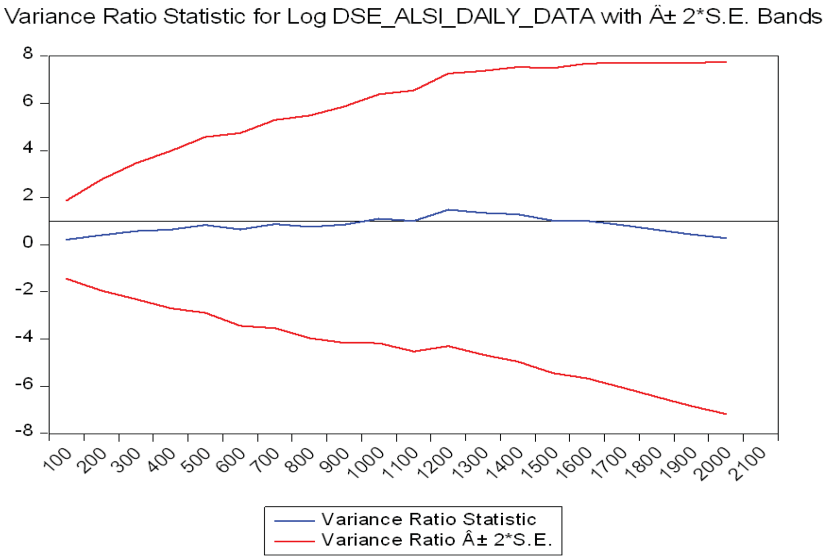

Fig. 1. Graphical illustration of the efficiency of the DSE ALSI daily data over the test periods (November 2006 to August 2015)

The DSE ALSI weekly data has a test period that has a minimum of 25 and a maximum of 475 with a step of 25. The joint test of the DSE ALSI weekly data shows that the *p*-value is 0.9488 which is greater than 0.05, we fail to reject the null hypothesis; instead, we accept the null hypothesis. Results of the variance ratio test, DSE ALSI weekly data are reported in Table 6 and Figure 2 below.

Table 6. Results of the variance ratio test DSE ALSI weekly data

Joint tests		Value	df	Probability
Max |z| (at period 25)*		1.403706	76	0.9488
Wald (Chi-Square)		5.134426	19	0.9974
Individual tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
25	0.098310	0.642364	-1.403706	0.1604
50	0.069798	0.922525	-1.008322	0.3133
75	0.099730	1.135601	-0.792770	0.4279
100	0.106598	1.314594	-0.679603	0.4968
125	0.121476	1.471984	-0.596830	0.5506
150	0.134761	1.614101	-0.536050	0.5919
175	0.123132	1.744680	-0.502595	0.6152
200	0.111083	1.866146	-0.476338	0.6338
225	0.135854	1.980175	-0.436399	0.6625
250	0.142583	2.087986	-0.410643	0.6813
275	0.176811	2.190497	-0.375800	0.7071
300	0.139199	2.288421	-0.376155	0.7068
325	0.132981	2.382324	-0.363938	0.7159
350	0.096917	2.472663	-0.365227	0.7149
375	0.057147	2.559815	-0.368328	0.7126

Table 6 (cont.). Results of the variance ratio test DSE ALSI weekly data

Joint tests		Value	df	Probability
400	0.062700	2.644097	-0.354488	0.7230
425	0.049673	2.725774	-0.348645	0.7274
450	NA	2.805074	NA	NA
475	NA	2.882193	NA	NA

Source: * Probability approximation using studentized maximum modulus with parameter value 19 and infinite degrees of freedom.

Figure 2 below shows a graph of the level of efficiency of the DSE ALSI weekly data. It shows the level of efficiency of the DSE ALSI weekly data has increased as the test periods increased.

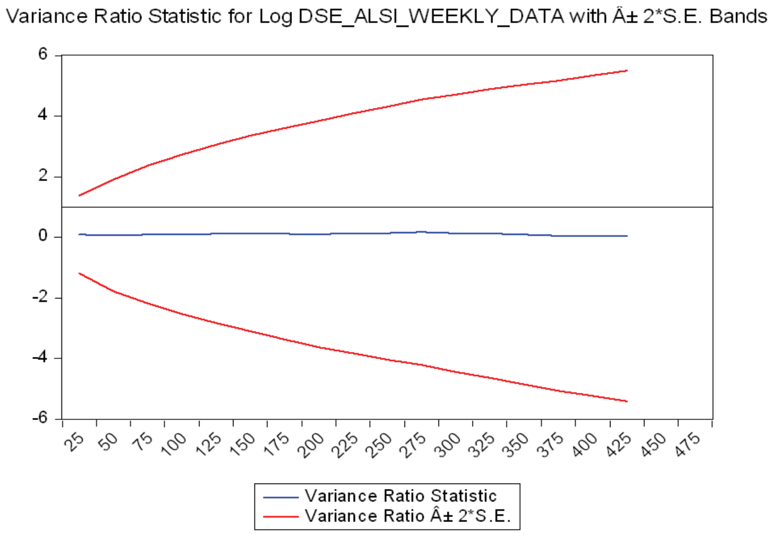

Fig. 2. Graphical illustration of the efficiency of the DSE ALSI weekly data over the test periods (December 2006 to August 2015)

The DSE share index daily data has a test period that has a minimum of 100 and a maximum of 1 600 with a step of 100 (i.e., 100 observations). The joint test of the DSE ALSI daily data shows that the *p*-value is 0.9964 which is greater than 0.05. Therefore, the authors fail to reject the null hypothesis, instead, the author accepts the null hypothesis. Results of the variance ratio test, DSE share index daily are reported in Table 7 and Figure 3 below.

Table 7. Results of the variance ratio test DSE share index daily data

Joint tests		Value	df	Probability
Max |z| (at period 100)*		1.010136	142	0.9964
Wald (Chi-Square)		1.847719	16	1.0000
Individual tests				
Period	Var. Ratio	Std. Error	*z*-Statistic	Probability
100	0.028519	0.961733	-1.010136	0.3124
200	0.036657	1.365237	-0.705623	0.4804
300	0.051709	1.674166	-0.566426	0.5711
400	0.051633	1.934372	-0.490271	0.6239
500	0.076962	2.163507	-0.426640	0.6696
600	0.069641	2.370596	-0.392458	0.6947
700	0.082682	2.560994	-0.358188	0.7202
800	0.083115	2.738185	-0.334851	0.7377
900	0.096526	2.904587	-0.311051	0.7558
1000	0.099082	3.061959	-0.294229	0.7686
1100	0.077009	3.211629	-0.287390	0.7738
1200	0.110532	3.354627	-0.265147	0.7909
1300	0.107340	3.491775	-0.255646	0.7982
1400	0.066246	3.623735	-0.257677	0.7967
1500	0.017458	3.751057	-0.261937	0.7934

Table 7. Results of the variance ratio test DSE share index daily data

Joint tests		Value	df	Probability
1600	NA	3.874196	NA	NA

Source: * Probability approximation using studentized maximum modulus with, parameter value 16 and infinite degrees of freedom.

Figure 3 below shows a graph of the level of efficiency of the DSE share index daily data. It shows the level of efficiency of the DSE share index daily data has increased as the test periods increased.

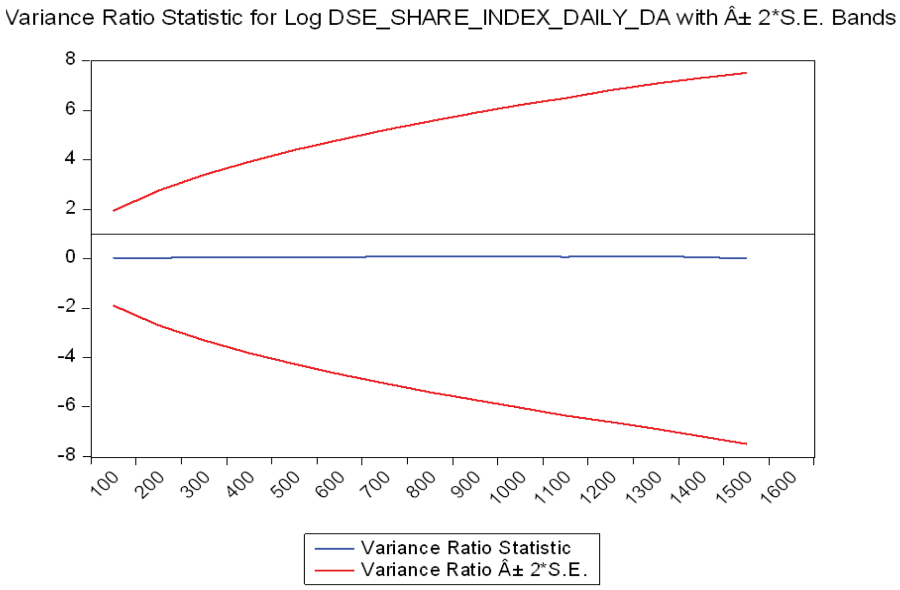

Fig. 3. Graphical illustration of the efficiency of the DSE share index daily data over the test periods (January 2009 to August 2015)

The DSE share index weekly data has a test period that has a minimum of 25 and a maximum of 350 with a step of 25. The joint test of the DSE ALSI weekly data shows that the *p*-value is 0.9401 which is greater than 0.05, we fail to reject the null hypothesis; instead, we accept the null hypothesis. Results of the variance ratio test, DSE share index weekly data are reported in Table 8 and Figure 4 below.

Table 8. Results of the variance ratio test DSE share index weekly data

Joint tests		Value	df	Probability
Max lzl (at period 25)*		1.296936	62	0.9401
Wald (Chi-Square)		2.309447	14	0.9995
Individual tests				
Period	Var. Ratio	Std. Error	z-Statistic	Probability
25	0.077618	0.711201	-1.296936	0.1947
50	0.035223	1.021384	-0.944578	0.3449
75	0.042770	1.257294	-0.761341	0.4465
100	0.038765	1.455468	-0.660430	0.5090
125	0.051822	1.629724	-0.581803	0.5607
150	0.059739	1.787070	-0.526147	0.5988
175	0.045106	1.931643	-0.494343	0.6211
200	0.059314	2.066125	-0.455290	0.6489
225	0.056174	2.192373	-0.430504	0.6668
250	0.076716	2.311737	-0.399390	0.6896
275	0.093677	2.425234	-0.373706	0.7086
300	0.078534	2.533652	-0.363691	0.7161
325	0.030349	2.637617	-0.367624	0.7132
350	NA	2.737637	NA	NA

Source: *Probability approximation using studentized maximum modulus with parameter value 14 and infinite degrees of freedom.

Figure 4 below shows a graph of the level of efficiency of the DSE share index weekly data. It shows the level of efficiency of the DSE share index weekly data has increased as the test periods increased.

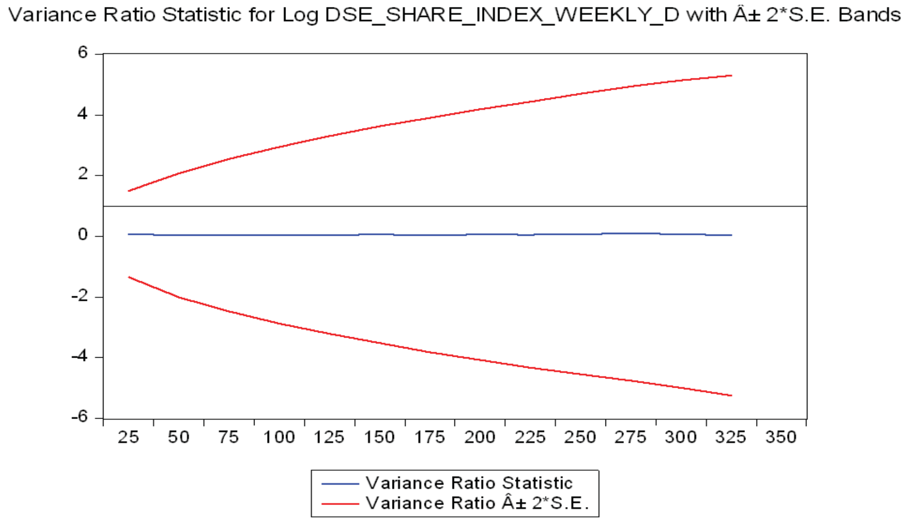

Fig. 4. Graphical illustration of the efficiency of the DSE share index weekly data over the test periods (January 2009 to August 2015)

The conclusion of the variance ratio test is that all four time series fail to reject the null hypothesis. Rather, the null hypothesis will be accepted which is the market under study is weak-form efficient. In addition, the efficiency of the DSE has increased over the years, as illustrated in Figures 1 to 4 above.

Conclusion

The main aim of this study was to determine the level of market efficiency of the DSE using both daily and weekly data of the DSE ALSI index and the DSE share index. Results of the efficiency of the DSE are mixed, because the serial correlation test, unit root tests and the runs test fail to support the EMH. However, these results are disputed by the more robust variance ratio test which supports the EMH. Overall, the results of the market efficiency of the Tanzania stock market are mixed. A key finding of the study is that the market efficiency of the DSE is time varying and has increased over the sample period, thereby confirming that the DSE supports the AMH.

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