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Original Paper

Testing The Random Walk (Rw) Behaviour of Botswana's Equity Returns

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Abstract

This paper examines the efficiency of Botswana's capital market by testing the presence of random walk (RW) behavior in the Domestic Companies Index covering a period of 1989-2013 and Foreign Companies Index covering a period of 2005-2013. These return series represent Botswana's equity market. Linear tests (i.e. Autocorrelations and ADF test) and nonlinear dynamics tests (i.e., Runs and R/S test) are applied to test the randomness of these return series. Results of the parametric autocorrelations test and the nonparametric runs test suggest that returns are serially correlated. Univariate unit root test (i.e. ADF) rejects the RW behavior of returns suggesting that the data is stationary. These results are further supported by those of the R/S test which indicates that all BSE index returns series possess strong persistent behavior which supports momentum investing. Generally, the results reject the Random walk behavior governing Botswana's Equity market, implying that the market is weak-form inefficient. Overall, these results suggest that it is possible for investors to use historical stock market information to predict future stock prices employing some investments strategies to earn abnormal returns which nullifies the notion of market efficiency. Therefore in Botswana the efforts of technical and fundamental stock analysts are not futile.

Keywords

Botswana stock exchange, weak-form efficiency, random walk, linear tests, nonlinear tests

1. Introduction

This paper tests the informational efficiency of the Botswana's equity market by examining the presence of random walk behavior in the Botswana Stock Exchange (BSE) daily and monthly return series for two indices (the domestic Companies index (DCI) and the Foreign Companies index (FCI)). Previous empirical research on efficiency of BSE has made use of the All Companies Index (ACI). BSE has since discontinued the use of this market capitalization index in 2009 since it was biased towards foreign companies which have large value stocks. Reilly and Brown (2012) asserts that it is important to be aware of large market value stocks in an index since value weighted index is very sensitive to change in values of those stocks hence influencing the index value. Therefore, taking queue from this discourse it is save to conclude that the ACI was not a good index to use as a representation of the local equity markets hence this paper uses DCI and the FCI separately. The ACI was particularly biased toward Anglo American Plc. which has more than 80% market share and is on the foreign boards of the BSE listed companies (See table 1 below for more details). Other motivational factor apart from the data used is the fact that previous research has used older data covering period up to 2008which is even before the recessionary period of 2008-2009. A lot of transformation has taken place in the last 5 years with regards to Botswana's equity markets, like the introduction of Central Securities Depository, product developments like the introduction of the Exchange traded funds (ETF) and recent automation of the trading platform. These factors might have affected the efficiency of the market to date and therefore previous research has not captured it. As shown by Stoll (2006) these factors, particularly, the introduction of the electronic trading improve the efficiency of stock markets by increasing trading speed and lowering transaction costs associated with the open cry system. Yartey and Adjasi (2007) share the same sentiments and suggest that developments and improvements in efficiency of African stock markets can be attained through introduction of robust electronic trading systems and central depository systems. On the other hand Sioud and HMaied (2003) show that while automation has increased the liquidity of shares in the Tunisian stock market no notable improvements were observed in the efficiency or volatility of the market which runs contrary to their expectations of improvements in the efficiency.

Table 1. Market Capitalisation from December 2005 through December 2009

Year		31-Dec-05	31-Dec-06	31-Dec-07	31-Dec-08	31-Dec-09
Market	Domestic	13,418.10	23,776.87	32,703.00	27,706.07	28,536.15
Capitalisation	Foreign	301,144.60	510,407.79	535,325.00	286,260.24	286,260.24
(Pmillion)	All Company	314,562.70	534,184.66	568,028.00	313,966.31	374,537.22

Anglo American Currently (2013): Market Capitalisation Of P345,613,026.00

Source: Botswana Stock Exchange

An informational efficient market is a liquid and transparent market with a continuous flow of freely available information, available to all investors at the same time. An efficient market negates the possibility of any particular investor using the superior set of information to their advantage.

This paper tests the hypothesis that successive stock price movements (or returns) are independently and identically distributed which is the notion of Efficient Market hypothesis (EMH). The Hypothesis is tested against the null of dependence and non-identically distributed returns.

EMH implies that the generation of superior returns from analyzing past information is futile and will not outperform returns generated by the simple buy and hold strategies. In an EMH world, any inefficiency in security pricing is quickly eliminated, especially after accounting for transaction costs, and the market returns to the equilibrium level. The latter result is consistent with the rational expectations literature that predicts little or no trading in efficient markets (Lo, 1997). The fact that many investors continue security trading and many portfolio managers continue to employ active management techniques indicates that their beliefs run contrary to the EMH.

Efficient market theory (EMT) tests whether the EMH holds. Empirically, testing the EMH is equivalent to testing whether the series in question follow a random walk model. If the EMH holds and series follow a random walk, it means that successive stock price changes are independently and identically distributed but are not chaotic, implying that prices show no uniform pattern[1].The EMH was introduced by Fama (1970), who elaborated on the earlier work of Samuelson (1965) and other academics. Before Fama's work, many studies referred to the same idea as that of the EMH by postulating that the expected return of speculative strategies should be zero. Both, practitioners and academics, agree that, in an efficient market, all relevant market information should be incorporated in the current security price and any variation in it should be due to the arrival of unexpected news.

The EMH has three forms, differing in the set of available information: weak form, semi-strong, and strong forms of market efficiency. This paper concentrates on the weak-form efficiency. If the market is efficient in the weak form, it means that historical price movements are incorporated in current stock prices and it is impossible to use that information to predict future price movements. Tests of this form of efficiency include runs and autocorrelation tests and tests related to the performance of simple trading rules. The research on market efficiency has been carried out in different countries and using different techniques. The empirical results are controversial; however, generally results show that developed markets are weak-form efficient and developing markets, on the contrary, are found to be weak-form inefficient. The latter implies that developing countries' security prices do not follow the random walk model.

The layout of this paper is as follows. Next section (section 2) reviews the theory of market efficiency followed by the research carried out on the subject matter in Botswana, other developed and developing markets which represent section 3. Section 4 describes the data and methodology used and it also discusses results. The last section contains concluding remarks.

2. The Theory of Market Efficiency

The EMH assumes that the current stock price reflects all available information and, thus, represents the future price of the stock. If the current price is not the best predictor of the future price, one may

[1]Fama (1970) argues that any price changes must be random, uncorrelated, and show no observable trend if prices readily incorporate all available information and randomly arrive into the market. In other words, the sequence (or the order) of past returns is of no consequence in assessing the distribution of future returns.

exploit profit opportunities in the market using investment strategies. The latter strategies may vary depending on the form of market efficiency. A technical (fundamental) analysis is useful in a weak (semi-strong) form efficient market. The backbone of the EMH is to find out how the current stock price in the market differs from its fundamental value, which is determined as the present value of all future expected cash flows (e.g., dividends) discounted at the required rate of return.

To form empirically testable implications of the EMH, the set of available information and the process of price formation must be specified in a greater detail. Within the framework of expected returns, the equilibrium state of the market is the state that yields equilibrium continuously compounded rates of return. Since expected returns are measured with respect to the observable risk of the security conditioned on a relevant information set, it is important to measure the risk of the associated security correctly. Fama (1970) defines the expected price of a security at time t+1 as follows:

$$E(\tilde{P}_{j,t+1}|\Phi_t) = [1 + E(\tilde{r}_{j,t+1}|\Phi_t)]P_{j,t} \quad (1)$$

where E is the expected value operator; $P_{j,t}$is the price of security *j* at time t; $\tilde{P}_{j,t+1}$ is its price at time *t+1* (with reinvestment of any intermediate cash income from the security), $\tilde{r}_{j,t+1}$ is the one period percentage return $(P_{j,t+1} - P_{j,t}) / P_{j,t}$; Φ_t is a general symbol for whatever set of information is assumed to be " fully reflected" in the price at t ; and the tildes indicate that $p_{j,t+1}$and $r_{j,t+1}$ are random variables at *t*.

The value of the equilibrium expected return $E(\tilde{r}_{j,t+1}|\Phi_t)$ projected on the basis of information Φ_t is determined from the particular expected return theory at hand. The conditional expectation notation of (1) implies that the information in Φ_t is fully utilised in determining equilibrium expected returns irrespective of the expected return model used. Several return models that can be used under the EMH include the martingale, the sub-martingale, fair game and lastly, the random walk model (RWM)[2].This paper concentrates on the latter model (the RWM).

RWM, assumes that successive price changes are independently and identically distributed (i.e., they show no uniform pattern)[3]. If price changes follow a random walk, then they are serially independent with an error term following a white-noise process. The RWM does not assume that the mean of the distribution is independent but says that the entire distribution is independent, based on the available information set.

Under the RWM, the trajectory of series wanders randomly with drift (around an increasing trend) or without a drift. A RWM with drift implies that expected price changes may be non-zero. A stochastic

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[2]A detailed discussion of all these models can be found in Fama (1970)

[3]The RWM is an extension of the fair game model. While the fair game model states that the condition for the market equilibrium can be stated in terms of expected returns, the RWM describes the stochastic return generating process. Under the RWM, security prices follow a random pattern, either with or without drift.

variable is said to follow a RWM with drift if:

$$X_{t+1} = \delta + X_t + \varepsilon_{t+1} \quad (2)$$

where ε_{t+1} is an identically and independently distributed random variable ($\Sigma\varepsilon_{t+1} = 0$). A RWM without drift implies that δ equals zero in equation (2) above.

Proponents of an efficient stock market (e.g., Professor Michael Jensen) maintain that trading strategies including technical and/or fundamental analysis cannot be used to generate abnormal returns. In case abnormal returns are generated, this is taken as evidence of luck rather than as evidence of analysts' intelligent use of the market information. This is however difficult to reconcile with the theory of market efficiency if abnormal returns are generated on a persistent basis. Practitioners frequently disagree with the implications of the EMH. First, practitioners argue that they can generate abnormal returns by using their financial expertise and information, available in the market. Some, especially adept in using technical and fundamental analysis (i.e., Warren Buffet, George Soros, and Peter Lynch), have earned consistently positive abnormal returns over time. Second, the trading and investment management business would disappear in a world of nonpositive excess returns.

Technical analysts try to find an observable trend in stock price movements and trade on that information, believing that this trend will continue for some time before it reverts in the opposite direction. They stress that stock prices move in trends that persist. They believe that the process of and the adjustment to the information dissemination is gradual. New information is not immediately available to everyone. Instead, it is first disseminated from informed professionals to the aggressive investing public and, then, to the rest of investors. This means that stock prices move to a new equilibrium after the release of new information in a gradual manner, possibly causing persistence in stock price trends Reilly and Brown (2012).

Fundamental analysts believe that each security has its fundamental or intrinsic value, which differs across stock markets, industry classifications, individual companies and depends on underlying economic factors. If this is true, the intrinsic value of an investment asset at a point in time should be determined by examining such variables as current and future earnings (cash flows), interest rates, and risk variables. If the prevailing market price differs from its intrinsic value adjusted for transaction costs and determined on the basis of the fundamental analysis, the investor should buy the stock if it is undervalued and sell the stock if it is overvalued. Fundamental and technical analyses are rarely used in isolation. Instead, investment decisions are made using both.

3. Review of Related Literature

There is limited published research on efficiency of Botswana's equity market and all the research carried so far uses old data which does not incorporate transformation in the Botswana's equity markets that took place in recent years which are referred to in the introduction section of this paper. The following are some of the published research available. Mollah (2007) tests the weak-form market efficiency of Botswana stock exchange and applies the Kolmogov-Smirnov test, the runs test, the autocorrelation test, and the Autoregressive and ARIMA models to daily All Companies Index (ACI) return series over the period of 1989-2005 and rejects the RW behavior of equity returns. Jefferies and Okealhalam (1999) uses unit root tests (ADF, PP & KPSS) on stock indices of South Africa, Botswana and Zimbabwe and found that Botswana among the three have an inefficient market. Subsequently by doubting the power of unit root tests, Jefferies and Okealhalam (1999) used event studies to test the weak form efficiency in the same three markets and the results for Botswana and South Africa remained uncharged whilst the Zimbabwean market portrayed some inefficiencies. Chiwira and Muyambiri (2012) uses BSE's ACI for 2004-2008 and apply unit root tests (ADF & PP) as well as K-S, Autocorrelation and the runs tests and reject the RWM. Most of these researchers uses only linear test which takes into account distributional properties of the data. However as Pandey *et al,* (1998) suggest, commonly applied linear tests may fail to detect deterministic processes of a nonlinear nature that generate variates appearing random. So it is imperative to also apply nonlinear dynamics tests (e.g. R/S test and BDS test) to check randomness of return series so as to test RWH. These test results by different researchers are however consistent and they all reject the RWH governing the local equity market implying the market is not efficient despite the drawback of being mostly linear tests.

Contrary to expectations, empirical results related to the market efficiency in developing and less developed markets are mixed irrespectively of which form of market efficiency is examined although most point to the same findings of inefficient market. Jefferies and Smith (2005) use GARCH approach with time varying parameters to test change in weak form efficiency over time. They used seven African markets and found that only the JSE of South Africa maintained efficiency over time whilst others from the sample have shown varying efficiencies but mostly portraying inefficiencies over time. Mobarek*et al,* (2008) uses the same tests as Mollah (2007) on the Dhaka Stock Exchange data and found that the return series do not follow a random walk behavior. One of the reasons attributed to the results in Dhaka and BSE is illiquidity and poor information dissemination.

Mabhunu (2004) studies the behaviour of stock returns on JSE, using autocorrelation tests, and finds that the RWM holds. Similarly, Sharma and Kennedy (1977) find weak-form efficiency on the Bombay Stock Exchange. On the other hand, Roux & Gibertson (1978) find weak-form inefficiency on the JSE[4]. Abrosimova *et al,* (2005) test the validity of the RWM using unit root tests, autocorrelation tests, and variance ratio tests on the Russian, Czech, and Polish equity market. Their findings stand in contrast to those of Worthington and Higgs (2003), who find weak form inefficiency of the Russian equity market using serial correlation coefficient and runs tests, ADF, PP, KPSS, and multiple variance ratio tests. Contrary to findings of Branes (1986), Laurence (1986) finds a little deviation from the weak-form EMH in Kuala Lumpur and Singapore Stock Exchange. Butler and Malaika (1992) examine two thinly traded stock markets in the Middle East and find a significant departure from the RWM in the Saudi

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[4] This finding contradicts that of Mabhunu (2004) but this could be attributable to the less developed nature of the market by then.

market, and a statistically significant auto-correlation exhibited by individual stocks of the Kuwaiti market. In a World Bank study, Claessens *et al,*(1993) also report a significant serial correlation in equity returns of 19 emerging markets and suggest that stock prices in emerging markets violate the weak-form EMH.

Weak-form efficiency findings are mostly tilted towards finding inefficiency in developing markets, although there is always room for the interpretation of results. Errunza and Losq (1985) argue that potential causes for the observed market inefficiency results from (i) barriers to the dissemination of information and exhibit positive dependence with respect to the real cost of capital to speculators and negative dependence with respect to the speed of information dissemination; (ii) common characteristics of loose disclosure requirements; thinness and discontinuity in trading and a less developed nature of markets. Although, they do not completely rule out the independence hypothesis as it might be justified by the existence of risk free assets; the negligible non-diversifiable risk; and the perfect market assumption. Butler and Malaikah (1992) attribute findings of market inefficiency to such institutional factors as illiquidity; market fragmentation; trading; reporting delays; and the absence of official market makers.

4. Data, Methodology and Results

4.1 Data Analysis

The data used in this research includes two equity index price series, taken from BSE database, which are the Domestic Companies Index (DCI) and Foreign Companies Index (FCI). The sample covers 1989-2013and it consists of Daily and Monthly index data. The longest series is the DCI daily series which extends from 19th June 1989 - 3rd of May 2013 with 4035 observations. The shortest series is the FCI Monthly series which extends from January2005 - April 2013 with 100 observations.

This paper uses index price series which are converted into continuously compounded returns using logarithms. Logarithmic returns are used because they are more likely to be normally distributed. Most of the statistical tests generally require the data used for testing to be normally distributed (Moustafa, 2004; Mollah, 2007). Freund *et al* (1997) also argues that logarithmic transformation removes most of linear dependence between successive returns. To cater for a problem of thinness and illiquidity in trading associated with most emerging markets, the compounded returns are calculated on trade-to-trade basis[5] and adjusted for interval variability. A number of academics support this approach e.g. Bowie (1994) and Mlambo and Biekpe (2007). This approach is however, not expected to remove

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[5]The adjusted trade-to-trade returns are calculate as follows:

$\acute{R}_t = 1/K_t\,[\,\ln(P_t) - \ln(P_{t\text{-}Kt})]$

Where:

$\acute{R}_t$ is trade-to-trade returns adjusted for interval effects

P_t is the stock's traded price in period *t*

$P_{t\text{-}Kt}$ is the price of stock Kt periods in the past

K_t is the length of time (in days) between the trade in period t and the previous successive trade.

all zero returns between trading periods but to minimize them, since zero returns will still be observed if trading occurs but does not affect the value of the stock. The study also ignores dividend, bonuses or right issues in return calculations because many previous studies (e.g., Lakonishok & Smidt (1988) and Fishe*et al*. (1993)) have shown that whether they are incorporated in the calculation or not have no effect on the results. **Table 2** below summarizes the descriptive statistics of the two BSE index return series.

Table 2. Descriptive Statistics

Index	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
DCIDAY	4035	-0.05	0.0951	0	0.00459	3.786	71.106
FCIDAY	2073	-0.24	0.2039	0	0.01477	0.06	86.578
DCIMONTH	287	0	0.0083	0	0.0013	1.322	7.065
FCIMONTH	100	-0.02	0.0089	0	0.00251	-2.396	20.132

Results in Table 2 show that the distribution of the return series does not follow a normal curve[6]. Skewness statistics for all index return series are non-zero except for FCI Daily returns with skewness value of 0.060 which is close to zero. Kurtosis statistics for all index return series are greater than 3, meaning that their underlying distribution is leptokurtic[7]. Specifically, high kurtosis values are reported for the DCI Daily Index, FCI Daily Index, and the FCI Monthly index, which are 71.11, 86.58, and 20.13 respectively. This means that the distribution of Botswana index returns is not normal, violating the prior condition of a random walk model and provides preliminary ground for rejection of the random walk behavior governing Botswana equity return series.

4.2 Methodology, Empirical Results and Discussions

This paper use variety of statistical techniques to detect the randomness of return series of the Botswana stock market indices. Linear and non-linear dynamics tests are employed. Linear tests used include Autocorrelation test (AC) and the Augmented Dickey Fuller test (ADF) and the non-linear tests include the Runs test and the Rescaled Range Analysis test (R/S analysis).

[6] A perfectly normal distribution is the one with a skewness value of zero and a kurtosis of approximately 3 in a Gaussian distribution. Kendal (1943) show that a normal kurtosis is equal to 2.902 using the model, 3(n-1/n+1) that he developed. Where n= sample size.

[7] Statistically, Kurtosis statistics greater than 3 indicate a leptokurtic distribution (the one which is highly peaked and has a greater percentage of small deviations from the mean return (more small surprises) and a greater percentage of extremely large deviations from the mean return (more big surprises).

To examine the serial dependence in return series, the serial correlation coefficients (i.e the autocorrelation test)[8] and the runs test are used. The autocorrelations test is a parametric test and it assumes that the data used come from some sought of probability distribution. **Tables 3** through **Table 6** present autocorrelation coefficients and their associated Box-Ljung statistics that follows the Chi-square distribution up to 20 lags. The Box-Ljung statistics is distributed as chi-square distribution because the sample size is large for all the indices studied. The results reject the null hypothesis of no autocorrelation for all the indices at 1% significant level, which again provides evidence against random walk behavior prevailing in Botswana's equity returns.

Table 3. Autocorrelations (DCIDAY)

Lag	Autocorrelation	Std. Error[a]	Value [b]	df	Sig.[c]
1	0.105	0.016	44.421	1	0.0
2	0.096	0.016	81.524	2	0.0
3	0.066	0.016	99.135	3	0.0
4	0.144	0.016	183.454	4	0.0
5	0.095	0.016	219.92	5	0.0
6	0.117	0.016	275.308	6	0.0
7	0.069	0.016	294.326	7	0.0
8	0.1	0.016	335.044	8	0.0
9	0.054	0.016	346.663	9	0.0
10	0.112	0.016	397.609	10	0.0
11	0.08	0.016	423.559	11	0.0
12	0.066	0.016	441.377	12	0.0
13	0.05	0.016	451.487	13	0.0
14	0.115	0.016	504.798	14	0.0
15	0.079	0.016	529.808	15	0.0
16	0.049	0.016	539.656	16	0.0
17	0.065	0.016	556.686	17	0.0
18	0.025	0.016	559.135	18	0.0
19	0.057	0.016	572.297	19	0.0
20	0.073	0.016	593.755	20	0.0

Table 4. Autocorrelations (FCIDAY)

Lag	Autocorrelation	Std. Error[a]	Value [b]	df	Sig.[c]
1	-0.213	0.022	94.423	1	0.0
2	0.052	0.022	100.13	2	0.0
3	-0.005	0.022	100.18	3	0.0
4	-0.043	0.022	103.93	4	0.0
5	0.165	0.022	160.37	5	0.0
6	-0.08	0.022	173.77	6	0.0
7	0.04	0.022	177.07	7	0.0
8	-0.104	0.022	199.53	8	0.0
9	0.045	0.022	203.76	9	0.0
10	0.118	0.022	232.98	10	0.0
11	-0.076	0.022	244.9	11	0.0
12	0.025	0.022	246.16	12	0.0
13	-0.048	0.022	250.89	13	0.0
14	0.054	0.022	257.04	14	0.0
15	0.043	0.022	260.98	15	0.0
16	0.019	0.022	261.75	16	0.0
17	-0.03	0.022	263.69	17	0.0
18	-0.003	0.022	263.71	18	0.0
19	-0.038	0.022	266.74	19	0.0
20	0.005	0.022	266.79	20	0.0

a. The underlying process assumed is independence (white noise) b. Box-LjungStatistics c. Based on the asymptotic chi-square approximation

[8] In its basic form, the auto-correlation model can be represented as follows: $U_t = LnR_{mt} – LnR_{mt-1}$ and it tests the relationship between current and previous period stock prices. Mollah (2007) explains this in details.

Table 5. Autocorrelations (DCIMONTH) **Table 6. Autocorrelations (FCIMONTH)**

Lag	Autocorrelation	Std. Error[a]	Value [b]	df	Sig.[c]	Lag	Autocorrelation	Std. Error[a]	Value [b]	df	Sig.[c]
1	0.436	0.059	55.111	1	0.0	1	0.164	0.099	2.778	1	0.1
2	0.236	0.059	71.325	2	0.0	2	0.109	0.098	4.018	2	0.13
3	0.137	0.059	76.783	3	0.0	3	0.055	0.098	4.338	3	0.23
4	0.104	0.058	79.931	4	0.0	4	0.109	0.097	5.596	4	0.23
5	0.044	0.058	80.509	5	0.0	5	-0.099	0.097	6.644	5	0.25
6	0.071	0.058	81.993	6	0.0	6	0.076	0.096	7.264	6	0.3
7	0.059	0.058	83.01	7	0.0	7	0.071	0.095	7.811	7	0.35
8	0.053	0.058	83.849	8	0.0	8	0.081	0.095	8.536	8	0.38
9	0.053	0.058	84.676	9	0.0	9	0.082	0.094	9.282	9	0.41
10	-0.014	0.058	84.738	10	0.0	10	-0.023	0.094	9.34	10	0.5
11	0.018	0.058	84.837	11	0.0	11	0.086	0.093	10.181	11	0.51
12	0.098	0.058	87.741	12	0.0	12	0.005	0.093	10.183	12	0.6
13	-0.023	0.057	87.906	13	0.0	13	-0.033	0.092	10.307	13	0.67
14	-0.035	0.057	88.278	14	0.0	14	-0.123	0.092	12.115	14	0.6
15	0.012	0.057	88.319	15	0.0	15	0.012	0.091	12.132	15	0.67
16	0.025	0.057	88.515	16	0.0	16	-0.05	0.091	12.44	16	0.71
17	0.005	0.057	88.523	17	0.0	17	-0.005	0.09	12.443	17	0.77
18	-0.015	0.057	88.588	18	0.0	18	0.01	0.09	12.456	18	0.82
19	-0.071	0.057	90.151	19	0.0	19	-0.018	0.089	12.498	19	0.86
20	-0.075	0.057	91.919	20	0.0	20	-0.065	0.089	13.042	20	0.88

a. The underlying process assumed is independence (white noise) b. x-LjungStatistics c. Based on the asymptotic chi-square approximation

The runs test as discussed by Defusco et al (2004) is a nonparametric test that imposes no prior distributional assumptions and may be better suited to detect statistical dependencies and/or randomness than the parametric tests like the autocorrelation test used above and the Augmented Dickey test that will be discussed next. The null hypothesis under the runs test is that the observed series are random. Assuming that the successive outcomes are independent, the number of runs is distributed normally with the following mean and standard deviation:

mean= $\frac{2n_A\ n_B}{n}$ + 1,S.D = $\sqrt{\frac{2n_A\ n_B(2n_A\ n_B - n)}{n^2(n-1)}}$; $n = n_A + n_B$, where $n_A$andn_B are the number of "+" and "-" symbols respectively. This means that the null hypothesis of randomness is rejected if the calculated number of runs falls outside of the 95% confidence interval [$\mu - 1.96\sigma \le k \le \mu + 1.96\sigma$] and fails to be rejected otherwise.

The results of the runs test are presented in **table 7**. The actual number of runs and the confidence interval limits are computed using the actual return series for each index. The hypothesized number of runs should be equal or close to the actual number of runs for RW to hold. Results in **table 7** show that the calculated number of runs falls outside the confidence interval, which means the hypothesized number of runs are not equal to the actual number of runs hence rejecting the RW hypothesis. These results support that of the autocorrelation test and provide additional reason to suspect that Botswana's equity market is not weak-form efficient.

Table 7. Runs Test

	DCIDAY	FCIDAY	DCIMONTH	FCIMONTH
Cases < Test Value	2008	752	143	50
Cases >= Test Value	2027	1321	144	50
Total Cases	4035	2073	287	100
Number of Runs	1667	841	82	43
Z	-11.067	-5.63	-7.391	-1.6
Asymp. Sig. (2-tailed)	0.00	0.00	0.00	0.11

The results of Augmented Dickey-Fuller (ADF) test are presented in **table 8**. The model below which represents the specifications underlying the ADF test is used to test for the presence of a unit root. See Xiao and Philips (1998) for further elaboration of the ADF model.

$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta y_{t-1} + \cdots + \delta_{p-1} \Delta y_{t-p+1} + \varepsilon_t$, where, *Yt* represent variable under consideration at time t (i.e. DCI or FCI value in this case), α is a constant, β the coefficient on a time trend and p, the lag order of the autoregressive process. Imposing the constraints $\alpha = 0$ and $\beta = 0$ corresponds to modelling a random walk and using the constraint $\beta = 0$ corresponds to modelling a random walk with a drift.

The null hypothesis here is that the time series have a unit root and is not stationary, that is the coefficient of *Yt-1* (i.e. γ) is equals to zero otherwise the unit root hypothesis is rejected.

Table 8. Augmented Dickey-Fuller Test

Index	Test	Test statistic	P-Value
DCIDAY	ADF	-10.7	0.01
FCIDAY	ADF	-12.3	0.01
DCIMONTH	ADF	-5.18	0.01
FCIMONTH	ADF	-4.35	0.01

Table 8 above presents the ADF test results with their associated p-values which reject the null hypothesis of a unit root at 1% level of significance for all the indices, indicating that the return series for the BSE are stationary hence proving that indeed the market is weak-form inefficient.

The consistency of the test results presented above gives confidence that the equity returns in Botswana do not follow a RW. However, since some researchers [e.g., Pandey *et al,* (1998)] argue that commonly applied linear tests may fail to detect deterministic processes of a nonlinear nature that generate variates appearing random, this paper further apply the modified Lo's Rescaled range analysis (R/S) test[9], a test better suited to capture the nonlinear dynamics even better than the Runs test. R/S test is among tests developed with advances in the theory of chaos to test for the possibility of a chaotic random data generating process in a time series. R/S uses Hurst exponent (a measure of long term memory of a time series). Hurst exponent is estimated through OLS of the form: Log (R/S) = H x log (N) + log (*a*) with *a* denoting a constant and H - the Hurst exponent. A non-deterministic process (H= 0.5) is a process for which past history of events has no impact on the future. A long memory process (H< 0.5) means that a positive trend in one N-length sub-period is more likely to be followed by a negative trend in the next N-length sub-period. A persistent process (H> 0.5) means that a positive (negative) trend is more likely to be followed by another positive (negative) trend.

The results of the R/S analysis are summarised in **table 9**. The calculated Hurst exponents generally confirm the presence of a non-linear dependencies present in Botswana's equity return series. All the index returns studied except the FCI daily returns are characterised by a strong persistent behaviour which usually guides momentum investing. The FCI daily returns show a weak persistent behaviour which is more inclined to supporting random walk behaviour of the return series.

Table 9. Hurst Exponents Estimates

Index	Hurst Exponent
DCIDAY	0.818823
FCIDAY	0.534217
DCIMONTH	0.688762
FCIMONTH	0.656866

[9]Lo's (1991) R/S is given by the following formula:

$$\hat{Q}^q{}_n = \frac{1}{\sigma_n(q)}\left[\max\sum_{j=1}^{n}(X_j - \overline{X}_n) - \min\sum_{j=1}^{n}(X_j - \overline{X}_n)\right] \text{where}$$

$$\hat{\sigma}^2{}_n(q) = \frac{1}{n}\sum_{j=1}^{n}(X_j - \overline{X}_n)^2 + \frac{2}{n}\sum_{j=1}^{q}\varpi_j(q)\left[\sum_{i=j+1}^{n}(X_i - \overline{X}_n)(X_{i-j} - \overline{X}_n)\right]$$

and

$$\varpi_j(q) = 1 - \frac{j}{q+1}, q < n.$$

The results of all tests used in this paper including test for non-linear dynamics are uniform in proving that the returns series of Botswana's equity markets are not random and hence provides evidence that the Botswana stock market is weak form inefficient. These results are consistent with that of Mollah (2007) and Chiwira and Moyambiri (2012) in nullifying weak-form efficiency of Botswana's equity markets even though the former used a shorter time series data covering 1989-2005 and the latter use most recent data covering only 2004-2008.

5. Conclusion

This paper empirically examines the validity of the weak-form EMH on Botswana equity markets by testing the presence of random walk behaviour in the DCI and FCI daily and monthly returns. Different statistical techniques are used to assess the weak-form market efficiency. Overall, the results suggest that the Botswana stock market returns are predictable, hence violating the notion of market efficiency. The latter conclusion is invariant to the choice of a statistical technique used. Both parametric (e.g. Autocorrelation test) and non-parametric (e.g. Runs Test) test procedures were used to test the validity of the EMH on the BSE. Reported autocorrelation coefficients reject the null hypothesis of no autocorrelation for all index returns and these results are consistent with results of the runs test which reject the null hypothesis of random walk in return series. Univariate unit roottest (ADF) is used to test for stationarity in return series of the two indices. The null for the ADF test is the presence of a unit root and the test results of the ADF test reject the null meaning that the data is stationary.

After ruling out the first order integration of return series, a test for the presence of non-linear dynamics to detect deterministic processes of a nonlinear nature which linear tests may fail to capture is performed. For this reason, the modified Lo's R/S statistic is used to test for the presence of long-memory properties of the data and the results show that Botswana equity returns exhibit strong persistent behaviour which means once a trend has been established in returns it will continue for some time before reverting to the opposite direction.

Results of this paper are consistent with the results expected from an emerging or developing market because generally empirical results show that these markets are not efficient in the weak form. However contrary to this belief though, the expectation in Botswana was that it should be efficient based on time component, that the BSE was established a long time back and hence its efficiency should have improved over time. This is more so because there has been some introduction of new equity products like the exchange traded funds as well as the Automation of the trading system. Moreover clearing and settlement have been improved by the introduction of Central Securities Depository Botswana. Results of this study however show that these developments have not improved the efficiency. Possibly the impact of these has not yet been pronounced, so future research is necessary to check if these will not improve efficiency in the long run. This result are however consistent with that of Freund and Pagano (2000) who find no improvement in the efficiency of both the Toronto Stock Exchange and the New York Stock exchange before and after automation. In addition Sioud and

HMaied (2003) show that while automation has increased the liquidity of shares in the Tunisian stock market no notable improvements were observed in the efficiency or volatility of the market.

Moreover, further research might also focus on examining how the predictability exhibited by the BSE equity returns can be used to generate abnormal returns, net of management fees and commissions, to investors, traders, and market makers. This is necessary because the results of this research imply that it is possible to beat the market and earn supernormal profit by benefiting on the informational inefficiencies present in Botswana's equity market. In sum, the study show that efforts of technical and fundamental analyst in Botswana on predicting future stock prices and returns are worthwhile and this gives them more courage in their work to continuously apply technical and fundamental strategies to invest actively. However, caution should be exercised all times by investors or investment advisors who promise guaranteed returns because finance theory states that no investment returns should be guaranteed even if there is high probability of attaining them.

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