Unobserved structural shifts and asymmetries in the random walk model for stock returns in African frontier markets

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UNOBSERVED STRUCTURAL SHIFTS AND ASYMMETRIES IN THE RANDOM WALK MODEL FOR STOCK RETURNS IN AFRICAN FRONTIER MARKETS

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ABSTRACT: The purpose of this study is to examine the weak-form market efficiency hypothesis (EMH) for 8 African Frontier markets (Nairobi Securities Exchange of Kenya, the Nigerian Stock Exchange of Nigeria, Botswana Stock Exchange of Botswana, Zimbabwe Stock Exchange of Zimbabwe, Johannesburg Stock Exchange of South Africa, Egyptian Exchange of Egypt, Casablanca Stock Exchange of Morocco, the Tunis Stock Exchange of Tunisia). To achieve this purpose we employ unit root testing procedures which are robust to both nonlinearities and smooth structural breaks. To further allow for vigorousness in our empirical analysis we employ two time series datasets for each of the capital markets, namely daily and weekly time series. To the best of our knowledge, our study becomes the first, to investigate the weak-form EMH for all 8 African frontier markets whilst simultaneously accounting for asymmetries and smooth structural breaks. Our empirical findings suggest that most African frontier markets are not market efficient, in the weak sense form, with the exception of the

Kenyan stock market and to a very much lesser extent the Botswana and South African stock series. Important policy and investor implications are drawn in our study.

Keywords: Africa; Efficient market hypothesis (EMH); Unit roots; Nonlinearities; Fourier approximation.

JEL Classification Code: C21; C22; C51; G14.

1 INTRODUCTION

Following the seminal influences of Harrod (1939) and Domar (1946) and the subsequent contributions of Solow (1965), Swan (1965) and Lucas (1988), the evolution of an economy's capital stock has been unanimously considered as the engine of dynamic economic growth and development. In more modern times, capital markets can be viewed as markets in which the ownership of an economy's capital stock is distributed amongst a variety of competitive yet rationale market participants. Economic Nobel laureates Paul Sameulson (1965) and Eugene Fama (1965) were amongst the first to recognize that the trajectory of returns on security prices can provide simple yet powerful inferences on the efficiency of capital markets considering the rationale behaviour of market participants. The Fama-Samuelson synthesis particularly argues that the independence of a sequence of changes in security prices implies that equilibrium conditions of production-investment decisions within capital markets satisfy a 'fair game' model in which speculative behaviour does not yield any predictable gains. In academic jargon, this phenomenon is more popularly branded as the efficient market hypothesis and has since its inception undergone severe criticism concerning its validity.

Even though the EMH has secured a considerable amount of empirical support within the academic literature, more particularly for advanced Western economies (see Titan (2015) for an exhaustive review of the associated literature), practioneers and other observers have nevertheless questioned the validity of the theory considering the number of re-occurring stock market crashes which have translated into larger, and in more severe cases, global financial crisis that have threatened the very essence of global economic stability. Ball (2009) notes that investors and financial regulators worldwide have been unable to predict several historic financial crises which have commonly emulated from the bursting of asset bubbles because they religiously believed in the EMH and its implication of self-correcting behaviour of capital markets. Initially, Keynes (1936) contended that investors in equity markets had 'animal spirits' and the stock market participants had characteristics of a 'beauty contest', in that the actions of many rational but short-horizon investors are similarly governed by their expectations about what other investors believe, rather than their genuine expectations about the true value of a firm (Gao, 2008). Later on, Grossman and Stiglitz (1980) cast some doubt on the EMH due to information asymmetry in which equilibrium in markets can only occur if there is no information existing within the markets. In particularly, the authors argue that in the existence of information and the costs of obtaining it "…prices cannot perfectly reflect the information which is available, since if it did then, those who spend resources to get it would receive no compensation …" (Grossman and Stiglitz, 1980). And even more recently there has emerged a new breed of economists who have emphasized on the psychological and behavioural elements of stock-price determination and strongly believed that stock prices must be at least partially predictable on the basis of past price behaviour as well as other certain valuation metrics (Malkiel, 2003).

From an empirical standpoint, the disputes over the validity of the market efficiency hypothesis, which in their weak-form are primarily based on unit root testing procedures are no less conclusive. Torous et al. (2004) argue that by their very construction, conventional unit root tests such as the Dickey-Fuller (ADF) and PP tests have low power to reject the null hypothesis of a unit root when the underlying data generated according to the local-to-unity specification. Perron (1989) as well as Zivot and Andrews (1994) demonstrate that these tests further exhibit low testing power in the presence of structural breaks in the data caused by severe structural changes such as the 1970 oil crisis. Moreover, Kapetanois et al. (2003) further show that conventional unit root tests have low testing power in distinguishing between unit root and nonlinear, stationary processes. And even more recently, Becker et al. (2006) and Enders and Lee (2012) demonstrate that both nonlinearities and smooth structural breaks can be efficiently captured within unit root testing frameworks through an augmentation of a flexible Fourier approximation. In light of the two most severe two crisis periods (Asian financial crisis of 1998-2000 and the global financial crisis of 2007-2009 experienced) over the last two decades, the ability of FFF to capture a series of smooth structural breaks within a time series without prior knowledge of the break dates renders the model function superior to other existing unit root testing procedures.

Our study applies the nonlinear unit root test of Kapetanois et al. (2003) augmented with a flexible Fourier form (FFF) approximation to examine the weak-form efficient market hypothesis for a group of African frontier markets. In general, Africa has experienced a relatively large amount of economic growth in the twenty-first century and yet less than 40 percent of the countries in Africa have stock exchanges which are functioning across the continent (Yartey and Adjasi, 2007). Although there has been some notable progress in terms of the number of securities exchange platforms, there is a lot of work left to improve the Africa's financial market structure because more than half of the continent is yet to form functional capital markets. Nevertheless, there exists a number of frontier African markets which accounts for a majority of trades within the continent and these include the Nairobi Securities Exchange (Kenya), the Nigerian Stock Exchange (Nigeria), the Botswana Stock Exchange (Botswana), the Zimbabwe Stock Exchange (Zimbabwe), the Johannesburg Stock Exchange (South Africa), the Egyptian Exchange (Egypt), the Casablanca Stock Exchange (Morocco) and the Tunis Stock Exchange (Tunisia). Our study is principally concerned on extending on the current knowledge of weak-form market efficiency in these frontier markets as this would be useful towards investors who hold portfolios as well as towards policymakers in their efforts to secure investor's confidence in African markets.

Up-to-date, a handful of studies have investigated the weak-form market efficiency for African stock markets and a summary of the country-specific and panel based-studies for the previous literature is presented in Tables 1 and 2, respectively. As can be observed from both Tables 1 and 2 there is inconclusiveness over the existence of weak-form market efficiency for panels of different countries and for different authors investigating the same country. We perceive this ambiguity to raise from the use of 'out-dated' unit root testing procedures which are subject to a number of criticisms including the failure to account for important structural breaks and nonlinearity hence leaving the subject matter open to further deliberation. Against this gap in the literature our study serves to fill this empirical hiatus using appropriate econometric techniques.

We therefore structure the remainder of the paper as follows. Section 2 of the paper presents our empirical framework. Section 3 presents the empirical data and the results. The paper is concluded in section 4.

Table 1: Summary of literature review for the individual-based studies

Author(s)	Country/ Countries	Period	Method	Main Result: Efficient / non-efficient
Fowdar et al. (2007)	Mauritius	January 1999 – December 2004D	ADF and KPSS tests	Inefficient
Sunde and Zivanomoyo (2008)	Zimbabwe	January 1998 – November 2008M	ADF tests	Inefficient
Nwosa and Oseni (2011)	Nigeria	January 1986 – December 2010M	ADF and PP tests	Inefficient
Chiwira and Muyambiri (2012)	Botswana	December 2011 – January 2012W, M	ADF and PP tests	Inefficient
Kamau (2013)	Kenya	January 2008 – December 2012D	ADF and PP tests	Efficient
Ogege and Mojekwu (2013)	Nigeria	January 1985 – December 2010M	ADF and PP tests	Inefficient
Nwidobie (2014)	Nigeria	January 2000 – December 2012	ADF test	Inefficient
Obayabona and Igbiniso (2014)	Nigeria	January 2006 – December 2011M	ADF and PP tests	Inefficient
Yadirichukwu and Ogochukwu (2014)	Nigeria	January 1984 – December 2012M	ADF unit root tests	Inefficient
Balparda et al. (2015)	Kenya	January 2001 – December 2009D	ADF, PP, KPSS and ERS tests	Inefficient
Grater and Struweg (2015)	South Africa	October 1998 – April 2014M	ADF and PP tests	Efficient
Kitso and Ummersingh (2015)	Mauritius	July 2001 – July 2014D	ADF, PP and KPSS tests	Efficient
Magaji et al. (2015)	Nigeria	1985 – 2009A	ADF test	Efficient
Phiri (2015)	South Africa	January 2000 – December 2014W	ADF, PP, Enders and Granger (1998) and Bec et al. (2004) tests	Inefficient
Njugana (2016)	Kenya	January 2001 – January 2015D,W	ADF and PP tests	Inefficient
Fusthane and Kapingura (2017)	South Africa	January 2005 – December 2016M	ADF and PP tests	Efficient

Note: D ≡ daily; W ≡ weekly; M ≡ monthly.

Table 2: Summary of literature review for the panel-based studies

Author(s)	Country/ Countries	Period	Method	Main Result: Efficient / non-efficient
Kawakastu and Morey (1999)	Including Zimbabwe	January 1976 November 1997M	KPSS and DF-GLS	Efficient
Lagoarde-Segot and Lucey (2006)	Including Egypt, Morocco and Tunisia	January 1998 – November 2004D	KPSS test	Egypt and Tunisia efficient and Morocco inefficient
Alam and Uddin (2009)	Including South Africa	January 1988 – March 2003M	ADF test	Inefficient
Enowbi et al. (2010)	Including Egypt, Morocco, South Africa, Tunisia	January 2000 – March 2009D	ADF, PP and KPSS	Efficient
Lee et al.(2010)	Panel of developed and developing including: Botswana, Egypt, Kenya, Mauritius, South Africa	January 1999 – May 2007M	LLC, IPS, Breitung, Fisher ADF, Fischer PP, Hadri tests	Inefficient
Nwosu et al. (2013)	Egypt, Kenya, Nigeria, South Africa	January 1998 – December 2008W	ADF and KPSS	Inefficient
Adigwe et al. (2017)	Including Botswana, Egypt, Kenya, Mauritius, Morocco, Nigeria, South Africa, Tunisia, Zimbabwe	January 2013 – December 2015M	ADF tests	Inefficient

Note: D ≡ daily; W ≡ weekly; M ≡ monthly.

2 EMPIRICAL FRAMEWORK

2.1 Theoretical foundations

At the theoretical nucleus of the EMH lies the expected return or "fair game" model as expounded in Fama (1970) who mathematically constructed his theory based on the following model function:

$$E(p_{j,t+1}|\ \Omega_t) = [1 + E(sr_{j,t+1}|\ \Omega_t)]\ p_{j,t} \qquad (1)$$

From equation (1) E is an expectations operator, $p_{j,t+1}$ is the share price at t whereas $p_{j,t+1}$ is the next period share at t+1, $sr_{j,t+1}$ is the one-period percentage return computed as ($p_{j,t+1}$ - $p_{j,t}$)/ $p_{j,t}$. and Ω_t is the general information set which is assumed to be fully reflected in the share price at time t. Under the 'fair game' model, any possibility of investors expecting profits or returns in excess of equilibrium are ruled out such that the following condition is satisfied:

$$E(x_{j,t+1}| \Omega_t) = 0 \qquad (2)$$

Where $x_{j,t+1}$ denotes the excess market value of the share at t+1 such that $E(x_{j,t+1}| \Omega_t) = p_{j,t+1} - E(p_{j,t+1}| \Omega_t)$. Equivalently equation (2) can be re-formulated in terms of returns such that:

$$E(r_{j,t+1}| \Omega_t) = 0 \qquad (3)$$

Where $z_{j,t+1}$ denotes the excess market returns at t+1 such that $E(r_{j,t+1}| \Omega_t) = r_{j,t+1} - E(r_{j,t+1}| \Omega_t)$. Conditions (2) and (3) imply that share prices and their returns present a "fair game" to investors. Nevertheless, the "fair game" model states that the conditions of market equilibrium can be stated in terms of expected returns and yet says nothing concerning the details of the stochastic process of the time series. Fama (1970, 1971) propose that the following random walk model to capture the stochastic properties of stock returns:

$$f(r_{j,t+1}| \Omega_t) = f[r_{j,t+1}) \qquad (4)$$

In which the density function, f, is identical for all t. In further assuming that the expected return on the stock price is constant over time, then:

$$E(r_{j,t+1}| \Omega_t) = E(r_{j,t+1}) \qquad (5)$$

And from equation (5), the mean of the distribution of $r_{j,t+1}$ is now independent of information set Ω_t, available at time t, hence reflecting the weak-form of market efficiency in which market participants cannot use past price or return patterns to make abnormal profits.

2.2 Econometric modelling

Another way of expressing the random walk model of stock returns as in equation (5), would be to specify it as the following autoregressive (AR) specification as suggested by Dickey and Fuller (1979):

$$sr_t = \rho sr_{t-1} + e_t , \qquad t = 1,2,\ldots,T \text{ and } e_t \sim N(0, \sigma^2) \qquad (6)$$

From equation (6), the stock returns series, sr_t, is consider mean-reverting such that it confirms to the weak-form EMH holds only if $\rho < 1$ whereas if $\rho =1$, then the series evolves as a random walk with a variance which grows exponentially as $t \to \infty$. A more generalized form of regression (6) is the following Augmented Dickey Fuller (ADF) regression:

$$\Delta sr_t = \alpha_i + \beta_i sr_t + \sum_{j=1}^{p} \lambda_j \Delta sr_{t-j} + e \qquad (7)$$

Where Δ denotes a first difference operator and $\sum_{j=1}^{p} \lambda_j \Delta sr_{t-j}$ is a truncated lag which absorbs up any excess serial correlation in the test regression. The DF test statistic used to test the unit root null hypothesis (i.e. H_0: $\beta_i = 0$) against the stationarity alternative (i.e. H_1: $\beta_i < 0$) is the t-ratio of the β_i coefficient i.e.

$$DF = \frac{\Delta sr M sr_{-1}}{\sqrt{\sigma^2 sr'_{-1} My sr_{-1})}} \qquad (8)$$

Where $M = I_T - \tau_T(\tau'_T, \tau_T)^{-1}\tau'_T$ and $\sigma^2 = \Delta y_i M_{xi} \Delta y_i/(T\text{-}1)$. As previously mentioned, conventional unit root tests like the ADF test fail to distinguish between nonlinearity and unit root processes within time series. As an alternative, Kapetanois et al. (2003) extend upon the convention Dickey Fuller testing regression found in regressions (8) – (9), into an exponential smooth transition autoregressive (ESTAR) model. In following their practice, the ESTAR model of stock returns can be specified as:

$$\Delta sr_t = \psi_i sr_{t-1} + [1\text{-exp}(-\Phi sr_{t-1}^2)] + \sum_{j=1}^{p} \rho_i \Delta sr_{t-i} + e_t \quad (9)$$

Under the null hypothesis, the stock returns series follows a unit root process (i.e. H_0: $\Phi = 0$) whilst the alternative hypothesis is that the time series evolves as a stationary ESTAR model. Since the direct testing of the null hypothesis is not feasible due to the presence of nuisance parameters under the null hypothesis, then Kapetanios et al. (2003) re-parameterize equation (11) using a first order Taylor series approximation. From the resulting auxiliary nonlinear unit root testing regression:

$$\Delta sr_t = \delta_i sr_{t-i}^3 + \sum_{j=1}^{p} \rho_i \Delta sr_{t-i} + e_t \quad (10)$$

The null hypothesis of a linear unit root process can be now tested as H_0: $\delta_i = 0$ against the alternative of stationary ESTAR process (i.e. H_1: $\delta_i = 0$). In similarity to the conventional ADF test, the asymptotic critical value of the Kapetanios et al. (2003) unit root test is computed as:

$$t_{KSS} = \frac{\hat{\delta}}{S.E.(\hat{\delta})} \quad (11)$$

Since the t_{KSS} statistic does not follow an asymptotic standard normal distribution, Kapetanios et al. (2003) derive critical values for the test statistics for the test performed on raw time series, de-meaned data (i.e. $z_t = x_t - \bar{x}_t$) and de-trended data (i.e. $z_t = x_t - \hat{\mu} - \hat{\delta}t$) where $\bar{x}_t$ is the sample mean and $\hat{\mu}$ and $\hat{\delta}t$ are the OLS estimates of μ and δ, respectively. One major shortcoming with the KSS unit root test is its inability to directly account for structural breaks in the regression. Of recent, there has been a growing consensus that a flexible Fourier form (FFF) approximation of unit root tests has good size and power properties in detecting a series of unknown smooth structural breaks (see Enders and Lee (2012) and Rodrigues and Taylor (2012)). Therefore, in augmenting the KSS unit root test using a single frequency Fourier function, the testing regression can be specified as:

$$\Delta sr_t = \delta_i sr_{t-i}^3 + \sum_{j=1}^{p} \rho_i \Delta sr_{t-i} + a_i \sin\left(\frac{2\pi Kt}{T}\right) + b_i cos\left(\frac{2\pi Kt}{T}\right) + e_t, \quad t = 1,2,\ldots,T. \tag{12}$$

Where K is the singular approximated frequency selected for the approximation, whilst coefficients a and b measure the amplitude and displacement of the sinusoidal. Enders and Lee (2012) place emphasis on estimating a Fourier function with a singular frequency to avoid problems of over-fitting and loss of regression power. Moreover, Enders and Lee (2012) propose that regression (12) be estimated for all integer values of K which lie between the interval [1, 5] and selecting the estimation which produces the lowest sum of squared residuals (SSR).

3 DATA AND EMPIRICAL FINDINGS

3.1 Empirical data

Our time series variables have been sourced from Thomson Reuters Datastrem and consists of closing prices of stock returns for Nairobi Securities Exchange of Kenya, the Nigerian Stock Exchange of Nigeria, Botswana Stock Exchange of Botswana, Zimbabwe Stock Exchange of Zimbabwe, Johannesburg Stock Exchange of South Africa, Egyptian Exchange of Egypt, Casablanca Stock Exchange of Morocco, the Tunis Stock Exchange of Tunisia. Note that all series cover a period of 2001 to 2017 except for the Kenyan series begins in 2006 and ends in 2017. To ensure rigour in our empirical analysis, we employ two set of empirical time series (daily and weekly series). Since our empirical analysis requires the use of stock market returns, the transformation of the share prices (p_t) into returns (sr_t) can be achieved:

$$\text{sr}_t = \frac{p_t - p_{t-1}}{p_{t-1}} \text{ or } \text{sr}_t = \frac{p_t}{p_{t-1}} - 1 \qquad (13)$$

And in further transforming the equation (#) in logarithmic form, and noting that log (1) = 0, results in the following compounded series of stock returns:

$$\log(\text{sr}_t) = \log(p_t) - \log(p_{t-1}) \qquad (14)$$

After transforming the time series using equation (14), which becomes our officially empirical data, we provide the summary statistics for the series in Table 3, with Panel A showing the statistics for daily series and Panel B for the weekly series. In terms of return averages the highest averages in both Tables are found for Tunisia, followed by South Africa, Kenya, Botswana, Egypt, Mauritius, Morocco and finally Nigeria with the lowest returns. In terms of volatility, as measured by the standard deviation, the most volatile series are found for the Egyptian series followed by Nigeria, South Africa, Kenya, Mauritius, Morocco, Tunisia and lastly Botswana. Also note that the reported p-values for the Jarque-Bera statistics are all 0.00, a finding which validates the expected non-normality behaviour in the stock return series. The time series for the daily and weekly series as found in Figures 1 and 2, respectively, graphically validate the finding of non-normality in the observes series.

Table 3: Descriptive statistics of time series

Panel A: Daily series	Mean	Median	Maximum	minimum	Std. dev.	j-b (p-value)	Obs.
South Africa	0.023	0.015	6.833	-7.581	1.22	0.00	3548
Botswana	0.006	0.000	3.925	-4.775	0.34	0.00	3548
Mauritius	-0.005	0.000	8.005	-6.382	0.69	0.00	3548
Kenya	0.014	0.000	7.486	-5.141	0.82	0.00	2309
Nigeria	-0.038	0.000	11.758	-9.475	1.17	0.00	3548
Tunisia	0.031	0.005	4.109	-5.004	0.58	0.00	3548
Egypt	0.0046	0.000	7.314	-17.99	1.72	0.00	3548
Morocco	-0.009	0.000	4.464	-4.667	0.69	0.00	3548
Panel B: Weekly series							
South Africa	0.108	0.153	16.04	-9.63	2.61	0.00	887
Botswana	0.029	0.073	5.02	-6.73	1.04	0.00	887
Mauritius	-0.02	-0.008	7.91	-15.72	1.91	0.00	887
Kenya	0.06	0.20	15.31	-10.45	2.40	0.00	461
Nigeria	-0.19	-0.05	15.62	-14.24	3.53	0.00	887
Tunisia	0.1553	0.13	8.4943	-13.63	1.63	0.00	887
Egypt	0.02	0.23	19.32	-21.96	4.53	0.00	887
Morocco	-0.05	-0.01	5.36	-9.80	1.67	0.00	887

Figure 1: Stock returns for Frontier markets in Africa (Daily series)

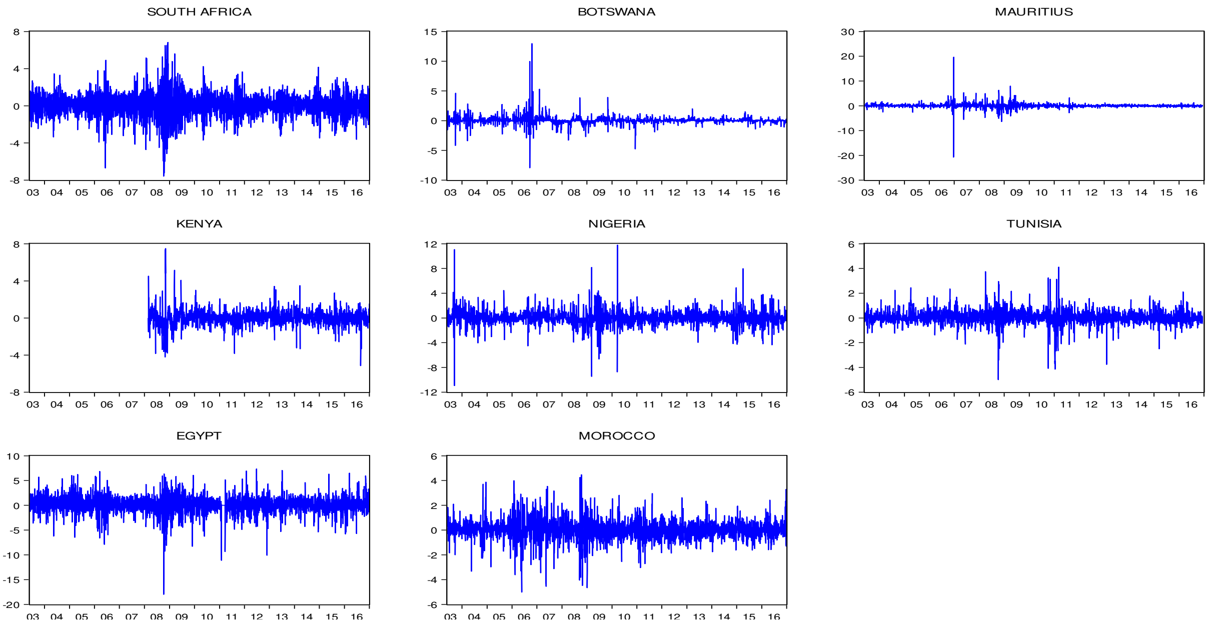
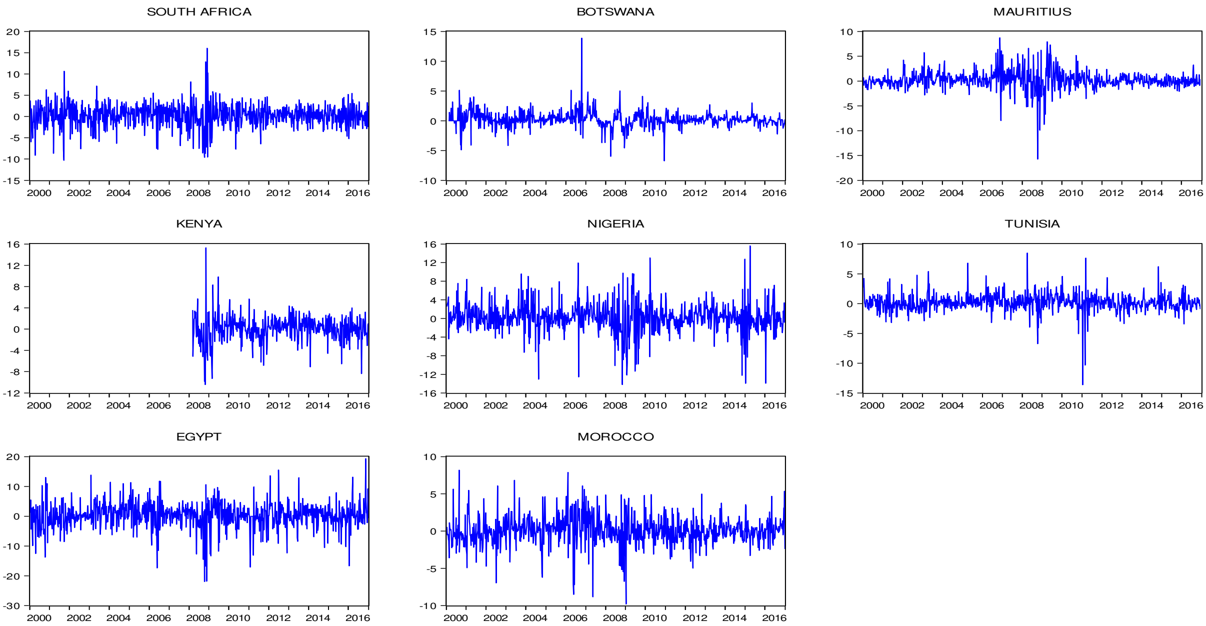


Figure 2: Stock returns for Frontier markets in Africa (Weekly series)



3.2 Conventional unit root test results

Table 1 presents the results from the three most commonly used conventional unit root tests (ADF, PP and KPSS). All tests are performed with a drift as well as with a drift and trend with the optimal lag length of the tests being determined by a minimization of the Schwartz criterion. Panel A presents the results for the daily series whilst Panel B reports the results for the weekly series. In both panels both ADF and PP tests manage to reject the unit root null hypothesis for all African countries at all levels of significance regardless of whether the tests are performed with a drift or with both a drift and trend hence providing evidence against the weak-form EMH. These results are similar to those previous obtained in Fowdar et al. (2007), Sunde and Zivanomoyo (2008), Lee et al. (2010), Nwosa and Oseni (2011), Chiwira and Muyambiri (2012), Ogege and Mojekwu (2013), Nwosu et al. (2013), Nwidobie (2014), Yadirichukwu and Ogochukwu (2014), Balparda et al. (2015), Njugana (2016) and Adigwe et al. (2017). We also note that these results are contrary to those found in Kawakastu and Morey (1999), Enowbi et al. (2010), Kamau (2013), Grater and Struweg (2015), Kitso and Ummersingh (2015), Magaji et al. (2015) as well as Fusthane and Kapingura (2017). However, when the KPSS test is applied, we observe discrepancies in the results. For instance, when the KPSS test is performed on the daily series, only South Africa and Botswana, unanimously fail to reject the stationarity null hypothesis regardless of whether the test is performed with a drift or with a drift and trend. These latter results are comparable to those found in Lagoarde-Segot and Lucey (2006), Balparda et al. (2015) and Enowbi et al. (2010).

Table 4: Conventional unit root test results

	ADF		PP		KPSS	
Panel A: Daily series	Intercept	Trend and Intercept	Intercept	Trend and Intercept	Intercept	Trend and Intercept
South Africa	-58.52*** [0]	-58.55*** [0]	-59.11*** [22]	-59.24*** [23]	0.29 [22]	0.07 [23]
Botswana	-7.18*** [29]	-7.38*** [29]	-68.45*** [31]	-68.0716*** [31]	0.68** [31]	0.15** [31]
Mauritius	-9.25*** [29]	-9.47*** [29]	-60.62*** [23]	-60.54*** [22]	0.61** [23]	0.05 [22]
Kenya	-28.70*** [0]	-28.70*** [0]	-27.86*** [22]	-27.84*** [22]	0.19 [6]	0.17** [6]
Nigeria	-8.69*** [29]	-8.75*** [29]	-43.13*** [8]	-43.15*** [9]	0.32 [10]	0.14* [10]
Tunisia	-10.77*** [22]	-10.91*** [22]	-46.59*** [9]	-46.64*** [10]	0.62** [6]	0.09 [5]
Egypt	-9.63*** [27]	-9.71*** [27]	-50.46*** [2]	-50.60*** [3]	0.53** [7]	0.27 [6]
Morocco	-9.78*** [27]	-9.93*** [27]	-46.25*** [3]	-46.36*** [1]	0.74*** [12]	0.20** [11]
Panel B: Weekly series						
South Africa	-7.49*** [13]	-7.51*** [13]	-31.55*** [6]	-31.53*** [6]	0.08 [5]	0.07 [5]
Botswana	-5.12*** [14]	-5.27*** [14]	-28.52*** [17]	-28.28*** [16]	0.34 [18]	0.07 [18]
Mauritius	-4.90*** [16]	-4.97*** [16]	-26.66*** [13]	-26.64*** [13]	0.23 [15]	0.13* [14]
Kenya	-4.34*** [11]	-4.37*** [11]	-17.93*** [5]	-17.92*** [5]	0.21 [2]	0.18** [2]

Nigeria	-5.99*** [15]	-6.16*** [15]	-28.79*** [14]	-28.75*** [13]	0.4463** [14]	0.08 [13]
Tunisia	-5.20*** [20]	-5.19*** [20]	-27.61*** [10]	-27.60*** [10]	0.20 [11]	0.19** [11]
Egypt	-4.69*** [19]	-4.68*** [19]	-27.87*** [8]	-27.86*** [8]	0.18 [9]	0.20** [9]
Morocco	-4.97*** [20]	-4.96*** [20]	-26.72*** [8]	-26.70*** [8]	0.25 [9]	0.26*** [9]

Notes: "***", "**", "*" denote the 1%, 5% and 10% critical levels

In recognition of these conventional tests being often criticized for having weak power in distinguishing between unit roots and stationarity properties in time series, we further apply the DF-GLS test of Elliot et al. (1996) as well as the MZ_A, MZ_B, MS_B and MP_T tests of Ng and Perron (1996, 2001) to our empirical series. Table 3 reports the results of these tests performed with a drift as well as with and drift and trend. Following intuition provided by Ng and Perron (2001), we apply the modified AIC to more efficiently select the optimal lag length of the tests. As can be observed from the test results from the daily series reported in Panel A of Table 4, all test statistics reject the unit root null hypothesis at all critical levels for both DF-GLS and N-P tests, with the exception of the South African series in which the unit root null cannot be rejected for all N-P statistics regardless of whether the test is performed with a drift or a drift and trend. However, the results are reported in Panel B for the weekly series paint a different picture, with unit root null failing to be rejected in all tests for the South African, Kenyan and Tunisian stock markets hence unanimously advocating for the weak-form EMH in these stock exchanges. For the Nigerian and Egyptian stock return series the EMH only holds when the Ng-Perron tests are applied (with an intercept as well as with a trend and intercept) whilst for the Moroccan series the hypothesis only holds when the Ng-Perron tests performed with a intercept and trend. Nevertheless, with the large discrepancies between the results obtained from the daily and the weekly series, we can safely conclude our findings from these tests as being generally inconclusive

Table 5: Modified unit root test results

	Elliot et al. (2001)		Ng and Perron (1996, 2001)							
	DF-GLS		MZA		MZT		MSB		MPT	
Panel A: Daily series	Intercept	Intercept and trend	intercept	Intercept and trend	intercept	Intercept and trend	intercept	Intercept and trend	intercept	Intercept and trend
South Africa	-2.04**	-3.88***	-3.59	-6.22	-1.31	-1.76	0.37	0.28	6.83	14.66
	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]
Botswana	-6.93***	-6.98***	-20.5***	-20.97**	-3.20***	-3.24**	0.16***	0.1544**	1.20***	4.35**
	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]
Mauritius	-5.51***	-7.07***	-13.66**	-22.78**	-2.61***	-3.37**	0.19**	0.15**	1.79**	4.03***
	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]
Kenya	-28.7***	-7.43***	-85.8***	-89.5***	-21.1***	-6.65***	0.02***	0.07***	0.04***	1.18***
	[0]	[26]	[0]	[26]	[0]	[26]	[0]	[26]	[0]	[26]
Nigeria	-8.68***	-8.61***	-71.85	-68.2***	-5.99***	-5.84***	0.08***	0.09***	0.35***	1.34***
	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]
Tunisia	-3.01***	-5.64***	-8.99**	-18.98**	-2.12**	-3.05**	0.24*	0.16**	2.72**	4.97**
	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]
Egypt	-4.89***	-7.04***	-13.38**	-26.23**	-2.56**	-3.62***	0.19**	0.14***	1.93**	3.48***
	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]	[29]
Morocco	-5.81***	-7.99***	-18.5***	-43.1***	-3.03***	-4.62***	0.16***	0.11***	1.37***	2.22***
	[29]	[28]	[29]	[28]	[29]	[28]	[29]	[28]	[29]	[28]
Panel B: Weekly series										
South Africa	-1.58	-2.54	-2.42	-2.11	-1.09	-0.92	0.45	0.44	10.10	37.46
	[13]	[20]	[13]	[20]	[13]	[20]	[13]	[20]	[13]	[20]
Botswana	-4.87***	-4.95***	-28.4***	-30.1***	-3.77***	-3.88***	0.13***	0.13***	0.86***	3.03***
	[14]	[14]	[14]	[14]	[14]	[14]	[14]	[14]	[14]	[14]
Mauritius	-3.74	-4.80***	-9.86**	-16.92*	-2.20**	-2.90*	0.22**	0.17*	2.57**	5.39*
	[16]	[16]	[16]	[16]	[16]	[16]	[16]	[16]	[16]	[16]
Kenya	-0.99	-2.17	-1.85	-4.07	-0.93	-1.38	0.50	0.34	12.74	21.95
	[11]	[11]	[11]	[11]	[11]	[11]	[11]	[11]	[11]	[11]
Nigeria	-2.19**	-4.04***	-4.93	-11.62	-1.56	-2.39	0.32	0.21	4.98	7.96
	[17]	[20]	[17]	[20]	[17]	[20]	[17]	[20]	[17]	[20]
Tunisia	-1.30	-2.34	-2.67	-12.55	-1.11	-2.50	0.42	0.19	9.00	7.26
	[12]	[16]	[12]	[16]	[12]	[16]	[12]	[16]	[12]	[16]
Egypt	-3.99***	-4.47***	-2.67	-4.02	-1.11	-1.37	0.42	0.34	8.99	22.15
	[19]	[19]	[19]	[19]	[19]	[19]	[19]	[19]	[19]	[19]
Morocco	-4.02***	-4.16***	-8.46**	-11.44	-1.98*	-2.35	0.23**	0.21	3.36*	8.21
	[20]	[20]	[20]	[20]	[20]	[20]	[20]	[20]	[20]	[20]

Notes: "***", "**", "*" denote the 1%, 5% and 10% critical levels. Optimal lags length as determined by the modified AIC reported in [].

3.3 KSS test without FFF

Before presenting the results for the KSS tests performed with a FFF, Table 4 firstly reports the findings of the KSS test performed without a FFF for 'control' purposes. The results from the daily series as reported in Panel A of Table 4, shows that the test statistics estimated from all series manage to reject the unit root null hypothesis in favour of stationary, nonlinear series at all levels of significance, with the exception of the Kenyan series, in which the estimated KSS statistics for the raw series (-0.95), the de-meaned series (-0.95) and the de-trended series (-0.94) are greater value than their respectively 10 percent critical values. Similarly, the results obtained for the weekly series indicate that the unit root hypothesis is rejected at all levels of significance for all series with the exception of sole exception of when the test is performed on the de-trended data for Botswana, in which there is slight evidence of the weak-form EMH.

Table 6: KSS unit root tests without FFF

	Raw	De-meaned	De-trended
Panel A: Daily series			
South Africa	-5.78*** [7]	-5.93*** [7]	-5.93*** [7]
Botswana	-7.86*** [10]	-7.84 *** [10]	-7.84*** [10]
Mauritius	-6.41*** [10]	-26.54*** [10]	-26.64*** [10]
Kenya	-0.95 [11]	-0.95 [11]	-0.94 [11]
Nigeria	-17.74*** [9]	-17.76*** [9]	-17.73*** [9]
Tunisia	-9.38*** [13]	-9.49*** [13]	-9.49*** [13]
Egypt	-3.86*** [5]	-3.91*** [5]	-3.90** [5]
Morocco	-4.61*** [12]	-4.54*** [12]	-4.55*** [12]
Panel B: Weekly series			
South Africa	-6.061*** [6]	-6.06*** [6]	-6.39*** [6]
Botswana	-2.58** [6]	-2.58** [6]	-2.56 [6]
Mauritius	-7.59*** [6]	-7.59*** [6]	-7.54*** [6]
Kenya	-4.81*** [6]	-4.81*** [6]	-4.82*** [6]
Nigeria	-6.71*** [5]	-6.71*** [5]	-6.50*** [5]
Tunisia	-3.66*** [6]	-3.66*** [6]	-3.65** [6]
Egypt	-6.07*** [8]	-6.07*** [8]	-6.18*** [8]

Notes: “***”, “**”, “*” denote the 1%, 5% and 10% critical levels. Critical values are derived from Kapetanois et al. (2003) as follows. For the raw series -2.82(1%), -2.22 (5%), -1.92(10%), for the de-meaned series -3.48(1%), -2.93(5%), -2.66(10%), for the de-trended series -3.93(1%), -3.40(5%), -3.13(10%). Optimal lags length as determined by the Schwarz criterion reported in [].

3.4 KSS test inclusive of FFF

Table 7 present the results of the KSS tests augmented with Fourier approximation for the raw data, the de-meaned data and the de-trended data, respectively. As before, Panel A in each of the Tables presented the empirical findings for the daily series whilst Panel B presents those for the weekly series. In beginning our discussions with the findings from Panel A, all series reject the unit root null hypothesis at significance levels of at least 5 percent, with the exception of the Kenyan series, in which the produced statistics of -0.85 (raw), -0.44 (de-meaned) and -0.48 (de-trended) exceed their 10 percent critical values. In turning to the findings reported in Panel B for the weekly series, we similarly find that all series reject the unit root null hypothesis at all levels of significance, with the sole exception of the de-trended Botswana series where the t-static of -2.97 is greater than the associated 10 percent critical value. We therefore summarize these findings as strong evidence against weak-form efficiency for all observed frontier markets with the exception of the Kenyan stock market which more-or-less displays weak-form efficiency.

Table 7: KSS test with FFF

	raw series		de-meaned series		de-trended series	
Panel A: Daily series	t-stat	k	t-stat	k	t-stat	k
South Africa	-2.94*** [16]	5	-3.10** [16]	5	-3.11 [16]	5
Botswana	-7.86*** [10]	5	-7.84 *** [10]	5	-7.84*** [10]	5
Mauritius	-26.40*** [10]	2	-26.53*** [10]	2	-26.63*** [10]	2
Kenya	-0.85 [22]	2	-0.44 [22]	2	-0.48 [22]	2
Nigeria	-17.07*** [13]	3	-17.07*** [13]	3	-16.93*** [13]	3
Tunisia	-9.38*** [13]	1	-9.49*** [13]	1	-9.46*** [13]	1
Egypt	-3.43*** [6]	1	-3.48*** [6]	1	-3.47** [6]	1
Morocco	-4.62*** [12]	1	-4.35*** [12]	1	-4.54*** [12]	1
Panel B: Weekly series						
South Africa	-6.06*** [6]	4	-6.38*** [6]	4	-6.39*** [6]	4
Botswana	-2.99*** [4]	5	-2.97*** [4]	5	-2.97 [4]	5
Mauritius	-7.60*** [6]	5	-15.92*** [6]	5	-7.55*** [6]	5
Kenya	-4.80*** [6]	4	-4.80*** [6]	4	-4.79*** [6]	4
Nigeria	-6.70*** [5]	5	-6.64*** [5]	5	-6.50*** [5]	5
Tunisia	-3.66*** [6]	5	-3.65*** [6]	5	-3.65** [6]	5
Egypt	-8.14*** [4]	1	-8.14*** [4]	1	-8.24*** [4]	1
Morocco	-9.09*** [5]	5	-9.02*** [5]	5	-9.02*** [5]	5

Notes: "***", "**", "*" denote the 1%, 5% and 10% critical levels. Critical values are derived from Kapetanois et al. (2003) as follows. For the raw series -2.82(1%), -2.22 (5%), -1.92(10%), for the de-meaned series -3.48(1%), -2.93(5%), -2.66(10%), for the de-trended series -3.93(1%), -3.40(5%), -3.13(10%). Optimal lags length as determined by the Schwarz criterion reported in [].

4 CONCLUSIONS

Concerned with whether African capital markets are efficient, in the weak-form sense, our study applied a nonlinear unit root test augmented with a FFF to 8 African frontier markets (South Africa, Botswana, Mauritius, Kenya, Nigeria, Tunisia, Egypt and Morocco) which collectively account for over 95 percent of total market activity in the content. To ensure robustness of our empirical analysis we employ two set of time series data, one daily and the other weekly which covers a period of 2003 to 2017, with the exception of the data for the Nairobi Stock Exchange in which the data only begins in 2006. Prior to our main empirical estimation we conduct conventional unit root testing procedures (i.e. ADF, PP and KPSS tests) on each of the series, of which the ADF and PP tests provide support against the weak-form EMH whilst the findings from the KPSS tests are inconclusive. In then applying the second-generation unit root tests of Elliot et al. (1996) and Ng-Perron (1995, 2001), we find that most series do not conform to the weak-form EMH with the sole exception of South Africa. However, in finally applying the more definitive KSS tests augmented with a FFF, we find that of all observed countries, it is the Kenyan series which provides the strongest evidence of weak-form EMH and to a lesser extent the South African and Botswana series. In light of the overriding the evidence against the weak-form market efficiency existing in African frontier markets, the results support the notion that market participants can use previous data as well as technical analysis to predict future stock returns. We therefore recommend that policymakers in these SSA countries should focus on developing their stock markets through automation of exchanges, demutualization, regional integration as well as the strengthening of regulatory frameworks.

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