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Equity Stock Markets in Africa: Empirical Evidence from the Random Walk Hypothesis

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Abstract

In this paper, weak-form market hypothesis is tested for some relevant African stock markets: Egypt, Kenya, Mauritius, Morocco, Nigeria, South Africa, Tunisia. Using daily and weekly data which span the period 2000 to 2012. We have used autocorrelation test, runs test, Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) uniroot test and parametric and nonparametric multiple variance tests. The empirical results show that African stock markets are not weak-form efficient using daily data; the South African one is characterized by a martingale difference sequence. We find that most of the stock tend to comply with weak-form efficiency when weekly data are used.

INTRODUCTION

The last decades have witnessed an increase in the amount of literature in the field of the Efficient Market Hypothesis (EMH) and Random Walk Hypothesis (RWH). The main motivation behind this branch of research is that the behavior of asset prices (returns) is the cornerstone in every financial application. The examination of market efficiency of financial asset is of interest for academicians, practitioners and regulators. While academicians seek to understand the behavior of asset returns over time, practitioners and investors are often interested in identifying market inefficiencies in asset returns; regulators in contrast are interested in improving the informational efficiencies of securities markets in which financial assets are traded. Knowledge of the behavior of the stock market, particularly in the efficiency and (or) randomness standpoint, is therefore of major concern to a large number of interested groups. According to Fama and French (1965) stock price movements are not to such a degree that one can predict them. Within the random walk hypothesis, prices adjust rapidly as new and consistent information become available. Today's price change results from today's news and it is independent of yesterday's old news. News is unpredictable and so are price changes. Many statistical tests were designed to test the RWH but the class based on variance ratio (VR) methodology, has known a great popularly in the recent years. Lo and Mackinlay (1988) pioneered this strand of literature proposing seminal work for testing Efficient Market and Random Walk. This type of statistic is based on the fact that aggregation of data sampled at different frequencies verifies the following properties under i.i.d (independently and identically distributed) hypothesis: the variance of the k period return should be k times the variance of one period return. If in one way or another it can be proved that the ratio is significantly different from one, the hypothesis of random walk in the stock price will be rejected. The globalization and the growth of financial markets spawned interest on the study of this issue, with many studies both on individual markets and regional markets. While the theory of efficient markets is well consolidated in developed markets (United States and Europe), we cannot say the same in the emerging markets; things are worse concerning African stock markets. The majority of studies relating to African stock markets have been focused on the Johannesburg Stock Exchange (JSE). Smith et *al*. (2002), Smith and Jefferis (2002) and Magnusson and Wydick (2002) among others. Appiah-Kusi and Menyah (2003) found the stock markets of Botswana, Ghana and Ivory Coast not weak-form efficient in the analyzed period. These results were stressed first in Magnusson and Widyck (2002) who found that the Botswana and Ghana markets do not comply with random walk hypothesis. In the same work, Appiah-Kusi and Menyah (2003) concluded that Egypt, Kenya, Mauritius, Morocco and Zimbabwe are weak-form efficient. The investigation of Kiweu (1991) and Dickinson and Muragu (1994) reached the same conclusion for Kenya over the period spanning from 1986 to 1996 and 1979 to 1988 respectively, while Chiwira (2001) found the Zimbabwe stock exchange to be weak-form efficient.

Smith et *al* (2002) concluded unlikely that there is no weak-form efficiency for the periods January 1990 to August 1998 for Morocco and Mauritius, and January 1993 to August 1998 for Egypt. Bundo (2000) concluded in the same manner for the stock Exchange for Mauritius (SEM) from the period 1992 to 1998. Asal (2000) found Egypt Stock Exchange to be weak-form inefficient for the period 1992 to 1996 although he found some evidence of moving towards efficiency in 1996. Smith (2008) in a recent work showed that Egypt, Nigeria, Tunisia and South Africa stock markets comply with the martingale difference hypothesis and concluded that the random walk hypothesis is out of reach for the 11 African stock markets examined using joint variance ratio test. Studies which have investigated the EMH and the RWH in the African market used either monthly or weekly data rather than daily data and the analyzed period was very short. The principal limiting factor as pointed out by Dickinson and Muragu (1994), has been the non-availability of computerized data bases. The other argument of using those very low frequency data is the problem of thin trading. Increasing the time intervals can be pursued to reduce the potential biases associated to thin trading by increasing the probability of having at least one trade in the interval, see Dickinson and Muragu (1994) for the topic. Nowadays, technological innovation and trade globalization have brought us into a new era of financial markets, therefore many well-known financial databases can provide daily and high-frequency data for almost all markets, including African stock markets.

The main contribution of this work is to enrich the existing literature of random walk and EMH theory in African markets using both daily and weekly data; perhaps of more importance, this study examines the crisis effect on the market efficiency. To our knowledge, this is the first contribution in this sense, even though, since the contribution of Lo and Mackinlay (1988), variance ratio tests have been common tools for testing market efficiency. Both parametric and nonparametric variance ratio tests are used to examine the aforementioned issues. We use a period of 12 years, the longest period ever used in African markets. We divide the sample in three periods January 2000 to October 2012, January 2000 to July 2007 (pre-crisis period) and August 2007 to October 2012 (crisis period) to highlight the crisis effects in our study. The remainder of the paper is divided as follow: a brief literature reviews is presented in Section 1. Section 2 discusses the various empirical methodologies used, while the description of the data employed is provided by Section 3. Section 4 analyzes empirical results. We end the paper by summarizing the relevant findings in Section 5.

I. LITERATURE REVIEW

The literature on random walk hypothesis in financial time series has been a subject of much attention in the empirical finance literature. If the time series of an asset price follows a random walk, then its return is non-predictable and investors are unable to make abnormal returns consistently over time. According to the efficient markets hypothesis, a market is efficient if stock prices reflect all currently available information such that future prices cannot be predicted on the basis of this information (Fama, 1965). The validity of random walk has strong implications for market efficiency, and so this issue is relevant for academicians, investors and regulatory authorities. Although there have been numerous empirical studies which test for random walk in stock prices, most of these studies are focused around major developed markets and emerging markets of Asia, Latin America, Eastern Europe, but very little is known about the behaviour of emerging markets in Africa as the weak-form hypothesis has received little attention from researchers. While the general conclusion of the existing studies supports the weak-form efficiency for developed markets, the research findings for emerging markets are mixed and mostly reject the weak-form efficiency in these markets.

Some notable studies of market efficiency include Smith et *al*. (2002), Magnusson and Wydick (2002), Jefferis and Smith (2005), Simons and Laryea (2005), Appiah-Kusi and Menyah (2003), Smith (2008) and Mollah and Vitali (2011) for African countries; Abraham et al. (2002) for Middle East countries; Huang (1995), Chang and Ting (2000), Ryoo and Smith (2002), Groenewold and Ariff (1998) for Asian countries; Lo and Mackinlay (1988), Kim et *al*. (1991) for Western countries; Worthington and Higgs (2004), Smith and Ryoo (2003) for European countries.

Smith et *al*. (2002) tested the i.i.d random walk hypothesis using joint variance ratio tests with weekly data on eight composite stock indices during the period from January 1990 to August 1998. They found that except for the South African stock market, none of the other stock markets examined (Botswana, Egypt, Kenya, Mauritius, Morocco, Nigeria, Zimbabwe) followed an i.i.d random walk. Jefferis and Smith (2005) used a GARCH approach with time-varying parameters to test the changing efficiency of seven stock markets in Africa with weekly data over the period from early 1990 to June 2001. They found that the Johannesburg stock market was weak-form efficient, and three stock markets became weak-form efficient towards the end of their study period, these were Egypt and Morocco from 1999 and Nigeria from early 2001. These contrast with Kenya and Zimbabwe stock markets which show no tendency towards weak-form efficiency and the Mauritius market which displays a slow tendency to eliminate inefficiency. Magnusson and Wydick (2002) use the partial autocorrelation test to examine the efficiency of eight largest African stock markets from 1989 to 1998 in comparison with nine Asian and Latin American markets. They find that six out of the eight examined African stock markets are weak-form efficient. In another multi-country analysis Appiah-Kusi and Menyah (2003) apply a GARCH-M model with weekly data of eleven African stock market indices. Their findings suggest that Egypt, Morocco, Kenya, Zimbabwe and Mauritius are weak-form efficient, whereas those of Ghana, Nigeria, Swaziland, Botswana, South Africa and the Ivory Coast are not efficient. In a recent work, Smith (2008) tested the hypothesis that a stock market price index follows a random walk for eleven African stock markets, Botswana, Côte d’Ivoire, Egypt, Ghana, Kenya, Mauritius, Morocco, Nigeria, South Africa, Tunisia and Zimbabwe using joint variance ratio tests with finite-sample critical values, over the period beginning January 2000 and ending September 2006. The i.i.d random walk hypothesis is rejected in all eleven markets. In four stock markets, Egypt, Nigeria, Tunisia and South Africa, weekly returns are a martingale difference sequence.

Abraham et al. (2002) studied Middle East markets, Saudi Arabia, Kuwait and Bahrain, using variance ratio and run tests. The initial results indicated a rejection to the random walk hypothesis in all three markets. However, after taking into consideration possible infrequent trading, they applied a correction to the index using Beveridge and Nelson’s (1981) decomposition index returns. As a results, they failed to reject the random walk hypothesis in Saudi Arabia and Bahrain stock markets, whereas it was rejected in the Kuwait stock market.

Worthington and Higgs (2004) perform an analysis of twenty European countries, from August 1995 to May 2003, using various methodologies such as serial correlation test, runs test, augmented Dickey Fuller test and a variance ratio test. They find that only five countries out of twenty follow the most binding criteria for a random walk, namely, Germany, Ireland, Portugal, Sweden and the United Kingdom, while France, Finland, the Netherlands, Norway and Spain meet only some of the requirements for a random walk. Smith and Ryoo (2003) perform an analysis of weekly data for five European indexes, covering the period from April 1991 to August 1998 using a variance ratio test. They reject the random walk hypothesis for Greece, Hungary, Poland and Portugal but not for Turkey.

Lo and Mackinlay (1988) studied Western markets. They apply multiple variance ratio to test the random walk in six equity markets using both monthly and daily data. The results provide no evidence of random walk in all six markets using monthly data. Working with daily data supports that the RWH for France, Germany, UK and Spain follow the random walk but not for Greece and Portugal.

Huang (1995) examined the stock prices of Korea and Hong Kong. They concluded that the stock prices of the two markets do not follow random walk. Ryoo and Smith (2002), however, concluded on the contrary that the Korean stock market is efficient. Chang and Ting (2000) found that the stock market of Taiwan is not efficient.

II. RESEARCH METHODOLOGY

Within the random walk hypothesis framework, Campbell et al (1997) define three subsequent sub-hypothesis with further stronger tests for random walk.

The process of random walk can be expressed in the following form:

$$P_t = c + P_{t-1} + \varepsilon_t,\ \ \varepsilon_t \sim IID(0, \sigma^2)$$

c is the expected price change (drift) and $\varepsilon_t \sim IID(0, \sigma^2)$ denotes that the increments ε_t are independently and identically distributed with mean 0 and variance σ^2

The most restrictive version known as Random Walk 1 (RW1) implies independent and identically distributed (IID) prices increments or successive one-period returns. As those authors recognized, this assumption is not reasonable for financial returns over a long term period and, hence, they relax this assumption and define the Random Walk 2 model (RW2). The RW2 implies independent but not identically distributed increments and it allows for unconditional heteroskedasticity in the successive price changes series. It is clear that RW2 encompasses RW1, the only difference being that the process RW2 allows for unconditional heteroscedasticity in increments. A least restrictive version of random walk can be obtained by replacing the independence assumption in process RW2 by the assumption that the increments are uncorrelated. This form of random walk is the weakest, it can be called Random Walk 3 or RW3. RW1 and RW2 are special cases of RW3. An interesting example of process RW3 is process for which $COV(\varepsilon_t, \varepsilon_{t-k}) = 0$ for all $k \neq 0$ but $COV(\ \varepsilon_t{}^2, \varepsilon_{t-k}{}^2) \neq 0$. This form of process allows for conditional heteroscedasticity (for example the models ARCH, GARCH).

Campbell et al. (1997) also illustrate the martingale model which implies that a security price change, conditional on the price history of that security, is expected to be equal to zero, namely the price at time t+1 is expected to equal the price at time t , so that the price is equally like to increase and to decrease. If the price index series is said to follow a martingale, then the return series is said to follow a Martingale Difference Sequence (MDS), while the martingale model does not require IID increments and allows for time varying volatility, the RW is highly restrictive in the sense that if an asset's price follows a martingale, the subsequent changes are unpredictable but the variance of price changes conditional on past variance is not, as in the random walk hypothesis, because time-varying conditional variance is not permitted. The martingale model is, therefore, a generalized version of the random walk model.

These considerations make that a number of complementary testing procedures for random walk or weak-form market efficiency will be examined. We start with the parametric serial correlation test of independence in the series. As a matter of choice, unit root test can be used to determine if the difference between series is stationary or the series exhibit non-stationary as assume in random walk hypothesis. Hence, the independence assumption of successive price changes, implied by the RWH, is investigated through autocorrelation analysis and runs test. Finally, both parametric and nonparametric multiple variance ratio procedures can focus attention on the uncorrelated residuals in the series, under assumptions of both homoskedastic and heteroskedastic random walks.

A. Serial independence tests

The spontaneous test of the random walk for an individual time series is checking for serial correlation. If the stock market index returns exhibit a random walk, the returns are uncorrelated at all leads and lags. We perform least square regressions of daily and weekly returns on lags one to seven of the return series. To test the joint hypothesis that all serial coefficients $\rho(t)$ are simultaneously equal to zero, we apply the Ljung-Box test, which fits the chi-square distribution, for small samples:

$$Q_{LB} = n(n+2)\sum_{t=1}^{m} \frac{\hat{\rho}^2}{n-t}$$

where $\hat{\rho}(t)$ is the serial correlation coefficient at lag t , with $0 \leq t \leq m$, Under the null hypothesis, Q_{LB} is asymptotically χ^2 distributed with t degrees of freedom. The null hypothesis is rejected if the computed value Q_{LB} is greater than the critical value of χ^2 with t d. f. at the specified significance level.

B. Runs test

To test for serial independence in the returns we also employ a runs test, which determines whether successive price changes are independent of each other, as should happen under the null hypothesis of a random walk. By observing the number of runs, that is, the successive price changes (or returns) with the same sign, in a sequence of successive price changes (or returns), we can test that null hypothesis. We consider two approaches: in the first, we define as a positive return (+) any return greater than zero, and a negative return (-) if it is below zero; in the second approach, we classify each return according to its position with respect to the mean return of the period under analysis. In this last approach, we have a positive (+) each time the return is above the mean return and a negative (-) if it is below the mean return. This second approach has the advantage of allowing for and correcting the effect of a possible time drift in the series of returns. Note that this is a non-parametric test, which does not require the returns to be normally distributed. The runs test is based on the assumption that if price changes (returns) are random, the actual number of runs (R) should be close to the expected number of runs μ_R.

Let n_+ and n_- be the number of positive returns (+) and negative returns (-) in a sample with n observations, where $n = n_+ + n_-$. For large sample sizes, the test statistic is approximately normally distributed

$$Z = \frac{R-\mu_R}{\sigma_R} \approx N(0.1)$$

where $\mu_R = \frac{2n_+n_-}{n}$ and $\sigma_R = \sqrt{\frac{2n_+n_-(2n_+n_- - n)}{n^2(n-1)}}$

C. Unit root tests

We used three different unit root tests to assess the null hypothesis of unit root. This means that the covariance of the innovation is equal to zero at all leads and lags and the covariance of their square is not constant, namely $COV(\varepsilon_t, \varepsilon_{t-k}) = 0$ for all $k \neq 0$ but $COV(\varepsilon_t, \varepsilon_{t-k}) \neq 0$

They are the augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test, and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test. We first apply the well-known ADF unit root test of the hypothesis of non stationarity which is in the form of the following regression

$$\Delta P_t = \alpha_0 + \alpha_1 t + \rho_0 P_{t-1} + \sum_{i=2}^{q} \rho_i \Delta P_{t-i} + \varepsilon_{it}$$

where P_t is the price at time *t*, and $\Delta P_t = P_t - P_{t-1}$, ρ_i are coefficients to be estimated, q is the number of lagged terms, *t* is the trend term, α_1 is the estimated coefficient for the trend, α_0 is the constant, and ε is white noise. The null hypothesis of a random walk is $H_0 : \rho_0 = 0$ and its alternative hypothesis is $H_1: \rho_0 \neq 0$. Failing to reject H_0 implies that we do not reject that the time series has the properties of a random walk. We use the critical values of MacKinnon (1994) in order to determine the significance of the t-statistic associated with ρ_0.

The PP test incorporates an alternative (nonparametric) for the null hypothesis of a unit root which accounts for the problem of auto-correlation in the residuals without adding lagged differences to the test regression, more precisely it allows for weak dependence and heterogeneity of the error term. For both ADF test and the PP test, the null hypothesis is the existence of a unit root whereas for the KPSS test it is the existence of no unit root in the time series.

D. Variance Ratio Tests

An important property of the random walk is explored by our final test, the variance ratio test. If P_t is a random walk, the ratio of the variance of the q^{th} difference scaled by q to the variance of the first difference tends to equal one, that is, the variance of the *q*-differences increases linearly in the observation interval,

$$VR(q) = \frac{\sigma^2(q)}{\sigma^2(1)}$$

where $\sigma^2(q)$ is 1/q the variance of the q-differences and $\sigma^2(1)$ is the variance of the first differences. Under the null hypothesis *VR(q)* must approach unity. The following formulas are taken from Lo and MacKinlay [1988], who propose this specification test, for a sample size of *nq*+1 observations $(P_0, P_1, \dots, P_{nq})$:

$$\sigma^2(q) = \frac{1}{m}\sum_{t=q}^{nq}(P_t - P_{t-q} - q\hat{\mu})^2$$

Where $m=q(nq-q+1)(1-\frac{q}{nq})$ and $\hat{\mu}$ is the sample mean of $(P_t - P_{t-1})$:

$\hat{\mu} = \frac{1}{nq}(P_{nq} - P_0)$ and $\sigma^2(q) = \frac{1}{nq-1}\sum_{t=1}^{nq}(P_t - P_{t-1} - \hat{\mu})^2$

Lo and MacKinlay (1988) generate the asymptotic distribution of the estimated variance ratios and propose two test statistics, Z(q) and Z*(q), under the null hypothesis of homoskedastic increments random walk and heteroskedastic increments random walk respectively. If the null hypothesis is true, the associated test statistic has an asymptotic standard normal distribution. Assuming homoskedastic increments, we have $Z(q) = \frac{VR(q)-1}{\emptyset_0(q)} \approx N(0,1)$

where $\emptyset_0 = [\frac{2(2q-1)(q-1)}{3q(nq)}]^{1/2}$.

Assuming heteroskedastic increments, the test statistic is $Z*(q) = \frac{VR(q)-1}{\emptyset_e(q)} \approx N(0,1)$

where $\emptyset_e = [4\sum_{t=1}^{q-1}(1-\frac{1}{q})\hat{\delta}_t]^{1/2}$ and $\hat{\delta} = \frac{\sum_{j=t+1}^{nq}(P_j - P_{j-1} - \hat{\mu})^2(P_{j-t} - P_{j-t-1} - \hat{\mu})^2}{[\sum_{j=1}^{nq}(P_j - P_{j-1} - \hat{\mu})^2]^2}$

which is robust under heteroskedasticity, hence can be used for the analysis of a longer time series. The procedure proposed by Lo and MacKinlay (1988) is devised to test individual variance ratio tests for a specific q-difference, but under the random walk hypothesis, we must have VR(q)=1 for all q.

E. Multiple Variance Ratio Test By Chow And Denning (1993)

Chow and Denning (1993) point out that failing to control the test size for variance ratio estimates results in large Type I errors. To control the test size and reduce the Type I errors, Chow and Denning (1993) extend Lo-MacKinlay's (1988) conventional variance ratio test methodology and form a simple multiple variance ratio test, which uses Lo-MacKinlay test statistics as the Studentized Maximum Modulus (SMM) statistics.

Consider a set of m variance ratio tests $\{M_r(q_i)|i = 1,2,\dots,m\}$ where $M_r(q) = VR(q) - 1$, associated with the set of aggregation intervals $\{q_i \backslash i = 1,2,\dots,m\}$. Under the random walk hypothesis, there are multiple sub-hypotheses:

$$H_{0i}: M_r(q_i) = 0 \text{ for } i = 1,2,\dots,m$$
$$H_{1i}: M_r(q_i) \neq 0 \text{ for } i = 1,2,\dots,m$$

The rejection of any or more H_{0i} rejects the random walk null hypothesis. In order to facilitate comparison of this study with previous research (Lo and MacKinlay, 1988 and Campbell et al. 1997) on other markets, the q is selected as 2, 4, 8, and 16. For a set of test statistics $\{Z(q_i) \backslash i = 1,2,\dots,m\}$ the random walk hypothesis is rejected if any one of the $\{VR(q_i)\}$ is significantly different from one, so only the maximum absolute value in the set of test statistics is considered. The Chow and Denning (1993) multiple variance ratio test is based on the result:

$$PR\{\max(|Z(q_1)|,\dots,|Z(q_m)|) \leq SMM(\alpha;m;T)\} \geq 1-\alpha$$

in which $SMM(\alpha;m;T)$ is the α point of the Studentized Maximum Modulus (SMM) distribution with parameters m and T (sample size) degrees of freedom. Asymptotically,

$$\lim_{T\to\infty} SMM(\alpha;m;T) = Z_{\frac{\alpha^*}{2}}$$

where $Z_{\frac{\alpha^*}{2}}$ is standard normal with $\alpha^* = 1-(1-\alpha)^{1/m}$. Chow and Denning (1993) control the size of the multiple variance ratio test by comparing the calculated values of the standardized test statistics, either Z(q) or Z*(q) with the SMM critical values. If the maximum absolute value of, say, Z(q) is greater than the critical value at a predetermined significance level then the random walk hypothesis is rejected.

F. Non-Parametric VR Tests Using Ranks And Signs By Wright (2000)

Suppose that P_t is a time series of asset returns with a sample size of T. $Y_t = P_t - P_{t-1}$. Let $r(Y_t)$ be the rank of Y_t among $Y_1, Y_2, \dots, Y_t$.

$$r_{1t} = \frac{\left(r(Y_t) - \frac{T+1}{2}\right)}{\sqrt{\frac{(T-1)(T+1)}{12}}}$$

$$r_{2t} = \Phi^{-1}\left(\frac{r(Y_t)}{T+1}\right)$$

where Φ is the standard normal cumulative distribution function (Φ^{-1} is the inverse of the standard normal cumulative distribution function).

$$R_1 = \left(\frac{\frac{1}{Tk}\sum_{t=k}^{T}(r_{1t} + r_{1t-1} + \cdots + r_{1t-k+1})^2}{\frac{1}{T}\sum_{t=1}^{T} r_{1t}^2} - 1\right) \times \left(\frac{2(2k-1)(k-1)}{3kT}\right)^{-1/2}$$

$$R_2 = \left(\frac{\frac{1}{Tk}\sum_{t=k}^{T}(r_{2t} + r_{2t-1} + \cdots + r_{2t-k+1})^2}{\frac{1}{T}\sum_{t=1}^{T} r_{2t}^2} - 1\right) \times \left(\frac{2(2k-1)(k-1)}{3kT}\right)^{-1/2}$$

Note that

$$\frac{1}{T}\sum_{t=1}^{T} r_{1t}^2 = 1$$

so that this term may be omitted from the definition of equation R_1, whereas

$$\frac{1}{T}\sum_{t=1}^{T} r_{1t}^2 \cong 1$$

For any series P_t , let $u(Y_t, q) = 1_{(Y_t > q)} - 0.5$. . So, $u(Y_t, 0)$ is $\frac{1}{2}$ if Y_t is positive and $-\frac{1}{2}$ otherwise. Let $s_t = 2u(Y_t, 0)$. Clearly, s_t is an independent and identically distributed (iid) series with mean 0 and variance 1. Each s_t is equal to 1 with probability $\frac{1}{2}$ and is equal to -1 otherwise. The sign-based variance ratio test statistic S_t is defined as

$$S_1 = \left(\frac{\frac{1}{Tk}\sum_{t=k}^{T}(s_t + s_{t-1} \dots + s_{t-k+1})^2}{\frac{1}{T}\sum_{t=1}^{T} s_t^2} - 1\right) \times \left(\frac{2(2k-1)(k-1)}{3kT}\right)^{-1/2}$$

Belaire-Franch and Contreras (2004) emphasize that it is possible to extend the idea of Chow and Denning (1993) to the tests proposed by Wright (2000). Thus, the joint tests of rank and sign is defined as follow:

$$JR_1 = \max_{1 \le i \le m} |R_1|$$

$$JR_2 = \max_{1 \le i \le m} |R_2|$$

$$JS_1 = \max_{1 \le i \le m} |S_1|$$

This test follows a Studentized Maximus Modulus (SMM) distribution, with m and T degrees of freedom.

III. DATA AND DESCRIPTIVE STATISTICS

We carry out the test of random walk and weak form market efficiency using market value-weighted time series of stock price index for seven major African stock markets: Egypt (EG), Kenya (KE), Mauritius (MU), Morocco (MA), Nigeria (NG), South Africa (ZA), and Tunisia (TU). The data analysed consist of both daily and weekly data observations which span the period beginning 03 January 2000 to 22 October 2012. All data are retrieved from the financial databases of the Bloomberg archive and expressed in domestic currency. The series include dissimilar sampling periods, given the varying availability of each market index, giving different lengths for daily observations although the weekly observations have all the same length. The end date for all series is 22 October 2012 with KE, MU and ZA starting on 03 January 2000, EG and MA on 04 January 2000, while NG and TU commencing on 05 January 2000. Bloomberg indices are a widely employed source for real-time financial literature on the basis of the degree of comparability and flexibility.

Following Borges, M.R. (2010), we apply the empirical tests to the whole twelve year period. We also split the whole period into two sub-periods, the pre-crisis period from January 2000 to July 2007 and the crisis period from August 2007 to October 2012. The separation of the time series into two sub-groups has the advantage of evidencing structural change and highlight the crisis effect of the analysed stock markets, therefore the markets may follow random walk in some periods while in others that hypothesis may be excluded. We are particularly interested in examining the last four years, from August 2007 to October 2012, because it has not been covered by previous studies and it is the period that financial market had been affected by global financial crisis. The weekly price series is constructed with the closing price on Wednesday, to minimize day-of-the-week effects. If the Wednesday observation is not available, due to market closing, we use the Tuesday observation, and if that is also not available, we use Thursday, and so on.

For both daily and weekly data, we computed the natural log of the relative price for the corresponding interval to produce a time series of continuously compounded returns, such that $r_t = \ln\left(\frac{p_t}{p_{t-1}}\right)$; where p_t and p_{t-1} represent the stock index prices at time t and $t-1$, respectively.

[INSERT TABLES 1, 1a AND 1b HERE]

The summary statistics of daily and weekly returns for the seven markets indices are presented in Table 1, 1a and 1b. Specifically, information on the mean return, median, standard deviation, maximum, minimum, skewness coefficient, kurtosis coefficient and the Jacque-Bera test are presented. Table 1 for daily result shows that the lowest mean returns are in Morocco (0.00015), and Kenya (0.00018) while the highest mean returns are for Nigeria (0.00054). The lowest minimum and highest maximum returns are in Nigeria: -0.1094 and 0,1176, respectively. The standard deviations of returns range from 0.0065 (Tunisia) to 0.0169 (Egypt). On the contrary, for weekly data, the lowest mean returns are in Mauritius (0.00203), and Egypt (0.00219) while the highest mean returns are for Tunisia (0.0208). All return series are significantly skewed, except those of Tunisia when considering daily data and Nigeria, South Africa and Tunisia for weekly data. The results for skewness and kurtosis imply that the distributional properties of all seven return series appear non-normal for daily and weekly data. All markets except Kenya and Nigeria for daily data and Kenya and Mauritius for weekly data are negatively skewed, indicating the greater probability of large decreases in returns than rises, while for Kenya, Mauritius and Nigeria, this means the greater likelihood of large increases in returns than falls. The kurtosis in all market returns is also large, indicating leptokurtic distributions. Finally, the calculated Jarque-Bera statistics and corresponding p-values in Table 1 are used to test the null hypothesis that the daily and weekly distributions of African market returns are normally distributed. All p-values are smaller than the 0.01 level of significance, suggesting that the null hypothesis can be rejected in all periods and for all types of data. None of these returns is then well approximated by the normal distribution.

In Table 1a and 1b, the summary statistics for daily and weekly market returns over the two sub-periods are presented. During the pre-crisis period, all returns are positive for all stock markets. On the contrary, during the crisis period, the mean return becomes negative for Egypt, Kenya, Morocco and Nigeria for daily data; the same results are obtained for weekly data. The crisis period is characterized by lower average market return and higher volatility except for Tunisia, for which the mean return has increased during the crisis period. Departure from normal distribution is more consolidated, however. The level of kurtosis is high in the whole sample, but with a tendency to decrease in the latter period. The Jarque-Bera statistic rejects the hypothesis of a normal distribution of daily and weekly returns in all countries and periods.

IV. EMPIRICAL RESULTS AND ANALYSIS

In this section, we present the empirical results of the tests presented above and analysed in terms of theoretical and critical framework. A brief summary of the results is included in order to have a comprehensive overview of our results.

Serial correlation

The results for the test on serial correlation and Ljung Box Q-statistics are presented in Tables 2 and 3 for daily and weekly returns.

[INSERT TABLE 2 HERE]

From results of Table 2, we can see that all stock markets exhibit strong positive autocorrelation. The positive serial correlation coefficients are indicative of return persistence (or predictability), with persistence being higher in Nigeria (0.1480) and Kenya (0.1430) and lower in Mauritius (0.001) and South Africa (0.05). It is worth noting that the positive sign of the autocorrelation coefficients indicates that consecutive daily returns tend to have the same sign, so that positive (negative) return in the current day tends to be followed by an increase (decrease) of return in the next few days. The first order autocorrelations range from 0.266 for Kenya to 0.001 for Mauritius. To emphasize our results, we extend the investigation to more than one lag and consider k=30 (see Dickinson and Muruga 1994). The regressions strongly prove that the daily return of day t is correlated with the return of day t-1. All Ljung Box Q-statistic at lag k=30 are higher than the critical value at both 5% and 1% significance levels. This indicates that the null hypothesis of no autocorrelation is rejected for all indices. The significant non zero autocorrelation along with the significant Ljung Box Q-statistic suggest rejection of the third hypothesis of random walk, viz. of the RW3.

[INSERT TABLES 3 HERE]

Results from the auto-correlation test on weekly returns over the whole sample period are reported in Table 3.

The evidence of positive serial correlation at lag 1 of weekly returns is present for all countries except South Africa, as most lag coefficients are not significantly different from zero. The Ljung Box Q-statistics reject the null hypothesis of all coefficients being jointly equal to zero up to lag 30 for all indices, except for Nigeria and Tunisia.

Auto-correlation of the daily and weekly changes in the seven stock indices is also tested for the two sub-periods. Results are available upon request. During the pre-crisis period, results of the Ljung Box Q-statistics indicate that Nigeria, South Africa and Tunisia are not statistically different from zero. Therefore, time series for these countries are consistent with the random walk theory. Regarding the Crisis period, the same conclusion is found for Egypt, Kenya, Morocco, Nigeria and Tunisia. Considering weekly returns, the time series of Nigeria, South Africa and Tunisia are consistent with the random walk during the first sub-period; the same conclusion is found for Egypt, Kenya, Morocco, Nigeria and Tunisia during the second sub-period. However, since the autocorrelation test relies on the assumption of normally distributed returns, these results must be interpreted with caution.

Unit Root tests

A unit root test tests time series for stationarity and finds out whether a time series is non-stationary. The most common tests are the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test. The null hypothesis is that the series have a unit root (the index series is non-stationary), while the latter tests if it represents a stationary process (no unit root). Another way to deal with stochastic trends (unit root) is by taking the first difference of the variable. If the series is non-stationary and the first difference of the series is stationary, the series contains a unit root or follows the random walk.

[INSERT TABLES 4 AND 5 HERE]

As can been seen from table 4 and 5, at level (log-price) the results of the ADF test and PP test of null hypothesis are true for any type of returns (daily and weekly) and for any stock markets under investigation but at the first difference, the null hypothesis of unit root is strongly rejected as the t-statistic value of the ADF and PP are greater than their critical values both at 5% and 1% level of significance which means that all index series become stationary. So it can be said that all indices contain a unit root, that is, non-stationary in their level forms, but stationary in their first differenced forms.

[INSERT TABLES 4a, 4b, 5a and 5b HERE]

When considering the two sub-periods as they appear from tables 4a, 4b, 5a and 5b, the ADF and PP t-statistics do not reject the null hypothesis of unit root for any type of returns (daily and weekly) and any stock markets under investigation in the level form. But inversely, for the first differences of all indices and for both test statistics, the null hypothesis of a unit root is strongly rejected.

[INSERT TABLES 6, 6a and 6b HERE]

Concerning the KPSS test, the results reported in table 6, 6a and 6b are consistent with those of the competing test. When analysing the full sample and the two sub-periods, we notice that the LM statistics are significant both at the 5% and 1% confidence level, thus rejecting the null hypothesis of stationarity for all indices at levels, meaning that all price index series are nonstationary. Different results are obtained for the first-difference of the price index series for South Africa, the first-differenced series are proved to be stationary; for Morocco, the null hypothesis of trend-stationarity is strongly rejected even though stationarity is accepted when the trend is removed. The stationarity when the trend is removed from the equation is also accepted for the remaining African stock markets with milder rejection. Nigeria stock market proves to be trend-stationary: actually, the hypothesis of stationarity is rejected when the trend is removed from the regression. Except for the Nigeria market, the RWH necessary condition of unit root seems to hold for all price indices. Furthermore, the first-differenced series are shown to be stationary for all indices during the pre-crisis period, except for indices from Morocco, Mauritius and index from Tunisia which proves to be stationary when trend are removed in its first-

differenced form. During the crisis period, the null hypothesis of stationarity is accepted for the first-difference of all index price series. Results computed for weekly data are in line with our findings; in addition, the statistic tests for first-difference during the crisis period fall in the critical value band, this prerequisite condition is consolidated further when the variance ratio test is computed.
Based on unit root tests, it may be concluded that all indices under investigation show signs of random walk.

Runs Test

We show the empirical results from the run test over the entire period in the Tables 7, 7a and 7b.

[INSERT TABLES 7, 7a, 7b HERE]

It is important to stress that these results are back out from nonparametric test since it does not assume any form for the returns. The tables display the number of observations, the mean return, the number of actual and expected runs as well as the Z-statistic. We notice that the number of runs is always less than the expected number of runs, for daily and weekly data, and for all periods. This was stressed earlier by several international studies (Borges 2011, Worthington and Higgs 2004, Abraham et al. 2002). This produces a negative value for the Z-statistic. The negative value indicates the presence of positive serial autocorrelation between returns, by far, as shown by the results from auto-correlation test, the first-order autocorrelations are positive and significantly different from zero for the whole sample period, in most cases for the pre-crisis and crisis period as far as daily data are concerned. The null hypothesis of the return series satisfying a random walk is rejected at 1% level for all indices except for ZA where rejection occurred at 5%, in the full sample using daily data. The results are in line with those found in the first sub-period. In the second sub-period, the Z-statistic for South Africa stock exchange shows that the null hypothesis of random walk cannot be rejected neither at 1% or 5% level of significance. The number of runs is not statistically different from the expected number of runs, which is consistent with a random walk hypothesis. When analysing weekly data the same behaviour is remarked for the all sample except for ZA. In the first sub-period, the hypothesis of randomness fails to be rejected for EG, NG and ZA. During the turbulence period, at 1% significance level, the Z-statistic is not significant only for

MU whereas it is significant both at 1% and 5 % for MA, ZA and TU. By and large, the significant Z-statistics of KE and MU using both daily and weekly data, indicates some dependence in their returns series which jeopardizes market efficiency . The low number of runs in the weekly returns also rejects the random walk hypothesis for KE, MU, TU. But the latter is accepted only during the crisis period.

Parametric variance ratio test

Tables 8, 8a and 8b present the result of variance ratio test for the seven stock markets analyzed. Following some preceding studies, we choose q=2,4,8,16 as in Ayadi and Pyun (1994).

[INSERT TABLES 8, 8a, 8b HERE]

In the first step we test the random walk hypothesis for daily data in the full sample which spans from January 2000 through October 2012. We expect to have the ratio of (1/q) times the variance of the q-differences over the variance of the first-differences being equal to unity. For each interval in the table we can read VR(q), and the test statistics for the null hypotheses of homoskedastic, Z(q) and heteroskedastic, Z*(q) increments random walk. Under the multiple variance ratio procedure, only the maximum absolute values of the test statistics are examined: this is marked with brackets in the tables. The maximum absolute value of the test statistic that exceeds the critical value thereby indicates whether the null hypothesis of a random walk is rejected. If we consider the result of Egypt, the Z statistic associated with the maximum absolute value is higher than the critical values for daily equity returns under homoskedasticity assumption, the variance ratios VR(q) are statistically different from 1. Therefore, the results under homoskedasticity suggest that the behaviour of Egypt stock market cannot be described as meeting the random walk theory. The rejection of random walk from Z(q) under homoskedasticity could be due to the presence of heteroskedasticity and/or serial correlation. Consistent heteroskedasticity variance-ratio test Z*(q) is calculated to examine the problem. The result for the maximum absolute value is superior to the 1% and 5% level of significance viz. 2.49 and 3.02. The heteroskedastic random walk hypothesis is thus rejected because of autocorrelation in the daily increments of returns on Egyptian equity. We may conclude without ambiguity that Egypt stock market is weak-form inefficient; these same results are found for Kenya, Morocco, Nigeria and Tunisia. In addition, Lo and MacKinlay (1988) show that for q=2, estimates of the variance ratio minus one and the first-order autocorrelation coefficient estimator of daily price changes are asymptotically equal. For instance, considering the Egyptian stock market, the variance ratio at q=2 minus one is roughly equal to the serial coefficient at lag 1 in Table 2, implying that 18% of tomorrow's return can be predicted by today's return. Further, where VR(2) <1 as in ZA a mean reverting process is indicated, whereas when VR(2) >1 as in the remaining countries, persistence is suggested. This indicates that there is positive autocorrelation (or persistence) in Egypt equity returns over the long horizon. When analysing the South Africa market, at none of the sampling intervals the test statistics for the null hypotheses of homoskedastic, Z(q) and heteroskedastic, Z*(q) random walks are greater than the critical values of 2.49 and 3.02. This suggests that the South Africa equity market is weak form efficient. More readily, in the case of Mauritius the null hypothesis of a homoskedastic random walk is rejected [max abs(Z(q))=4.456], but the null hypothesis of heteroskedastic random walk is not [max abs(Z*(q))=1.036]. Therefore, the Mauritius stock market follows martingale difference sequence (MDS). This indicates that rejection of the null hypothesis of a homoskedastic random walk could be the result, at least in part, of heteroskedasticity in the returns, and cannot be assigned exclusively to the autocorrelation in returns. To test the consistency of the results presented in Table 8, we splitted the sample period into two subperiods and performed the variance ratio test for each sub-sample. The first sub-period is from January 2000 through July 2007 whereas the second period runs from August 2007 through October 2012. The results are presented in tables 8a and 8b. Under the homoskedastic assumption, the random walk hypothesis is rejected for both periods except for ZA. One interesting thing about the first sub-period is that all variance ratios are less than one for Mauritius equity market unlike in the second period when they are all greater than unity. In general, variance ratios are greater than one irrespectively from the sub-period under consideration for all stock markets. Apart from this observation the results of the first sub-period are consistent with those in the full sample. In the last sub-period, although the ZA stock market is still weak form efficient, the remaining stock markets do not satisfy either the random walk or the martingale difference sequence. In fact, we evidence high autocorrelation for all market indexes: this suggests than during the turbulence period the African stock markets became highly predictable.

In order to deal with the possible serial problem in daily data, the variance ratio was computed using weekly data for the whole sample and the different sub-periods.

Results are displayed in the same tables with the daily results in order to be able to make an immediate comparison between the VR tests on observations with different frequencies. Unlike daily data, the variance ratios are in general not statistically different from unity at the conventional 1% and 5% levels for weekly data. When analysing the full sample, both Egypt and Nigeria stock markets are definitely weak form inefficient, while Kenya, Mauritius, and Tunisia comply with MDS hypothesis. Morocco and South Africa are weak form efficient. In the second sub-period, Kenya and Tunisia lost their efficiency and became inefficient while the other stock markets are shown to remain efficient. Finally in the last sub-period, apart from Mauritius, the remaining stock markets are weak form efficient, and the Egypt stock market satisfies only the MDS.

These results contrast with the findings inherent to daily data, using very low frequency data some observations are neglected and this can convey distortions in empirical results. Additionally, daily data reflect more precisely the true behaviour of actual data with respect to the weekly counterpart.

Nonparametric variance ratio test

In order to shed some light on the ambiguity inherent in the results of the Lo and MacKinlay (1988) variance-ratios test regarding the daily stock markets returns behaviour in particular, we applied Wright's (2000) version based on ranks and signs to further examine the RW and the MDS hypothesis. Tables 9, 9a and 9b present the results of Wright's test for the entire sample. R1 and R2 report results of the rank based test whereas S1 presents the results of the sign based alternative.

[INSERT TABLES 9, 9a, 9b HERE]

The R1 and R2 test statistics reject the RW for the all stock markets analysed except for the ZA which evidences mixed results. The magnitude of rejections appears to be comparatively stronger than those of the Lo and MacKinlay (1988) test at any value of q for the whole financial price series investigated. When regarding S1 consistent statistics test, the MDS hypothesis is excluded for the full sample for all reasonable significance levels. Furthermore, the power of a test statistic of both ranks and signs increases with the lag, evidence which is also in line with that of Wright (2000). In addition, almost all rejections are in the upper tail of the null distribution, indicating that the resulting variance ratios are statistically greater than one at all lags for all the analysed series. The critical values for the Wright test are displayed in Table 10, they differ by the sample size n and have been generated through simulation; for this study we have used 1000 replications. Overall, the magnitude of rejections by the sign based test seems weaker than the rank based alternative, which is in line with the evidence of Wright (2000). To ascertain the impact of crisis over the period of examination, the test statistics are computed for two sub-samples as in the Lo and MacKinlay viz. from January 2000 to July 2007 and from August 2007 to October 2012. Tables 9a and 9b present the sub-sample results of Wright (2000). The evidence from rank and sign shows that the conclusions based on the full sample are not statistically significantly different from those of the first sub-sample periods for every stock markets under consideration. None of the analysed stock markets comply with RW and MDS hypothesis since their JR1, JR2, JS1 are greater than the critical values. Turning to the last sub-period, the results are very tricky as we find out that, during turbulence, all African stock markets were inefficient except ZA since for any lag of q, both by the ranks and signs based test statistics, neither the RW nor the MDS cannot be rejected at any reasonable significance level.

Examining now the results of weekly returns for the Egypt stock market in the entire sample, at the conventional 0.01 and 0.05 significance levels, the random walk and martingale hypothesis are rejected by both joint rank-based tests because $JR_1 = 3.275 > 2.826(2.284)$, $JR_2 = 3.394 > 2.876(2.268)$ JS_1 =3.674>2.916(2.244). Similar results are obtained for weekly returns in Kenya, Mauritius, Nigeria and Tunisia. Morocco stock market satisfies only the *JR2* hypothesis of joint test, thus this rejection could be the result of various dependence of higher degree of the moments or autocorrelation in weekly returns. The results for South Africa are different. The ZA does follow an i.i.d random walk and martingale at 1% critical value but fails in doing so at 5%. For the first sub-period, only EG and ZA are RDW and MDS, while NG, MA and TU present mixed results. However, MO, KE, MU, are definitely inefficient stock markets. During the last period, the RDW is unambiguously rejected for Kenya and Mauritius. It is nevertheless evident that over time, some of the inefficiencies seem to have disappeared gradually. Using the statistic *JS1*, the MDS hypothesis similarly cannot be excluded at any reasonable significance level for Kenya, Nigeria and Morocco. Although Egypt and South Africa stock markets remain efficient, some tendency of efficiency is noticeable in Morocco, Nigeria and Tunisia.

V. CONCLUDING REMARKS

In this work, the re-examination of random walk and weak form efficiency of some relevant African stock markets has been undertaken using both daily and weekly data. The parametric serial correlation coefficient and the nonparametric runs test are used to test for serial correlation; Augmented Dickey-Fuller, Phillips-Perron and Kwiatkowski, Phillips, Schmidt and Shin unit root tests are used to test for non-stationarity as a necessary condition for a random walk; and both parametric and non-parametric multiple variance test statistics are used to test for random walk under the varying distributional assumptions of homoskedasticity and heteroskedasticity. Empirical robust non-parametric variance-ratios test suggested by Wright (2000) in addition to the Lo and MacKinlay (1988) parametric alternative is applied to re-investigate if the major African stock returns follow random walk (RW) or martingale difference sequence (MDS). Empirical results found that computed returns are characterized by non-normalities in the market's returns series. On average, returns are found to be characterised by large standard deviations, excess kurtosis, and are either extremely skewed to the right or left, justifying the use of robust methodology. The results for the tests of serial correlation are in broad agreement and conclusively reject the presence of random walks in daily returns for all markets except South Africa. The unit root tests fail to reject the RWH, indeed the unit root tests carried on in this study accept RWH for all African stock market indices examined. However, this is a necessary but not sufficient condition for a random walk. The lack of power of the test urge to use the more sophisticated metrics for testing the RWH. Lo and MacKinlay (1988) variance-ratios test are generally ambiguous. While it provides conclusive evidence that the all African stock markets except South Africa and Mauritius return series violates both the RW and the MDS hypotheses over the full sample period as well as sub-sample periods when daily data are used, results regarding weekly data are rather mixed. By contrast, the results of Wright's (2000) test are conclusive. Both the ranks and signs based test statistics consistently reject the RW and the MDS hypotheses for daily data over the full sample and the first sub-sample periods for the return series of the African stock markets analysed, at the 1% and 5% significance level. However, the RW and the MDS hypotheses cannot be rejected for ZA during the period of turbulence. When weekly data are used, the results are in line with those of full sample, tendency to efficiency is noticed in the last sub-period, showing that the crisis has little effect in the African markets. The rejection of the weak form efficiency is not only consistent with previous evidence, but also theoretically not surprising. The size of the some African stock market as Kenya is comparatively small, and dominated by small capitalization stocks. Associated high average transaction costs, for instance, result in limited market activity and liquidity. Nevertheless, these are only persuasive rather than empirical arguments. It is admitted that evidence from elsewhere (e.g., Appiah-Kusi and Menyah, 2003), has demonstrated, for example, that size alone is neither necessary nor sufficient for a market to be weak form efficient.

Since African stock markets are on ongoing improvement, the analysis of market efficiency should be examined in the next coming years, because where the random walk hypothesis is actually rejected, those markets evidence tendency to efficiency as they could become more liquid and more institutionally sophisticated. To gain more insight, a study focused on the individual prices may shed a light on the size and liquidity: the reason being that, for individual stock markets, the liquidity, breadth, depth, transactional and informational efficiency are known. It is therefore possible to address the question of large capitalization and random walk.

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Table 1: Summary Statistics for the whole period using daily and weekly data (January 2000-October 2012)

	Daily								Weakly							
Market	N	Mean	Min	Max	St.Dev	Skewness	Kurtosis	J-B	N	Mean	Min	Max	St.Dev	Skewnes	Kurtosis	J-B
Egypt	3043	0.00047	-0.064	0.0786	0.0169	-0.6199*	9.685	58583	668	0.00219	-0.1899	0.1135	0.0409	-0.6358*	5.17	176
						-13.961	*75.280*							*-6.704*	*11.440*	
Kenya	2998	0.00018	-0.05	0.0196	0.0098	0.5636*	26.19	69607	668	0.0083	-1.3740	0.2588	0.0295	1.3073*	15.09	2453
						12.801	*527.220*							*13.783*	*63.740*	
Mauritius	3165	0.00043	-0.02	0.0282	0.009	-0.4583*	172.2	69607	668	0.00203	-1.6800	0.1968	0.0217	0.6194*	18.68	9750
						-10.525	*1942.810*							*6.531*	*98.520*	
Morocco	3063	0.00015	-0.032	0.0479	0.0086	-0.1131*	8.91	44650	668	0.0066	-1.3450	0.0767	0.0216	-0.3348*	7.11	482
						-2.597	*67.870*							*-3.53*	*21.670*	
Nigeria	3017	0.00054	-0,1094	0,1176	0,0113	0.1166*	18.134	28789	668	0.00246	-0.1411	0.1517	0.0324	-0.1151	6.52	346
						2.615	*169.650*							*-1.214*	*18.560*	
South Africa	3201	0.00046	-0.08	0.0589	0.0131	-0.1705*	6.32	14843	668	0.00226	-1.0750	0.1375	0.0286	-0.1461	4.51	66
						-3.939	*38.330*							*-1.54*	*7.960*	
Tunisia	2896	0.00047	-0.049	0.0591	0.0065	-0.0628	16.95	23458	668	0.0208	-0.0958	0.0867	0.015	-0.1297	9.61	1215
						-1.379	*153.160*							*-1.367*	*34.840*	

The critical values for the test statistics in italic for skewness and kurtosis at 5% level is ±1.96. The critical value for the Jacque-Bera test is 5.99. * indicates significance *at 5% level for skewness. Both the test statisitic for kurtosis and the Jarque-Bera test are siginficant at 5% for all series and hence they are not marked.*

Table 1a: Summary Statistics for the pre-crisis period using daily and weekly data (January 2000-July2007)

	Daily								Weakly							
Market	N	Mean	Min	Max	St.Dev	Skewness	Kurtosis	J-B	N	Mean	Min	Max	St.Dev	Skewnes	Kurtosis	J-B
Egypt	1793	0.00093	-0.072	0.1192	0.0161	0.0993	6.31	817	395	0.00432	-0.1456	0.1134	0.0389	-0.2092	3.87	15
						1.7173	*28.530*							*-1.697*	*3.520*	
Kenya	1796	0.00047	-0.103	0.1214	0.0091	0.6019*	32.53	65352	395	0.00208	-0.0859	0.1614	0.0259	1.1778*	9.83	859
						10.415	*255.430*							*9.556*	*27.710*	
Mauritius	1830	0.00067	-0.208	0.1968	0.0087	-1.0514*	316.57	749766	395	0.00308	-0.168	0.1968	0.00195	1.2549*	42.18	25363
						-18.362	*2738.120*							*10.182*	*158.930*	
Morocco	1775	0.0004	-0.055	0.0564	0.0087	-0.0087	9.23	2875	395	0.00174	-0.1037	0.0767	0.0223	-0.0306	5.83	132
						-0.149	*53.620*							*-0.248*	*11.490*	
Nigeria	1737	0.00133	-0.109	0.1106	0.0101	-0.0214	20.61	22448	395	0.00577	-0.1057	0.1289	0.0287	0.2917*	6.40581	197
						-0.364	*149.830*							*2.366*	*13.820*	
South Africa	1894	0.00065	-0.08	0.0589	0.0117	-0.2821*	6.21	836	395	0.00319	-0.103	0.0976	0.0268	-0.3323*	4.19	31
						-5.012	*28.480*							*-2.695*	*4.840*	
Tunisia	1604	0.00044	-0.049	0.0591	0.0058	0.5817*	20.91	21539	395	0.00179	-0.0493	0.0544	0.0132	0.4133*	4.95	74
						9.511	*146.450*							*3.354*	*7.920*	

The critical values for the test statistics in italic for skewness and kurtosis at 5% level is ±1.96. The critical value for the Jacque-Bera test is 5.99. * indicates significance *at 5% level for skewness. Both the test statisitic for kurtosis and the Jarque-Bera test are siginficant at 5% for all series and hence they are not marked.*

Table 1b: Summary Statistics for the crisis period using daily and weakly data (August 2007-October 2012)

	Daily								Weakly							
Market	N	Mean	Min	Max	St.Dev	Skewness	Kurtosis	J-B	N	Mean	Min	Max	St.Dev	Skewnes	Kurtosis	J-B
Egypt	1250	-0.00018	-0.172	0.0647	0.0179	-1.3585*	15.54	8576	273	-0.00076	-0.1899	0.1072	0.0435	-1.0517*	3.07	158
						-19.608	*90.510*							*-7.094*	*10.36*	
Kenya	1302	-0.00021	-0.101	0.1037	0.0107	0.5523*	23.57	23016	273	-0.00104	-0.1375	0.2588	0.0341	1.4118*	13.34	2114
						8.136	*151.490*							*9.523*	*44.98*	
Mauritius	1335	0.0001	-0.022	0.0801	0.0093	0.2299*	19.98	16042	273	0.00049	-0.0943	0.1329	0.0247	0.2161	5.26	317
						3.429	*126.610*							*1.458*	*17.74*	
Morocco	1288	-0.00019	-0.046	0.0481	0.0085	-0.2705*	11.41	3809	273	-0.00101	-0.1345	0.052	0.0207	-0.9252*	6.37	501
						-3.963	*61.590*							*-6.241*	*21.5*	
Nigeria	1280	-0.00053	-0.095	0.1176	0.0126	0.3042*	18.87	13458	273	-0.00251	-0.1411	0.1517	0.0367	-0.2406	2.99	105
						4.444	*115.930*							*-1.623*	*10.1*	
South Africa	1308	0.00022	-0.076	0.0683	0.0148	-0.0647	8.875	1882	273	0.00108	-0.1075	0.1375	0.0309	0.0585	1.69	32
						-0.956	*43.370*							*0.395*	*5.7*	
Tunisia	1292	0.00051	-0.05	0.041	0.0068	-0.5661*	16.69	10160	273	0.00245	-0.0958	0.0867	0.0174	-0.4912*	7.89	720
						-8.308	*100.450*							*-3.313*	*26.62*	

The critical values for the test statistics in italic for skewness and kurtosis at 5% level is ±1.96. The critical value for the Jacque-Bera test is 5.99. * indicates significance *at 5% level for skewness. Both the test statisitic for kurtosis and the Jarque-Bera test are siginficant at 5% for all series and hence they are not marked.*

Table 2: Results of the auto-correlation test for the whole period using daily data (2000-2012)

	Egypt	Kenya	Mauritus	Morocco	Nigeria	South Africa	Tunisia
No	3043	2998	3165	3063	3017	3201	2896
1	0.180*	0.266*	0.001	0.252*	0.348*	0.050*	0.221*
2	0.027	0.209*	0.038*	0.039*	0.174*	0.000	0.064*
3	0.030	0.103*	0.001	-0.004	0.020	-0.061*	0.000
4	0.030	0.017	0.056*	0.000	-0.005	-0.026	0.010
5	0.004	0.012	0.015	-0.005	-0.040*	-0.041*	0.005
6	-0.019	-0.028	0.003	-0.022	-0.043*	-0.022	-0.003
7	-0.026	-0.009	0.072*	0.020	0.005	0.024	-0.035
8	0.005	0.006	0.060*	0.012	0.039*	0.007	0.022
9	-0.009	0.031	-0.021	-0.013	0.033	0.002	-0.001
10	0.048*	0.016	0.007	-0.007	0.043*	-0.007	0.030
11	0.051*	0.013	0.009	0.033	0.043*	-0.040*	0.056*
12	0.031	0.020	0.028	0.014	0.045*	-0.004	0.031
13	0.030	0.038*	0.001	0.005	0.032	0.026	0.021
14	-0.026	0.029	0.013	0.034	0.016	0.018	0.041*
15	-0.016	0.030	0.012	0.001	0.001	0.027	0.011
16	0.014	0.032	0.019	-0.003	0.010	0.007	0.020
17	0.039*	0.002	-0.021	0.001	0.031	-0.031	0.025
18	-0.015	0.001	-0.003	0.035	-0.006	-0.026	0.020
19	0.016	-0.050*	0.045*	-0.025	0.014	-0.023	-0.001
20	0.010	-0.030	0.006	-0.015	0.011	0.025	0.014
21	0.010	-0.025	-0.005	-0.024	0.040*	-0.006	-0.005
22	0.010	-0.011	-0.007	-0.013	0.031	0.010	-0.005
23	0.007	0.000	0.018	-0.003	0.028	-0.027	-0.012
24	0.009	-0.006	0.024	0.017	0.027	-0.017	-0.005
25	0.008	0.020	0.002	0.025	0.040*	0.020	0.015
26	0.017	0.022	0.024	0.015	0.045*	0.044*	0.030
27	0.005	0.053*	0.016	-0.012	0.056*	0.012	-0.012
28	-0.004	0.061*	0.030	0.002	0.060*	0.008	0.008
29	0.022	0.054*	0.049*	0.005	0.022	0.005	0.022
30	0.032	0.058*	0.048*	-0.000	-0.030	-0.016	-0.002
LB Q-stat K=30	148.48‡	471.03‡	83.73‡	224.82‡	551.72‡	66.17‡	192.18‡

The confidence intervals at 5% level for the autocorrelation coefficients are: ±0.035 for n=3201, 3165, 3063 and ±0.036 for n=3043, 3017, 2998 and 2896. * indicates significance at 5% level. The Critical values for the Ljung-Box Q-statistic at lag k=30 are 43.77 and 50.89 at 5% and 1%, respectively. ‡ indicates rejection at 1% ; ‡‡ indicates rejection at 5% but acceptance at 1% level.

Table 3: Results of the auto-correlation test for the whole period using weekly data (2000-2012)

	Egypt	Kenya	Mauritus	Morocco	Nigeria	South Africa	Tunisia
No	668	668	668	668	668	668	668
1	0.094*	0.037	0.068	0.041	0.003	-0.101*	0.097*
2	0.023	0.037	0.106*	0.064	0.123*	-0.024	0.078*
3	0.077*	0.078*	0.005	0.007	0.024	0.069	0.024
4	0.015	-0.047	-0.027	-0.017	0.078*	-0.078*	0.041
5	0.044	-0.005	0.012	0.043	0.046	0.057	0.074
6	-0.034	0.157*	0.139*	-0.018	0.040	0.054	0.043
7	0.045	0.008	0.039	-0.005	0.032	-0.099*	0.006
8	0.106*	0.019	0.015	0.010	0.052	0.098*	-0.016
9	0.083*	0.055	0.034	-0.000	0.050	0.032	-0.004
10	0.029	-0.041	0.004	0.111*	-0.003	-0.059	-0.012
11	-0.072	0.032	0.076*	0.003	0.061	0.046	0.035
12	0.070	0.084*	0.179*	0.015	0.000	-0.083*	0.083*
13	0.080*	0.021	0.043	0.017	0.046	0.029	0.028
14	0.061	0.033	0.014	0.062	-0.009	0.088*	0.033
15	0.047	0.044	0.015	-0.007	0.015	0.000	0.049
16	0.089*	0.091*	0.083*	-0.034	0.043	-0.058	0.054
17	0.027	-0.030	0.059	0.050	0.022	0.075	0.026
18	0.016	0.059	0.029	0.018	-0.027	-0.043	-0.033
19	0.004	0.027	-0.028	0.005	0.031	-0.047	0.015
20	0.017	0.025	0.022	0.051	-0.005	0.073	0.044
21	0.019	0.058	0.017	0.019	-0.005	-0.040	0.019
22	0.046	0.025	-0.069	-0.019	0.090*	0.020	0.016
23	0.027	-0.043	0.063	0.012	0.033	-0.003	0.010
24	-0.020	0.020	0.006	-0.006	0.014	-0.037	-0.068
25	-0.011	0.057	0.008	0.129*	0.030	0.059	-0.049
26	0.055	0.001	-0.060	0.021	0.047	-0.015	-0.053
27	-0.017	0.048	-0.008	0.062	-0.021	-0.050	-0.006
28	0.024	0.024	0.034	0.002	-0.019	0.016	0.045
29	-0.004	0.037	0.006	-0.084*	-0.031	-0.041	-0.017
30	0.037	0.005	-0.027	0.057	-0.015	0.031	0.045
LB Q-stat K=30	55.34‡	55.46‡	73.20‡	44.72‡‡	39.02	69.04‡	41.33

The confidence intervals at 5% level for the autocorrelation coefficients are: ±0.076 for n=668. * indicates significance at 5% level. The Critical values for the Ljung-Box Q-statistic at lag k=30 are 43.77 and 50.89 at 5% and 1%, respectively. ‡ indicates rejection at 1% ; ‡‡ indicates rejection at 5% but acceptance at 1% level.

Table 4: Daily and Weekly Results of the Augmented Dickey-Fuller test for unit root for the whole sample period (January 2000 - October 2012)

	daily								weakly							
	Level				First difference				Level				First difference			
	constant and trend		constant only		constant and trend		constant only		constant and trend		constant only		constant and trend		constant only	
	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value
Egypt	-1.428	0.85	-0.767	0.83	-29.199	0.00	-29.202	0.00	-1.21	0.9085	-0.493	0.8934	-17.079	0.00	-17.088	0.00
Kenya	0.057	0.99	1.523	1.00	-22.919	0.00	-22.955	0.00	-1.275	0.894	-0.836	0.8084	-17.198	0.00	-17.21	0.00
Mauritius	-1.164	0.92	-0.480	0.90	-25.612	0.00	-25.619	0.00	-1.346	0.876	-0.588	0.8738	-15.834	0.00	-15.845	0.00
Morocco	-0.708	0.97	-1.707	0.43	-26.675	0.00	-26.659	0.00	-1.061	0.9353	-0.681	0.8517	-16.662	0.00	-16.674	0.00
Nigeria	-0.668	0.98	-1.161	0.69	-22.278	0.00	-22.266	0.00	-1.507	0.8267	-2.646	0.0838	-16.209	0.00	-16.063	0.00
South Africa	-1.007	0.94	0.845	0.99	-28.012	0.00	-27.983	0.00	-1.995	0.6039	-0.398	0.9105	-19.83	0.00	-19.841	0.00
Tunisia	-0.674	0.97	0.740	0.99	-24.596	0.00	-24.588	0.00	-1.739	0.7334	0.298	0.9772	-16.517	0.00	-16.475	0.00

The estimated T-statistics values from ADF tests are compared with Mackinnon's (1996) critical values. Constant and Trend: -3.9612 and -3.4114 at 1% and 5% level.
Constant only: -3.4324 and -2.8623 at 1% and 5% level

Table 4a: Daily and Weekly Results of the Augmented Dickey-Fuller test for unit root during the pre-crisis period (January 2000 - July 2007)

	Pre-crisis period															
	daily								weakly							
	Level				First difference				Level				First difference			
	constant and trend		constant only		constant and trend		constant only		constant and trend		constant only		constant and trend		constant only	
	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value
Egypt	-3.499	0.04	0.581	0.99	-20.504	0.00	-20.313	0.00	-3.129	0.10	1.156	1.00	-14.473	0.00	-13.881	0.00
Kenya	-0.165	0.99	2.278	1.00	-14.993	0.00	-14.757	0.00	-2.185	0.50	0.352	0.98	-16.974	0.00	-16.791	0.00
Mauritius	-1.543	0.81	1.589	1.00	-19.640	0.00	-19.512	0.00	-1.769	0.72	2.346	1.00	-21.378	0.00	-20.859	0.00
Morocco	-1.404	0.86	-0.497	0.89	-19.920	0.00	-19.926	0.00	-1.465	0.84	1.010	0.99	-18.116	0.00	-17.703	0.00
Nigeria	-1.501	0.83	0.646	0.99	-16.830	0.00	-16.867	0.00	-1.841	0.68	-0.477	0.90	-21.487	0.00	-21.514	0.00
South Africa	-1.435	0.85	2.190	1.00	-20.706	0.00	-20.574	0.00	-1.524	0.82	1.160	1.00	-21.336	0.00	-21.155	0.00
Tunisia	-0.179	0.99	1.241	1.00	-18.643	0.00	-18.532	0.00	-0.542	0.98	1.067	0.99	-17.102	0.00	-16.896	0.00

The estimated T-statistics values from ADF tests are compared with Mackinnon's (1996) critical values. Constant and Trend: -3.9612 and -3.4114 at 1% and 5% level.
Constant only: -3.4324 and -2.8623 at 1% and 5% level

Table 4b: Daily and Weekly Results of the Augmented Dickey-Fuller test for unit root during the crisis period (August 2007 - October 2012)

	Crisis period															
	Level				First difference				Level				First difference			
	constant and trend		constant only		constant and trend		constant only		constant and trend		constant only		constant and trend		constant only	
	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value	$ADF_{\tau-stat}$	p-value
Egypt	-0.425	0.99	-0.869	0.80	-20.737	0.00	-20.719	0.00	-1.691	0.75	-1.67	0.45	-14.539	0.00	-14.552	0.00
Kenya	-2.5	0.33	-2.408	0.14	-16.751	0.00	-16.869	0.00	-1.476	0.84	-1.787	0.39	-17.676	0.00	-17.635	0.00
Mauritius	-1.034	0.94	-0.928	0.78	-14.713	0.00	-14.722	0.00	-1.437	0.85	-1.441	0.56	-13.83	0.00	-13.851	0.00
Morocco	-0.619	0.98	0.320	0.98	-18.305	0.00	-18.277	0.00	-1.469	0.84	-0.509	0.89	-18.056	0.00	-18.007	0.00
Nigeria	0.165	1.00	-1.049	0.74	-14.951	0.00	-14.873	0.00	-0.736	0.97	-1.623	0.47	-15.657	0.00	-15.551	0.00
South Africa	-0.685	0.97	-0.176	0.94	-18.449	0.00	-18.447	0.00	-1.750	0.73	-0.873	0.80	-19.009	0.00	-18.981	0.00
Tunisia	0.101	1.00	-0.930	0.78	-16.664	0.00	-16.641	0.00	-0.930	0.95	-1.656	0.45	-15.81	0.00	-15.723	0.00

The estimated T-statistics values from ADF tests are compared with Mackinnon's (1996) critical values. Constant and Trend: -3.9612 and -3.4114 at 1% and 5% level.
Constant only: -3.4324 and -2.8623 at 1% and 5% level

Table 5: Daily and Weekly Results of the Phillips-Perron test for unit root for the whole sample period (January 2000 - October 2012)

	daily								weakly							
	Level				First difference				Level				First difference			
	constant and trend		constant only		constant and trend		constant only		constant and trend		constant only		constant and trend		constant only	
	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value
Egypt	-0.537	0.98	-0.423	0.91	-46.885	0.00	-46.896	0.00	-1.121	0.9256	-0.484	0.8952	-23.435	0.00	-23.451	0.00
Kenya	-0.007	0.99	0.446	0.98	-37.200	0.00	-37.226	0.00	-1.254	0.8989	-0.82	0.8133	-24.814	0.00	-24.832	0.00
Mauritius	-0.867	0.96	-0.426	0.91	-47.369	0.00	-47.379	0.00	-1.278	0.8933	-0.581	0.8752	-24.047	0.00	-24.064	0.00
Morocco	-0.213	0.99	-1.043	0.74	-40.870	0.00	-40.865	0.00	-1.037	0.9389	-0.668	0.855	-24.662	0.00	-24.68	0.00
Nigeria	-1.621	0.78	-2.527	0.11	-34.687	0.00	-34.682	0.00	-1.499	0.8293	-2.644	0.0843	-25.877	0.00	-25.696	0.00
South Africa	-1.831	0.69	0.252	0.98	-49.553	0.00	-49.550	0.00	-2.023	0.5889	-0.528	0.8865	-28.555	0.00	-28.574	0.00
Tunisia	-0.987	0.95	0.705	0.99	-42.850	0.00	-42.855	0.00	-1.564	0.8061	0.257	0.9753	-23.463	0.00	-23.445	0.00

The estimated T-statistics values from PP tests are compared with Mackinnon's (1996) critical values. Constant and Trend: -3.9612 and -3.4114 at 1% and 5% level. Constant only: -3.4324 and -2.8623 at 1% and 5% level

Table 5a: Daily and Weekly Results of the Phillips-Perron test for unit root during the pre-crisis period (January 2000 - July 2007)

	Pre-crisis period															
	daily								weakly							
	Level				First difference				Level				First difference			
	constant and trend		constant only		constant and trend		constant only		constant and trend		constant only		constant and trend		constant only	
	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value
Egypt	-3.550	0.03	0.208	0.97	-37.306	0.00	-37.218	0.00	-2.975	0.14	1.224	1.00	-18.98	0.00	-18.502	0.00
Kenya	-0.673	0.97	2.036	1.00	-29.954	0.00	-29.761	0.00	-2.173	0.51	0.486	0.98	-16.974	0.00	-16.791	0.00
Mauritius	-1.374	0.87	1.930	1.00	-43.243	0.00	-43.013	0.00	-1.735	0.74	2.263	1.00	-21.378	0.00	-20.859	0.00
Morocco	-1.378	0.87	0.708	0.99	-29.514	0.00	-29.427	0.00	-1.406	0.86	1.166	1.00	-18.116	0.00	-17.703	0.00
Nigeria	-1.573	0.80	-0.215	0.94	-26.604	0.00	-26.617	0.00	-1.917	0.65	-0.49	0.89	-21.487	0.00	-21.514	0.00
South Africa	-1.811	0.70	0.718	0.99	-37.287	0.00	-37.245	0.00	-1.413	0.86	0.988	0.99	-21.336	0.00	-21.155	0.00
Tunisia	-0.274	0.99	1.438	1.00	-35.387	0.00	-35.272	0.00	-0.330	0.99	1.188	1.00	-16.896	0.00	-17.102	0.00

The estimated T-statistics values from PP tests are compared with Mackinnon's (1996) critical values. Constant and Trend: -3.9612 and -3.4114 at 1% and 5% level. Constant only: -3.4324 and -2.8623 at 1% and 5% level

Table 5b: Daily and Weekly Results of the Phillips-Perron test for unit root during the crisis period (August 2007 - October 2012)

	Crisis period															
	Level				First difference				Level				First difference			
	constant and trend		constant only		constant and trend		constant only		constant and trend		constant only		constant and trend		constant only	
	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value	$PP_{\tau-sta}$	p-value
Egypt	-0.377	0.99	-1.068	0.73	-28.920	0.00	-28.888	0.00	-1.567	0.81	-1.577	0.50	-14.539	0.00	-14.552	0.00
Kenya	-0.917	0.95	-1.461	0.55	-22.986	0.00	-22.963	0.00	-1.546	0.81	-1.851	0.36	-17.676	0.00	-17.635	0.00
Mauritius	-0.156	0.99	-0.092	0.95	-26.402	0.00	-26.418	0.00	-1.299	0.89	-1.387	0.59	-13.83	0.00	-13.851	0.00
Morocco	-1.124	0.93	0.551	0.99	-29.081	0.00	-29.000	0.00	-1.659	0.77	-0.586	0.87	-18.056	0.00	-18.007	0.00
Nigeria	-0.092	0.99	-1.740	0.41	-22.644	0.00	-22.553	0.00	-0.698	0.97	-1.647	0.46	-15.657	0.00	-15.551	0.00
South Africa	-1.242	0.90	-0.691	0.85	-32.209	0.00	-32.215	0.00	-1.841	0.68	-1.004	0.75	-19.009	0.00	-18.981	0.00
Tunisia	-0.144	0.99	-1.439	0.56	-26.871	0.00	-26.829	0.00	-0.932	0.95	-1.756	0.40	-15.81	0.00	-15.723	0.00

The estimated T-statistics values from PP tests are compared with Mackinnon's (1996) critical values. Constant and Trend: -3.9612 and -3.4114 at 1% and 5% level. Constant only: -3.4324 and -2.8623 at 1% and 5% level

Table 6: Daily and Weekly Results of the KPSS test for unit root during the whole sample period (January 2000 - October 2012)

	daily				weakly			
	Level		First difference		Level		First difference	
	C/T	C	C/T	C	C/T	C	C/T	C
	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat
Egypt	1.740	8.280	0,321**	0.323	1.313	6.325	0,229*	0.223
Kenya	1.438	6.325	0,197*	0.193	0.462	2.059	0,137**	0.134
Mauritius	1.009	10.393	0,209*	0.220	0.306	3.249	0,131**	0.135
Morocco	1.190	8.809	0,330**	0.333	0.379	2.841	0,283*	0,286**
Nigeria	2.091	5.864	0.091	0,542*	0.306	3.241	0.064	0,388**
South Africa	0.972	10.324	0.083	0.082	0.311	3.186	0.076	0.075
Tunisia	1.287	10.037	0,192*	0.219	0.559	3.220	0,149**	0.216

The critical value for KPSS test: C/T (Constant and Trend) are 0.216 and 0.146 at 1% and 5% level, C (Constant only) are 0.739 and 0.463 at 1% and 5% level. * indicate rejection at 1% level and ** indicate rejection at 5% level.

Table 6a: Daily and Weekly Results of the KPSS test for unit root during the pre-crisis period (January 2000 - July 2007)

	daily				weakly			
	Level		First difference		Level		First difference	
	C/T	C	C/T	C	C/T	C	C/T	C
	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat
Egypt	1.313	6.325	0,287*	0,873*	0,475*	2,029*	0,287*	0,873*
Kenya	1.234	5.486	0,150*	0,432**	0,395*	1,841*	0,150**	0.432
Mauritius	1.316	6.644	0.080	0,846*	0,439*	2,188*	0.080	0,846*
Morocco	1.581	4.404	0.046	0,804*	0,530*	1,501*	0.046	0,804*
Nigeria	0.330	6.606	0.094	0.094	0,162**	2,288*	0.094	0.094
South Africa	1.493	6.139	0,371**	0.046	0,509*	2,034*	0.046	0.371
Tunisia	1.544	4.214	0.115	0,469**	0,393*	1,450*	0.115	0.469

The critical value for KPSS test: C/T (Constant and Trend) are 0.216 and 0.146 at 1% and 5% level, C (Constant only) are 0.739 and 0.463 at 1% and 5% level. * indicate rejection at 1% level and ** indicate rejection at 5% level.

Table 6b: Daily and Weekly Results of the KPSS test for unit root during the the crisis period (August 2007 - October 2012)

	daily				weakly			
	Level		First difference		Level		First difference	
	C/T	C	C/T	C	C/T	C	C/T	C
	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat	LM-stat
Egypt	0.321	1.853	0.074	0.093	0.113	0,652**	0.057	0.074
Kenya	1.234	5.486	0.099	0.221	0.194	0.371	0.083	0.176
Mauritius	0.487	1.598	0.113	0.118	0.159	0,496*	0.079	0.082
Morocco	0.414	2.057	0.094	0.181	0.144	0,684**	0.089	0.177
Nigeria	0.865	3.648	0.090	0.310	0,291*	1,175*	0.066	0.218
South Africa	0.723	2.640	0.057	0.148	0,242*	0,849*	0.060	0.156
Tunisia	0.940	4.776	0.080	0.286	0,307*	1,.518*	0.069	0.159

The critical value for KPSS test: C/T (Constant and Trend) are 0.216 and 0.146 at 1% and 5% level, C (Constant only) are 0.739 and 0.463 at 1% and 5% level. * indicate rejection at 1% level and ** indicate rejection at 5% level.

Table 7: Runs test for daily and weekly returns of the stock markets indexes for the whole period (January 2000-October 2012)

	Daily							Weekly						
	EG	KE	MU	MA	NG	ZA	TU	EG	KE	MU	MA	NG	ZA	TU
n_+	1583	1485	1494	1503	1384	1646	1391	347	313	316	314	323	363	313
n_-	1459	1612	1670	1559	1632	1555	1504	320	354	351	353	344	304	354
R	1350	1204	1232	1247	1121	1542	1239	307	274	250	313	299	327	284
μ_R	1519.5	1546.9	1578.1	1531.5	1498.8	1600.2	1446.3	334	333.2	333.6	333.4	334.1	331.9	333.2
σ_R	27.526	27.774	28.033	27.653	27.268	28.261	26.856	12.882	12.854	12.657	12.859	12.890	12.802	12.854
Z	-6.138*	-12.32*	-12.32*	-10.26*	-13.83*	-2.041**	-7.699*	-2.053**	-4.570*	-6.457*	-1.544	-2.690*	-0.343	-3.792*
$p-value$	0	0	0	0	0	0.041	0	0.04	0	0	0.122	0.007	0.734	0

The critical values for the Z-statistics are ±1.96 and ±2.576 at 5% and 1% level, respectively. * indicates rejection of H0 at 1% level, ** indicates rejection of randomness at 5% level but acceptance at 1% level.

Table 7a: Runs test for daily and weekly returns of the stock markets indexes for the pre-crisis period (January 2000-July 2007)

	Daily							Weekly						
	EG	KE	MU	MA	NG	ZA	TU	EG	KE	MU	MA	NG	ZA	TU
n_+	901	837	812	842	767	927	753	198	171	175	186	178	219	175
n_-	891	958	1017	932	969	966	850	196	223	219	208	216	175	219
R	807	692	710	690	652	892	669	190	154	141	177	183	184	168
μ_R	896.9	894.4	904	885.7	857.2	947.1	799.6	198	194.6	195.5	197.4	196.2	195.5	195.5
σ_R	21.159	21.118	21.081	20.999	20.544	21.739	19.939	9.911	9.738	9.788	9.789	9.881	9.788	9.788
Z	-4.226*	-9.578*	-9.167*	-9.296*	-9.296*	-2.512**	-6.523*	-0.756	-4.114*	-5.521*	-2.012**	-1.29	-1.128	-2.763*
$p-value$	0	0	0	0	0	0.012	0	0.449	0	0	0.044	0.1972	0.2591	0.0057

The critical values for the Z-statistics are ±1.96 and ±2.576 at 5% and 1% level, respectively. * indicates rejection of H0 at 1% level, ** indicates rejection of randomness at 5% level but acceptance at 1% level.

Table 7b: Runs test for daily and weekly returns of the stock markets indexes for the crisis period (August 2000-October 2012)

	Daily							Weekly						
	EG	KE	MU	MA	NG	ZA	TU	EG	KE	MU	MA	NG	ZA	TU
n_+	691	648	655	655	656	675	637	157	139	130	127	134	146	138
n_-	558	653	679	632	623	632	654	115	133	142	145	138	126	134
R	537	486	532	581	623	632	573	115	120	104	142	114	151	124
μ_R	618.4	651.5	667.8	644.3	640.1	653.8	646.4	133.8	136.9	136.7	136.4	136.4	136.3	137
σ_R	17.463	18.027	18.249	17.924	17.862	18.049	17.955	8.034	8.227	8.215	8.195	8.195	8.186	8.229
Z	-4.633*	-9.152*	-7.413*	-3.503*	-12.07*	0.348	-4.059*	-2.273**	-1.998**	-3.924*	0.621	-2.731*	1.739	-1.515
$p-value$	0	0	0	0	0	0.7274	0	0.023	0.046	0	0.534	0.006	0.081	0.13

The critical values for the Z-statistics are ±1.96 and ±2.576 at 5% and 1% level, respectively. * indicates rejection of H0 at 1% level, ** indicates rejection of randomness at 5% level but acceptance at 1% level.

Table 8: Results of the variance ratio tests for the whole sample period (January 2000-October 2012)

	Daily						Weekly					
	Chow-Denning MVR						Chow-Denning MVR					
	q	Lag 2	Lag 4	Lag 8	Lag 16	Max	q	Lag 2	Lag 4	Lag 8	Lag 16	Max
Egypt	VR(q)	1.18	1.314	1.416	1.528		VR(q)	1.097	1.213	1.367	1.739	
	Z(q)	9.935	9.253	7.75	6.617	9.935	Z(q)	2.507	2.938	3.201	4.338	4.338
	Z*(q)	5.529	5.49	4.995	4.572	5.529	Z*(q)	2.247	2.512	2.668	3.631	3.631
Kenya	VR(q)	1.268	1.665	1.93	2.143		VR(q)	1.04	1.142	1.274	1.578	
	Z(q)	14.927	19.792	17.489	14.453	19.792	Z(q)	1.033	1.966	2.39	3.391	3.391
	Z*(q)	4.122	6.409	6.917	6.956	6.956	Z*(q)	0.446	0.945	1.31	2.078	2.078
Mauritius	VR(q)	1.002	1.042	1.154	1.349		VR(q)	1.071	1.222	1.375	1.791	
	Z(q)	0.098	1.278	2.924	4.456	4.456	Z(q)	1.836	3.065	3.271	4.64	4.64
	Z*(q)	0.011	0.171	0.516	1.036	1.036	Z*(q)	0.609	1.159	1.434	2.337	2.337
Morocco	VR(q)	1.251	1.415	1.489	1.57		VR(q)	1.042	1.136	1.194	1.365	
	Z(q)	13.879	12.277	9.153	7.155	13.879	Z(q)	1.092	1.871	1.69	2.14	2.14
	Z*(q)	7.597	7.164	5.783	4.825	7.597	Z*(q)	0.871	1.528	1.421	1.822	1.822
Nigeria	VR(q)	1.348	1.709	1.848	2.063		VR(q)	1.006	1.147	1.372	1.725	
	Z(q)	19.136	20.818	15.74	13.26	20.818	Z(q)	0.15	2.023	3.248	4.256	4.256
	Z*(q)	7.562	8.988	7.892	7.635	8.988	Z*(q)	0.096	1.365	2.266	3.061	3.061
South Africa	VR(q)	1.051	1.046	0.95	0.895		VR(q)	0.899	0.861	0.853	0.924	
	Z(q)	2.865	1.397	-0.952	-1.345	2.865	Z(q)	-2.616	-1.915	-1.28	-0.449	2.616
	Z*(q)	1.976	0.943	-0.639	0.905	1.976	Z*(q)	-2.035	-1.503	-1.017	-0.362	2.035
Tunisia	VR(q)	1.222	1.396	1.462	1.58		VR(q)	1.096	1.217	1.407	1.634	
	Z(q)	11.939	11.381	8.403	7.089	11.939	Z(q)	2.484	2.998	3.555	3.722	3.722
	Z*(q)	4.528	4.666	3.918	3.721	4.666	Z*(q)	1.376	1.792	2.205	2.503	2.503

The critical values for the Chow-Denning MVR tests are 2.491 and 3.022 at 5% and 1% level, respectively. The absolute maximum value of the test statistics in the cells Max

Table 8a: Results of the variance ratio tests for the pre-crisis period (January2000-July 2007)

	Daily						Weekly					
	Chow-Denning MVR						Chow-Denning MVR					
	q	Lag 2	Lag 4	Lag 8	Lag 16	Max	q	Lag 2	Lag 4	Lag 8	Lag 16	Max
Egypt	VR(q)	1.156	1.269	1.384	1.463		VR(q)	1.072	1.126	1.245	1.649	
	Z(q)	6.587	6.104	5.496	4.449	6.587	Z(q)	1.425	1.344	1.648	2.925	2.925
	Z*(q)	4.118	4.014	3.857	3.349	4.118	Z*(q)	1.272	1.188	1.417	2.524	2.524
Kenya	VR(q)	1.235	1.657	2.04	2.377		VR(q)	1.167	1.349	1.625	2.039	
	Z(q)	9.951	14.867	14.907	13.254	14.907	Z(q)	3.304	3.706	4.193	4.685	4.685
	Z*(q)	2.518	4.479	5.64	6.294	6.294	Z*(q)	1.913	2.343	2.998	3.635	3.635
Mauritius	VR(q)	0.816	0.749	0.759	0.838		VR(q)	0.951	0.964	0.939	1.147	
	Z(q)	-7.861	-5.725	-3.478	-1.574	7.861	Z(q)	-0.964	-0.386	-0.406	0.665	0.964
	Z*(q)	-0.627	-0.568	-0.461	-0.279	0.627	Z*(q)	-0.213	-0.099	-0.126	0.251	0.251
Morocco	VR(q)	1.306	1.54	1.703	1.875		VR(q)	1.116	1.263	1.31	1.475	
	Z(q)	12.908	12.155	10.012	8.377	12.908	Z(q)	2.295	2.789	2.085	2.142	2.789
	Z*(q)	6.971	6.926	6.202	5.551	6.971	Z*(q)	1.801	2.234	1.713	1.797	2.234
Nigeria	VR(q)	1.325	1.654	1.649	1.773		VR(q)	0.92	1.007	1.072	1.176	
	Z(q)	13.555	14.581	9.151	7.321	14.581	Z(q)	-1.585	0.079	0.483	0.795	1.585
	Z*(q)	4.231	5.418	4.183	3.979	5.418	Z*(q)	-1	0.055	0.374	0.669	1
South Africa	VR(q)	1.069	1.119	1.069	1.006		VR(q)	0.936	0.898	0.912	0.992	
	Z(q)	3.002	2.784	1.019	0.065	3.002	Z(q)	-1.257	-1.082	-0.589	-0.036	1.257
	Z*(q)	2.064	1.937	0.7348	0.049	2.064	Z*(q)	-1.093	-0.962	-0.536	-0.034	1.093
Tunisia	VR(q)	1.206	1.338	1.413	1.599		VR(q)	1.157	1.31	1.475	1.727	
	Z(q)	8.237	7.239	5.586	5.45	8.237	Z(q)	3.11	3.29	3.187	3.276	3.29
	Z*(q)	3.598	3.555	3.22	3.405	3.598	Z*(q)	2.213	2.581	2.735	3.048	3.048

The critical values for the Chow-Denning MVR tests are 2.491 and 3.022 at 5% and 1% level, respectively. The absolute maximum value of the test statistics in the cells Max

Table 8b: Results of the variance ratio tests for the crisis period (August 2007-October 2012)

	Daily						Weekly					
	Chow-Denning MVR						Chow-Denning MVR					
	q	Lag 2	Lag 4	Lag 8	Lag 16	Max	q	Lag 2	Lag 4	Lag 8	Lag 16	Max
Egypt	VR(q)	1.209	1.364	1.451	1.599		VR(q)	1.127	1.313	1.523	1.878	
	Z(q)	7.391	6.892	5.386	4.812	7.391	Z(q)	2.097	2.759	2.913	3.288	3.288
	Z*(q)	3.819	3.824	3.281	3.138	3.824	Z*(q)	1.942	2.342	2.405	2.724	2.724
Kenya	VR(q)	1.302	1.676	1.82	1.916		VR(q)	0.934	0.975	0.989	1.243	
	Z(q)	10.878	13.024	10	7.508	13.024	Z(q)	-1.084	-0.218	-0.059	0.909	1.084
	Z*(q)	3.313	4.579	4.193	3.739	4.579	Z*(q)	-0.449	-0.102	-0.031	0.545	0.545
Mauritius	VR(q)	1.224	1.391	1.621	1.959		VR(q)	1.176	1.456	1.784	2.393	
	Z(q)	8.194	7.628	7.672	7.962	8.194	Z(q)	2.899	4.042	4.369	5.22	5.22
	Z*(q)	2.857	2.9	3.347	3.984	3.984	Z*(q)	2.105	2.985	3.258	3.84	3.84
Morocco	VR(q)	1.165	1.219	1.148	1.086		VR(q)	0.905	0.902	0.949	1.117	
	Z(q)	5.918	4.202	1.791	0.7	5.918	Z(q)	-1.563	-0.861	-0.279	0.438	1.563
	Z*(q)	3.311	2.548	1.171	0.486	3.311	Z*(q)	-1.277	-0.731	-0.248	0.391	1.277
Nigeria	VR(q)	1.362	1.733	1.96	2.183		VR(q)	1.061	1.21	1.5	1.909	
	Z(q)	12.939	14.007	11.608	9.613	14.007	Z(q)	1.002	1.86	2.79	3.408	3.408
	Z*(q)	6.629	7.043	6.439	5.959	7.043	Z*(q)	0.674	1.296	1.963	2.429	2.429
South Africa	VR(q)	1.036	0.981	0.838	0.78		VR(q)	0.858	0.818	0.801	0.879	
	Z(q)	1.304	-0.378	-1.985	-1.807	1.985	Z(q)	-2.336	-1.604	-1.109	-0.452	2.336
	Z*(q)	0.939	-0.261	-1.338	-1.194	1.338	Z*(q)	-1.713	-1.176	-0.817	-0.337	1.713
Tunisia	VR(q)	1.236	1.451	1.517	1.594		VR(q)	1.049	1.158	1.393	1.644	
	Z(q)	8.493	8.655	6.281	4.846	8.655	Z(q)	0.806	1.396	2.193	2.413	2.413
	Z*(q)	3.035	3.288	2.68	2.363	3.288	Z*(q)	0.426	0.792	1.277	1.525	1.525

The critical values for the Chow-Denning MVR tests are 2.491 and 3.022 at 5% and 1% level, respectively. The absolute maximum value of the test statistics in the cells Max

Table 9: Results of the variance ratio tests for the whole sample period (January 2000- October 2012)

	Daily						Weekly					
	Wright Joint VR						Wright Joint VR					
	q	Lag 2	Lag 4	Lag 8	Lag 16	Max	q	Lag 2	Lag 4	Lag 8	Lag 16	Max
Egypt	$R_1(q)$	8.873	8.126	7.233	5.907	8.873	$R_1(q)$	2.842	2.806	2.532	3.275	3.275
	$R_2(q)$	9.15	8.398	7.29	5.792	9.15	$R_2(q)$	2.549	2.715	2.633	3.394	3.394
	$S_1(q)$	6.89	6.425	5.783	5.39	6.89	$S_1(q)$	2.361	2.628	3.311	3.674	3.674
Kenya	$R_1(q)$	19.387	25.455	26.407	25.063	26.407	$R_1(q)$	5.562	6.918	7.272	7.15	7.272
	$R_2(q)$	20.598	26.453	26.064	23.784	26.453	$R_2(q)$	4.865	6.136	6.425	6.687	6.687
	$S_1(q)$	12.56	16.895	18.357	18.02	18.357	$S_1(q)$	3.91	5.691	5.883	4.998	5.883
Mauritius	$R_1(q)$	16.141	19.643	20.438	19.892	20.438	$R_1(q)$	6.248	6.873	6.885	7.004	7.004
	$R_2(q)$	16.658	19.244	19.268	18.55	19.268	$R_2(q)$	5.554	6.123	6.096	6.469	6.469
	$S_1(q)$	10.583	14.023	15.645	16.134	16.134	$S_1(q)$	6.776	7.595	6.695	5.917	7.595
Morocco	$R_1(q)$	13.352	13.94	11.802	10.947	13.94	$R_1(q)$	1.203	2.426	2.613	3.206	3.206
	$R_2(q)$	14.04	13.718	10.981	9.628	14.04	$R_2(q)$	1.078	2.103	2.058	2.53	2.53
	$S_1(q)$	9.758	10.171	9.365	9.222	10.171	$S_1(q)$	1.2	2.649	2.991	3.573	3.573
Nigeria	$R_1(q)$	23.283	26.449	22.834	20.252	26.449	$R_1(q)$	2.58	3.961	4.397	5.095	5.095
	$R_2(q)$	24.479	27.199	22.138	18.983	27.199	$R_2(q)$	1.475	3.106	3.941	4.784	4.784
	$S_1(q)$	14.457	17.879	16.792	15.984	17.879	$S_1(q)$	3.291	3.497	3.305	3.527	3.527
South Africa	$R_1(q)$	3.462	2.016	0.241	-0.173	3.462	$R_1(q)$	-1.794	-1.73	-1.292	-0.522	1.794
	$R_2(q)$	3.301	1.662	-0.48	-0.99	3.301	$R_2(q)$	-2.657	-2.163	-1.586	-0.689	2.657
	$S_1(q)$	2.497	2.074	1.409	1.975	2.497	$S_1(q)$	1.742	1.862	1.956	2.557	2.557
Tunisia	$R_1(q)$	12.785	12.969	11.276	11.236	12.969	$R_1(q)$	3.476	4.508	4.872	4.866	4.872
	$R_2(q)$	13.586	13.292	11.084	10.732	13.586	$R_2(q)$	3.092	4.059	4.404	4.36	4.404
	$S_1(q)$	8.196	9.05	8.406	8.841	9.05	$S_1(q)$	3.058	3.746	4.398	4.822	4.822

The absolute maximum value of the statistic tests for the Wright Joint VR tests are reported in the cells Max; The critical values for Wright Joint VR at 5% and 1% level, respectively are reported in a separate table.

Table 9a: Results of the variance ratio tests for the pre-crisis period (January 2007-July 2012)

	Daily						Weekly					
	Wright Joint VR						Wright Joint VR					
	q	Lag 2	Lag 4	Lag 8	Lag 16	Max	q	Lag 2	Lag 4	Lag 8	Lag 16	Max
Egypt	$R_1(q)$	6.465	6.021	5.519	4.585	6.465	$R_1(q)$	1.812	1.126	0.99	1.924	1.924
	$R_2(q)$	6.519	5.975	5.462	4.364	6.519	$R_2(q)$	1.545	1.115	1.139	2.047	2.047
	$S_1(q)$	5.055	4.507	3.913	3.94	5.055	$S_1(q)$	1.007	0.565	0.826	1.954	1.954
Kenya	$R_1(q)$	13.174	18.531	20.679	19.476	20.679	$R_1(q)$	5.168	6.159	6.806	6.525	6.806
	$R_2(q)$	14.17	19.6	20.861	18.915	20.861	$R_2(q)$	4.862	5.422	5.787	5.607	5.787
	$S_1(q)$	8.615	12.528	14.334	13.885	14.334	$S_1(q)$	4.03	5.628	6.003	4.684	6.003
Mauritius	$R_1(q)$	10.871	14.842	16.834	16.795	16.834	$R_1(q)$	5.646	5.933	6.116	5.926	6.116
	$R_2(q)$	11.035	14.126	15.062	14.574	15.062	$R_2(q)$	4.874	4.767	4.541	4.298	4.874
	$S_1(q)$	7.225	10.548	12.604	13.502	13.502	$S_1(q)$	5.44	6.139	5.611	4.769	6.139
Morocco	$R_1(q)$	12.922	14.417	13.254	12.408	14.417	$R_1(q)$	2.505	3.119	2.88	3.643	3.643
	$R_2(q)$	13.349	14.013	12.289	11.084	14.013	$R_2(q)$	2.373	2.86	2.322	2.701	2.86
	$S_1(q)$	8.927	10.216	10.109	10.069	10.216	$S_1(q)$	1.914	2.558	2.426	3.327	3.327
Nigeria	$R_1(q)$	15.884	17.882	14.828	13.217	17.882	$R_1(q)$	0.915	2.164	2.202	2.326	2.326
	$R_2(q)$	17.229	18.58	13.826	11.662	18.58	$R_2(q)$	0.285	1.155	1.252	1.388	1.388
	$S_1(q)$	8.928	11.571	11.407	11.206	11.571	$S_1(q)$	2.518	2.531	2.733	2.818	2.818
South Africa	$R_1(q)$	4.138	3.448	1.651	1.039	4.138	$R_1(q)$	-0.492	-0.827	-0.485	-0.15	0.827
	$R_2(q)$	3.789	3.27	1.342	0.424	3.789	$R_2(q)$	-1.312	-1.276	-0.849	-0.407	1.312
	$S_1(q)$	2.689	2.223	1.857	2.349	2.689	$S_1(q)$	3.123	3.069	3.099	3.774	3.774
Tunisia	$R_1(q)$	9.955	10.6	9.273	9.076	10.6	$R_1(q)$	2.969	3.67	3.596	3.79	3.79
	$R_2(q)$	10.575	10.581	9	8.754	10.581	$R_2(q)$	3.018	3.434	3.229	3.311	3.434
	$S_1(q)$	5.719	6.608	5.864	5.3224	6.608	$S_1(q)$	2.317	2.45	2.231	2.077	2.45

The absolute maximum value of the statistic tests for the Wright Joint VR tests are reported in the cells Max; The critical values for Wright Joint VR at 5% and 1% level, respectively are reported in a separate table.

Table 9b: Results of the variance ratio tests for the crisis period (August 2007-October 2012)

	Daily						Weekly					
	Wright Joint VR						Wright Joint VR					
	q	Lag 2	Lag 4	Lag 8	Lag 16	Max	q	Lag 2	Lag 4	Lag 8	Lag 16	Max
Egypt	$R_1(q)$	6.11	5.43	4.677	3.631	6.11	$R_1(q)$	2.216	2.86	2.683	2.519	2.86
	$R_2(q)$	6.389	5.817	4.721	3.648	6.389	$R_2(q)$	1.965	2.641	2.53	2.474	2.641
	$S_1(q)$	4.725	4.613	4.323	3.677	4.725	$S_1(q)$	2.546	3.435	4.181	3.14	4.181
Kenya	$R_1(q)$	14.243	17.413	16.51	15.816	17.413	$R_1(q)$	2.624	3.638	3.39	3.5	3.638
	$R_2(q)$	14.758	17.598	15.736	14.337	17.598	$R_2(q)$	1.889	2.961	3.156	3.156	3.156
	$S_1(q)$	9.232	11.336	11.345	11.29	11.345	$S_1(q)$	1.212	2.074	1.937	2.142	2.142
Mauritius	$R_1(q)$	11.936	13.131	12.449	11.763	13.131	$R_1(q)$	3.133	3.704	3.497	3.12	3.704
	$R_2(q)$	11.912	12.714	12.037	11.459	12.714	$R_2(q)$	3.071	3.8	3.776	3.774	3.8
	$S_1(q)$	7.735	9.173	9.128	8.843	9.173	$S_1(q)$	3.88	4.31	3.576	3.04	4.31
Morocco	$R_1(q)$	5.414	4.557	2.514	2.227	5.414	$R_1(q)$	-1.516	-0.317	0.167	0.106	1.516
	$R_2(q)$	5.806	4.518	2.156	1.455	5.806	$R_2(q)$	-1.68	-0.671	-0.109	0.1	1.68
	$S_1(q)$	4.487	3.605	2.45	2.324	4.487	$S_1(q)$	-0.485	1.004	1.68	1.522	1.68
Nigeria	$R_1(q)$	16.469	18.588	16.156	13.73	18.588	$R_1(q)$	2.502	3.051	3.52	3.905	3.905
	$R_2(q)$	16.791	18.869	15.96	13.141	18.869	$R_2(q)$	1.773	2.309	2.957	3.37	3.37
	$S_1(q)$	11.715	13.855	12.43	11.437	13.855	$S_1(q)$	2.182	2.398	1.814	2.042	2.398
South Africa	$R_1(q)$	0.662	-0.872	-1.677	-1.655	1.655	$R_1(q)$	-2.245	-1.901	-1.544	-0.855	2.245
	$R_2(q)$	0.994	-0.794	-2.036	-1.955	2.036	$R_2(q)$	-2.548	-2.007	-1.533	-0.78	2.548
	$S_1(q)$	0.47	0.0443	-0.481	-0.113	0.481	$S_1(q)$	-1.091	-0.842	-0.707	-0.798	1.091
Tunisia	$R_1(q)$	7.728	7.213	6.098	6.187	7.728	$R_1(q)$	1.538	2.168	2.364	1.544	2.364
	$R_2(q)$	8.33	7.773	6.169	5.911	8.33	$R_2(q)$	1.037	1.863	2.235	1.638	2.235
	$S_1(q)$	5.816	6.054	5.889	7.223	7.223	$S_1(q)$	1.94	2.949	4.181	4.866	4.866

The absolute maximum value of the statistic tests for the Wright Joint VR tests are reported in the cells Max; The critical values for Wright Joint VR at 5% and 1% level, respectively are reported in a separate table.

Table 10: Critical value for Wright joint VR tests: The critical values were simulated with 1000 replications

No		2896			2998			3043			3165			3201	
	1%		5%	1%		5%	1%		5%	1%		5%	1%		5%
$JR_1(q)$	3.045		2.357	2.958		2.324	2.726		2.306	2.909		2.342	3.021		2.363
$JR_2(q)$	3.037		2.356	2.864		2.339	2.904		2.302	2.972		2.365	2.973		2.373
$JS_1(q)$	2.975		2.375	2.856		2.351	3.051		2.314	2.933		2.293	2.916		2.244
		3017			3063			1279			668			394	
	1%		5%	1%		5%	1%		5%	1%		5%	1%		5%
$JR_1(q)$	3.071		2.491	2.726		2.271	2.83		2.306	2.826		2.284	2.897		2.302
$JR_2(q)$	3.046		2.492	2.904		2.296	2.892		2.302	2.876		2.268	2.961		2.267
$JS_1(q)$	2.957		2.308	3.051		2.396	3.16		2.314	2.916		2.244	2.915		2.295
		272			1792			1795			1829			1287	
	1%		5%	1%		5%	1%		5%	1%		5%	1%		5%
$JR_1(q)$	2.909		2.242	2.747		2.304	3.098		2.489	2.942		2.337	2.975		2.329
$JR_2(q)$	2.833		2.23	2.786		2.322	3.132		2.469	2.9		2.322	2.989		2.331
$JS_1(q)$	2.924		2.306	2.843		2.368	2.962		2.344	2.893		2.379	3.015		2.308
		1774			1736			1893			1603			1249	
	1%		5%	1%		5%	1%		5%	1%		5%	1%		5%
$JR_1(q)$	2.954		2.419	2.975		2.289	2.779		2.306	2.883		2.341	2.856		2.183
$JR_2(q)$	2.96		2.305	2.835		2.261	2.856		2.334	2.996		2.356	2.879		2.218
$JS_1(q)$	2.992		2.374	2.88		2.382	2.961		2.375	2.282		2.913	2.934		2.348
		1291			1301			1334			1307				
	1%		5%	1%		5%	1%		5%	1%		5%			
$JR_1(q)$	2.897		2.343	2.908		2.408	3.001		2.395	2.801		2.327			
$JR_2(q)$	2.769		2.344	3.094		2.404	2.938		2.408	2.832		2.335			
$JS_1(q)$	2.421		3.067	2.915		2.31	2.847		2.402	2.846		2.299			