North Africa Stock Markets: Analysis of Unit Root and Long Memory Process

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Abstracts

This paper investigates unit root and long memory behavior of stock returns from Egypt, Tunisa, and Morrocco stock markets. Results in the paper support evidence of stationary short memory process for returns of these markets. Stationary and short memory of stock returns imply shocks to these markets cannot persist for long periods, and most recent lagged returns have more predictive power for future returns than long-term factors.

تحليل الجذر الأحادي والذاكرة الطويلة لأسواق الأسهم بدول شمال أفريقيا

ملخص

تداعيات الهزات المالية التي تعصف بأسواق المال لفترات زمنية أطول يعتمد بدرجة كبيرة على درجة انفتاح السوق وفعالية الأطر التنظيمية والرقابية للسوق، بجانب ارتباط حركة أسعار الأسهم بأساسيات الاقتصاد المحلي. في هذه الورقة تم استخدام تحليل الجذر الأحادي والذاكرة الطويلة لأسواق الأسهم في تونس والمغرب ومصر وذلك لاختبار فعالية عوامل التصحيح الذاتي في هذه الأسواق أثناء تعرضها لهزة مالية طارئة. توضح نتائج الورقة أن عوائد الأسهم في هذه الأسواق تتسم بالارتباط الذاتي والذاكرة القصيرة الأمر الذي يدل على وجود عوامل التصحيح الذاتي في هذه الأسواق ما لم يتزامن أو يتبع حدوث الأزمة تدخل سلبي من الأجهزة الرقابية والتنظيمية في هذه الأسواق وذلك في إطار محاولات تصحيح الخلل.

1. Introduction

The increasing interest in random walk behavior and long memory process in asset returns in emerging markets, is mainly due to the increasing financial globalization and the increasing attention of international investors to explore profitable opportunities in emerging markets. Since the findings of Bekaert and Harvey (1995), who indicated emerging markets returns tend to be more persistence than those in more developed markets, the issue of long memory attracted a number of empirical research on capital markets. This is because, even for a stationary process the extent of persistance in stock returns can be of long memory nature that can not be captured precisely by the ARMA models, since the autocorrelations may decay at a far slower rate than the rate of decay in ARMA models. Wright (1999) tested long memory process for stock returns in seventeen emerging markets and indicated that only seven series exhibited long memory. Ding and Granger (1996) modelled volatility persistsnce of speculative returns for S&P 500 stocks and show significant long memory behavior. Bollererslev and Mikkelson (1996) show empirical evidence suggesting long run dependence in U.S stock market volatility, so that a shock to conditional variance dissipate at a slow hyperbolic rate. Granger and Ding (1996) present varieties of long memory models arising from aggregation, and time-changing coefficients.

The importance of unit root test in asset returns, in general, stem from the fact that the basic hypothesis underlying weak-form efficiency (presence of unit root) implies successive price changes in individual securities are independent random variables. Independence implies, of course, that the history of a series of changes cannot be used to predict future changes in any meaningful way.

To test for long-term dependence in stock returns for the three North Africa stock markets, in this paper, the variance ratio test for unit root, beside the log-periodogram regression, and Kwiatkowski et al (1992) test known as KPSS, approaches for long memory are employed.

The remaining parts of the paper are structured as follows: Section (2) includes some basic data analysis. Section (3) gives a brief theoritical exposition about the variance ratio test, the log-periodogram regression, and KPSS models. In section (4), estimation and discusion of results are presented. The final section (5) concludes.

2. Data Analysis

Data employed in this study are daily closing price indices for Tunisia, Egypt, and Morocco stock markets. The sample period is May-28- 2002 to Sept-2-2006, including 1125 observations. Summary statistics for stock returns are presented in table (1).

Table (1): Summary Statistics

	Tunisia	**Egypt**	**Morocco**
Mean (%)	0.04	0.11	0.08
St.deviation (%)	0.39	0.97	0.80
Skewness:	0.20	-0.84	-1.66
Ex. Kurtosis:	1.67	11.4	21.7
JB test **p-value**	137 (0.000)	621 (0.000)	224 (0.000)
Q(10) **(p-value)** **Q2(10)** **(p-value)**	25.3 (0.005) 241 (0.000)	25.5 (0.005) 127 (0.000)	17.8 (0.006) 101 (0.000)
LM ARCH(1) **(P-value)** **LM ARCH(5)** **(P-value)**	45.1 (0.003) 119.4 (0.000)	28.3 (0.005) 76.2 (0.001)	47.0 (0.003) 71.9 (0.001)

Table (1) indicate, while the three markets exhibit positive mean returns, they show varying unconditional volatility. The high values of excess kurtosis coefficients for Egypt and Morocco markets imply the distributions of returns is characterized by peakness relative to a normal distribution(1). The negative skewness results imply a higher probability for stock prices to decline. The Jarque-Bera (JB) test statistic provides evidence to reject the null-hypothesis of normality for the unconditional distribution of the daily price changes. The sample autocorrelation statistic indicated by Ljung-Box, Q statistic, show that the Q(10) test statistic rejects the null hypothesis of uncorrelated price changes up to ten lags for the three markets.

Investigation of ARCH behavior of stock returns, indicated by Q2(10) and LM test statistics show evidence of stock returns volatility persistence (ARCH effect) for all markets. Kocenda and Briatka (2005) test (known as K2K) also employed to account for hidden nonlinear dependence in stock returns by testing for strict white noise process that reflects a sequence of independent and identically distributed (iid) random variable(2). Results in table (2) reject the null hypothesis of independent and identically distributed (iid) stock returns for the three markets.

Table (2):Nonlinear dependence test (K2K)

Dimension	Tunisia	Egypt	Morocco
2	1.23	0.47	0.58
3	1.78	0.58	0.77
4	2.30	0.65	0.94
5	2.78	0.67	1.09
6	3.24	0.69	1.24
7	3.68	0.69	1.39
8	4.14	0.70	1.52
9	4.58	0.71	1.66
10	5.04	0.72	1.79

Values in entries are K2K statistics. Critical values included in K2K computer program. All values of K2K reject the null-hypothesis of iid, at 1% significance level.

3. Unit root and long memory process

The non-normality and highly persistent evidence for stock returns of the three markets implied by results in tables (1) &(2), necessitates the use of unit root test which is robust to many forms of heteroscedasticity.

A number of authors, DeJong et al (1992), Diebold and Rudebusch (1991), have detected low power of the standard unit root tests such as, augmented Dickey-Fuller (ADF, 1978), and Phillips and Perron (PP, 1988), as they fail to distinguish a highly persistent stationary process from a non-stationary process. And also the power of ADF and PP tests diminishes as deterministic terms are added to the test regression. That is, a test that includes a constant and trend in the test regression have less power than a test that only includes a constant in the test regression.

A non-parametric unit root test that is invariant to the normality distribution of the residuals and accommodates the heteroscedasticity, is the variance ratio test developed by Lo and MacKinlay (1988b)(3).

3.1 The Variance Ratio Test

To expose some elements of the variance ratio test theory, let yt denote a stochastic process satisfying the following recursive relation:

$$y_t = \mu + y_{t-1} + \varepsilon_t, \qquad E(\varepsilon_t) = 0 \quad \textit{for all } t$$
$$\textit{or}$$
$$\Delta y_t = \mu + \varepsilon_t, \qquad \Delta y_t = y_t - y_{t-1}$$

Where the drift μ is an arbitrary parameter. The essence of the random walk hypothesis is the restriction that the disturbance εt are serially uncorrelated, or that innovations are unforecastable from past innovations.

Lo and MacKinlay (1988b) developed the test of random walk under two null-hypotheses: independently and identically distributed Gaussian increments, and the more general case of uncorrelated but weakly dependent and possibly heteroskedastic increments.

3.1.1: The iid Gaussian Null Hypothesis

Let the null-hypothesis denote the case where innovations are identically distributed normal random variables with variance σ2 and suppose we obtain (nq+1) observations: y0 , y1 ……ynq of yt , where both n and q are arbitrary integers greater than one. Consider the following estimators for the unknown parameters μ and σ2 :

$$\hat{\mu} \equiv \frac{1}{nq}\sum_{k=1}^{nq}[y_k - y_{k-1}] \equiv \frac{1}{nq}[y_{nq} - y_0]$$

$$\hat{\sigma}_a^{\ 2} \equiv \frac{1}{nq}\sum_{k=1}^{nq}[y_k - y_{k-1} - \hat{\mu}]^2$$

The estimator $\hat{\sigma}_a$ is simply the sample variance of the first difference of yt . Consider the variance of qth differences of yt which under the null-hypothesis H1, is q times the variance of first-differences. By dividing by q we obtain the estimator $\hat{\sigma}_b^{\ 2}\ (q)$ which also converges to σ2 under H1, where

$$\hat{\sigma}_b^{\ 2}(q) \equiv \frac{1}{nq^2}\sum_{k=q}^{nq}[y_k - y_{k-q} - q\mu]^2$$

The estimator $\hat{\sigma}_b^{\ 2}\ (q)$ is written as a function of q to emphasize the fact that an alternative estimator of σ2 can be formed for each q. Under the null-hypothesis of a Gaussian random walk, the two estimators $\hat{\sigma}_a$ and $\hat{\sigma}_b^{\ 2}\ (q)$ should be almost equal; therefore the test of random walk is performed by computing the difference,

$H_d(q) = \hat{\sigma}_b^{\ 2}(q) - \hat{\sigma}_a^{\ 2}$ and checking its proximity to zero.

Alternatively, a test may also be based on the ratio

$H_r(q) = \frac{\hat{\sigma}_b^{\ 2}}{\hat{\sigma}_a^{\ 2}} - 1$, to check for its converges to zero as well. Lo and MacKinlay (1988b) show that Hr(q) possess the following limiting distribution under the null-hypothesis H1:

$$\sqrt{nq}H_r(q) \sim \quad N(0, \frac{2(2q-1)(q-1)}{3q}) \qquad (1)$$

3.1.2 <u>The Heteroskedstic Null Hypothesis</u>

Under conditions which allow for a variety of forms of heteroskedsticity, including ARCH processes, Lo and MacKinlay(1988) show the limiting distribution Hr(q) of the variance ratio as an approximate linear combination of autocorrelation, or

$$H_r(q) \sim \quad N(0, v(q)) \qquad (2)$$

Where

$$\hat{v}(q) = \sum_{j=1}^{q-1} \left(\frac{2(q-j)}{q} \right)^2 \hat{\delta}(j)$$

And $\hat{\delta}(j)$ is heteroskedasticity-consistent estimators of the asymptotic variance of the autocorrelation of Δy_t, defined as,

$$\hat{\delta}(j) = \sum_{k=j+1}^{nq} \frac{(y_k - y_{k-1} - \hat{u})^2 (y_{k-j} - y_{k-j-1} - \hat{u})^2}{\left(\sum_{k=1}^{nq} (y_k - y_{k-1} - \hat{u})^2 \right)^2}$$

Test of the null hypothesis of the heteroskedasticity in equation (2), under the normalized variance ratio, can be shown as:

$$z_2(q) = \sqrt{nq} H_r(q).\hat{v}^{-0.5}(q) \sim N(0,1)$$

Also the null hypothesis of homeskedasticity in equation (1), under the normalized variance ratio can be stated as:

$$z_1(q) = \sqrt{nq} H_r(q) \left(\frac{2(2q-1)(q-1)}{3q} \right)^{-0.5} \sim N(0,1)$$

3.2 <u>Log Periodogram Regression</u>

Given a discrete time series, y_t, with autocorrelation function, ρ_j, at lag j, Mcleod and Hipel (1978) define long memory as a process

$$\sum_{j=-n}^{n} |\rho_j| \qquad as \quad n \to \infty \qquad (3)$$

characterized as nonfinite. More formally, the process y_t is said to be integrated of order d, or I(d) if

$$(1-L)^d y_t = e_t \qquad (4)$$

For $0 < d < 0.5$, the process is long memory in the context of definition (3), since its autocorrelations are all positive and decay at a slow rate. For $-0.5 < d < 0$, the sum of absolute values of autocorrelations tends to a constant, thus the process has a short memory in the sense of condition (3)[(4)].

In the long memory process a shock e_t at time t, continues to influence future y_{t+k} for a longer horizon, k, than would be the case for the standard stationary ARMA process. A simple and useful device for checking long memory process is the correlogram, which is the plot of the estimated autocorrelation between y_t and y_{t-k}, against k. Granger and Ding (1996) indicate that the absolute values of the sample correlation is a better approach of detecting long memory process, so that $\rho_k |r_t| = corr(|r_t|, |r_{t-k}|)$, rather than $\rho_k (r_t) = corr(r_t, r_{t-k})$, which may not exhibit long memory process.

In this paper, we follow the analysis of Granger and Ding (1996) in applying the methodology suggested by Geweke and Porter-Hudak (GPH, 1983) to obtain an estimate of d, based on the slope of the spectral density function around the angular frequency $\lambda_j = 0$. More specifically, let $I(\lambda)$ be the periodogram of y at frequency λ, defined by (see Granger and Newbold, 1986):

$$I(\lambda_j) = \frac{1}{T^2}\left\{\left[\sum_{t=1}^{T}(|r_t| - |\bar{r}|)\cos(\lambda_j)\right]^2 + \left[\sum_{t=1}^{T}(|r_t| - |\bar{r}|)\sin(\lambda_j)\right]^2\right\}$$

where $\lambda_j = \dfrac{2\pi j}{T}$ (j=1,2,…..T-1) is the Fourier frequencies of the sample.
The log-periodogram regression estimate of d, is given by minus sign the coefficient β, in the regression equation (5)[(5)]:

$$\ln(I(\lambda_i)) = \alpha + \beta \ln\{4\sin^2(\lambda_j / 2)\} + v_j \qquad (5)$$

$$for\ \ j = 1, ...m,\ and\ m = g(T) < T$$

Where m is the sample size of the GPH spectral regression.

Following Wright (2000), and many other authors, in this paper m, is set to: $m = T^u \ \ for\ u = 0.60, 0.62, 0.64$. The t-test statistic $\hat{d} / (\sqrt{\pi^2 / 24m})$, can be used to test the null-hypothesis ($H_0 : d = 0$). If the OLS estimator $\hat{d}$ is significantly different from zero, and $0 < \hat{d} < 0.5$, then $|r_t|$ is fractionally integrated, and thus exhibit long memory process, and for $-0.5 < \hat{d} < 0$, short memory process.

3.3 <u>KPSS Test</u>

Another test for long memory stationary process is Kwiatkowski, Phillips, Schmidt, and Shin (1992) test, often referred to as KPSS test. This test initially was developed to test the null-hypothesis I(0), against the alternative I(1). However, Lee and Schmidt (1996) proved (Theorem 3, page 291) that the KPSS test is consistent with the null hypothesis of short memory, against stationary long memory alternatives, such as I(d) process for $d \in (-0.5, 0.5), d \neq 0$ .Thus, KPSS test can be used to distinguish short memory and long memory stationary processes.

To explain this test let yt , t=1,2,….,T, be the observed series. It is assumed that yt series can be decomposed into the sum of deterministic trend, a random walk, and stationary error or,

$$y_t = \beta t + r_t + e_t \qquad (6)$$

Where $r_t = r_{t-1} + \varepsilon_t$, $\qquad \varepsilon_t \to WN(0, \sigma^2{}_\varepsilon)$

The rt is I(0) and its initial value (r0) is treated as fixed and play the same role of an intercept term of the regression equation. Notice that rt is a pure random walk with innovation variance $\sigma_\varepsilon{}^2$.

The null-hypothesis that yt is trend stationary is formulated as:
H0: $\sigma^2{}_\varepsilon = 0$, which implies that rt is constant.

The KPSS test statistic is the Lagrange multiplier (LM) test for testing $\sigma^2{}_\varepsilon = 0$, against the alternative that $\sigma^2{}_\varepsilon > 0$, and is given by calculating the partial sum process of the residuals (et) generated from the regression of yt on an intercept and time trend. Letting $\hat{\sigma}^2{}_\varepsilon$ be the estimate of the error variannce, and $\hat{s}_t$ the partial sum of the residuals we calculate LM statistic as:

$$LM = \frac{T^{-2}\sum_{t=1}^{T}\hat{s}^2}{\hat{\sigma}^2(l)} \qquad (7)$$

Where $\hat{s}_t = \sum_{i=1}^{t} e_i \qquad t = 1,2,......T$

$\hat{\sigma}^2(l)$ (long run variance) is asymptotically consistent estimate of $\hat{\sigma}^2{}_\varepsilon$, estimated as:

$$\hat{\sigma}^2(l) = T^{-1}\sum_{t=1}^{T} e^2{}_t + 2T^{-1}\sum_{s=1}^{l} w(s,l)\sum_{t=s+1}^{T} e_t e_{t-s} \qquad (8)$$

Where w(s,l) is an optional lag window, l is lag truncation parameter. KPSS (1991) use the Bartlet window, $w(s,l) = 1 - s/(1+l)$, and they show that the test statistic in equation (7) has an asymptotic distribution equal to a functional of Brownian bridge, for level stationarity and for trend stationarity. For level stationarity the asymptotic distribution of (7) is shown as:

$$\hat{\eta}_u \xrightarrow{d} \int_0^1 v(r)^2 \, dr \qquad (9)$$

Where v(r) =w(r) – r w(1) . w(r) is a Wiener process (Brownian motion).

It should be noted that when testing for level stationarity the residuals, et, in equation (6) calculates the regression of yt on a constant only or $e_t = y_t - \bar{y}$.
For trend stationarity the asymptotic distribution is given by:

$$\hat{\eta}_r \xrightarrow{d} \int_0^1 v_2(r)^2 \, dr \qquad (10)$$

Where the second level Brownian bridge v2(r) is given by:

$$v_2(r) = w(r) + (2r - 3r^2)w(1) + (-6r + 6r^2)\int_0^1 w(r)dr$$

4. Estimation Results

Since results in tables (1) and (2), reject independent, and identical distribution (iid) hypothesis, in favor of the heteroscedasticity and serial correlation, test for random walk behavior can be reflected by z_2 statistic. Results in table (3) indicate the null hypothesis of unit root in stock returns can be rejected at 1% significance level , for the three markets. Rejection of unit root in the levels of asset returns is consistent with a number of empirical evidence related to emerging markets (Wright, 2000, and Harvey,1995a).

Table (3): The Variance Ratio Test

	q	Z2 values	
		Test Statistics	P-Values
Tunisia	4	130	0.000
	8	45.9	0.000
	16	19.2	0.000
Egypt	4	4.65	0.000
	8	3.02	0.001
	16	1.57*	0.060
Morocco	4	15.47	0.000
	8	7.49	0.000
	16	4.85	0.000

*significant at 10% level, but all other values significant at 1% level.

Given that a time series can be a stationary long memory process, then it requires to answer if the stock returns of the three markets exhibit long-range dependence. Results in table (4), include the log-periodogram regression estimates of $\hat{d}$ or $(-\hat{\beta})$ and t-test statistics, to test the null-hypothesis of d=0. For all choices of the sample size of the GPH spectral regression (m = 66, 80, 90), the point estimates of d are negative ($-0.5 < d < 0$), and significant at 1% level, for the three markets, indicating overwhelming evidence of short memory behavior of stock returns. The KPSS test results in table (5) also fail to reject, for both trend and level stationary statistics, the null of stationary short memory, against the alternative of stationary long memory of stock returns.

Table (4):Log-Periodogram Regression Results

Market	m	d	m	d	m	d
Tunisia (t-stat)	66	-0.45* (-5.70)	80	-0.39* (-5.44)	90	-0.37* (-5.47)
Egypt (t-stat)	66	-0.33* (-4.18)	80	-0.26* (-3.62)	90	-0.24* (-3.55)
Morocco (t-stat)	66	-0.37* (-4.68)	80	-0.29* (-4.04)	90	-0.27* (-3.99)

* indicate significance at 1% level.

Table(5): KPSS test statistics.

	$\hat{\eta}_r$ Statistic	$\hat{\eta}_u$ statistic
Tunisia	0.0016	0.030
Egypt	0.072	0.097
Morocco	0.17	0.64
Critical values: (5 %) (1 %)	 (0.146) (0.216)	 (0.463) (0.739)

$\hat{\eta}_r$ = trend stationarity and $\hat{\eta}_u$ = level stationarity .
Critical values from KPSS (1991), table (1).
The lag truncation parameter is set to 8 lags.

5. Concluding Remarks

Evidence of stationary short memory, in asset returns has important implications for investors as it validates standard derivative pricing models which are based on Brownian motion and martingale assumptions (Bollerslev et al 1996), and also imply that perfect arbitrage is possible (Mandelbrot, 1971). This paper investigated unit root and long memory of stock returns from three North Africa emerging markets: Tunisia, Egypt, and Morocco, using daily stock returns. Results of the paper reveal strong evidence of a stationary short memory process for the returns of the three markets. This result implies that a shock to any of these markets is not likely to persist for long period, and future returns can better be predicted using most recent lagged returns. The result stands in contrast with developed and efficient emerging markets, where lagged returns have little predictive power for future returns. Since persistence in stock returns could represent some market inefficiency, it could be exploited by international investors to earn excess returns. This is because in inefficient markets, it takes a considerable time for relevant information to disseminate across markets, and thus there is a tendency to either systematically understate or overstate the effects of such information on prices of securities.

Footnotes

(1) The skewness (sk) and excess kurtosis (k) statistics calculated using the formulas

$sk = \frac{m_3}{(m_2)^{3/2}}$, and $k = \frac{m_4}{(m_4)^2} - 3$, where m_j stand for the jth moment around the mean. Under the null-hypothesis of normality, the two statistics are normally distributed with standard errors, $\sigma_{sk} = \frac{\sqrt{6}}{N}$, and $\sigma_k = \frac{\sqrt{24}}{N}$, where N is the sample size.

(2) In fact, K2K test is a more general form of the test introduced by Brock, Dechert, and Scheinkman (1987), BDS, which is on testing the null-hypothesis that the data is independently and identically distributed, against unspecified alternative. Kocenda and Briatka (2005) developed a computer program for computing K2K statistics, and its critical values.

(3) Other nonparametric unit root tests include rank tests, developed by Breitung and Gourieroux (1997), Bierens (1987), and Granger et al (1997).

(4) It is not necessary to restrict d between –0.5 and 0.5, but then y_t will be non-stationary for d >0.5, or non-invertible for d <-0.5.

(5) Robinson (1995a) proved consistence of $\hat{\beta}$, so that $\sqrt{2m}(\hat{\beta} - \beta) \xrightarrow{d} N(0, \pi / 6)$

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Previous Publications

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