Testing Efficiency Performance of an Underdeveloped Stock Market

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Abstracts

Market inefficiency has influence on resource allocation, as price signals tend systematically understate or overstate the effects of information transmitted to the trading parties in the market. In this paper a number of statistical tests employed to assess the weak-form efficiency of Khartoum Stock Exchange (KSE) market. The finding of the paper indicates the inefficiency hypothesis cannot be rejected.

Keywords: Efficiency, unit root, volatility

1- Introduction:

The concept of an efficient market describes a market consisting of a large number of rational, profit maximizers actively competing with each other to predict future market values of individual securities and where important current information is almost freely available to all participants (Fama 1965). Thus if asset prices are to serve their function as signals for resource allocation they must successfully process and transmit all relevant information about future market developments to suppliers and demanders of the asset. Hence, for a stock market to be efficient, stock prices must always fully reflect all relevant and available information. In other words, a market is considered to be a sensitive processor of all new information with prices fluctuating in response to such information.

In inefficient market it takes a considerable time for the information to be dissiminated across the market, or that there is a tendency to either systematically understate or overstate the effects of such information on the price of the security. Abnormal security performance prior to an announcement may – but doesn't necessarily – imply that the market is inefficient. A market would be considered to be inefficient if anticipation effect was the result of purchases or sales by investors who have access to relevant information that has, for some reason, been withheld from the rest of the market, or the unique ability of some investors to use publically available information to predict more accurately announcements to be made.

The basic hypothesis underlying weak form efficiency is that 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.

In this paper, a number of statistical tests have been employed to test for weak-form efficiency of Khartoum Stock Exchange Market, after eight years from its operation. Testing the efficiency performance of KSE is topical as the government of Sudan has been launching for the past five years ambitious privatization programe relying on KSE in valuation of corporates.

The paper includes five sections. Section 2, highlights basic features of KSE. Section 3 describes the data used in the research. Section 4 shows the methodology of the research; and the final two sections includes the results of the emperical findings and the conclusion of the reasearch.

2-<u>Khartoum Stock Exchange Market</u>

KSE was officially started operating in 1994, with the objective of regulating and controlling the issuance of securities, and mobilizing private savings for investment in securities. Operations in the secondary market started in January 1995 with a listing of 24 companies. In the year 2004 the listed companies have increased to 46 companies. Despite its rapid growth in terms of market capitalization KSE is characterized as highly concentrated market as only top three companies constitute around 90% of the total market capitalization. And also considered an illiquid market as the shares of only three companies are tradable.

Securities traded in KSE are ordinary shares and investment units. Orders are handled through brokers during trading hours and shares prices are quoted in Sudanese dinars. All orders are processed manually, and trading in securities is taking place in the two markets, the primary and the secondary markets.

Despite its short history KSE has contributed a number of benefits to the investment climate in Sudan, among which, it promoted the auditing profession as one of the listing requirment of any company to submit audited accounts for the latest two years and every year after listing. And also enhanced awarness in securities investment as manifested in the increasing number of the investment funds in the country.

In terms of regulatory development indicators, KSE is still considered underdeveloped as it lags behind regional stock markets and have yet to furnish well regulated security trading environment, as this can be manifested in table (1).

Table(1): Regulatory and Institutional Development Indicators

	Market regulator	Clearing & settlement	International Custodian	Foreign participation	Exchange control	Trading System & days	Central Depository & reporting system
Tunisia	**yes**	**electronic**	**no**	**yes**	**Yes***	**Electronic 5 days**	**Yes local**
Egypt	**yes**	**electronic**	**yes**	**yes**	**no**	**Electronic 5 days**	**Yes intern**
Morocco	**yes**	**Manual****	**yes**	**yes**	**no**	**Electronic 5 days**	**Yes intern**
Khartoum	**no**	**Manual**	**no**	**yes**	**yes**	**Manual 5 days**	**No local**

Source: UNDP African Stock Markets Handbook, 2003

*For foreigners, sale of shares is restricted by elapse of six month period from the date of ownership.

**Efforts are underway to install electronic system for clearing and settlements.

3- Data desciption and analysis:

The data in this study is based on daily prices of three firms, whose shares are traded actively in the daily transactions of KSE, and constitutes 91% of the turn-over ratio of the total market transactions and 95% of total market capitalization in 2006. The sample period includes 967 observations during the period January, 2003 to April 2007.

The constituents of our sample include the following five firms[†]:

1/ Sudan Telecommunication Co.

2/ Gum Arabic Co.

3/ Sudanese-French Bank

Analysis of the price index series in table (2), shows KSE exhibit statistically insignificant autocorrelation function (ACF) coefficients in the four lag periods, as indicated by the calculated values of modified Box-Pierce statistic. This result violates the finding by Bekaert and Harvey (1995) that ACFs have some significant lag effects in stock

3- The weights in the index has been calculated using the average turn-over ratios for the constituents in the sample[†] returns of emerging markets‡. In terms of investment return, KSE shows, average monthly return of 0.2% during the sample period, reflecting the improving economic conditions for the past five years. Jarque-Bera test result of 172.6 with two degrees of freedom for joint normal Kurtosis and skewness reject the hypothisis of normality distribution of the return series.

Table (2): ACF

lag	ACF*	Modified Box-Pierce Statistic	Critical Values 5%
1	0.04	0.08	3.85
2	0.00	0.08	5.99
3	0.00	0.08	7.82
4	0.01	0.09	9.49

Modified Box-Pierce statistics known as LJung-Box-Pierce

*All values of ACF are insignificant

4- Methodology:

4.1: Dickey-Fuller Unit Root Tests

The augmented Dickey-Fuller (ADF) test is a test of unit roots in ARMA(p,q) model with unknown order. The ADF test, tests the null hypothesis that a time series y_t is I(1) against the alternative that that is I(0), assuming that the dynamic in the data have an ARMA structure. The ADF test is based on estimating the test regression

$$y_t = \beta' d_t + \theta y_{t-1} + \sum_{j=1}^{p} \psi_j \Delta y_{t-j} + \varepsilon_t$$

4-The insignificance of the autocorrelation coefficents in terms of KSE could be due to the aggregation of price series on monthly basis.‡

Where d_t is a vector of deterministic terms (constant, and trend).The p lagged difference terms, Δy_{t-j} are used to approximate the ARMA structure of the errors, and the value p is set so that the errors ε_t are serially uncorrelated. The error term is also assumed to be homoskedastic. The specification of the deterministic terms depends on the assumed behavior of y_t under the alternative hypothesis of trend stationary. Under the null-hypothesis, y_t is I(1) which implies that θ=1. The ADF t-statistic and normalized biased statistic are based on the least squares estimates of the regression equation above, given by

$$ADF_t = t_{\theta=1} = \frac{\hat{\theta}-1}{SE(\theta)}$$

$$ADF_n = \frac{T(\hat{\theta}-1)}{1-\hat{\psi}_1-\cdots-\hat{\psi}_p}$$

An alternative formulation of the ADF test regression is

$$\Delta y_t = \beta' d_t + \lambda y_{t-1} + \sum_{j=1}^{p} \psi_j \Delta y_{t-j} + \varepsilon_t$$

Where $\lambda=\theta-1$. Under the null-hypothesis, Δy_t is I(0) which implies that $\lambda=0$. The ADF t-statistic is then the usual t-statistic for testing $\lambda=0$ and the ADF normalized bias statistic is $T\hat{\lambda}/(1-\hat{\psi}_1-\cdots-\hat{\psi}_p)$.

An important practical issue for the implementation of the ADF test is the specification of the lag length p. If p is too small then the remaining serial correlation in the errors will bias the test. If p is too large then the power of the test will suffer. Ng and Perron (1993b) suggest the following data dependent lag length selection procedure that results in stable size of the test and minimal power loss. First, set an upper bound p_{max} for p.
Next, estimate the ADF test regression with $p=p_{max}$. If the absolute value of the t-statistic for testing the significance of the last lagged difference is

greater than 1.6 then set $p=p_{max}$ and perform the unit root test. Otherwise, reduce the lag length by one and repeat the process.

4.1: Phillips-Perron Unit Root Tests:

Phillips-Perron (1988) developed a number of unit root tests that have become popular in the analysis of Financial time series. The Phillips-Perron (PP) unit root tests differ from the ADF tests mainly in how they deal with serial correlation and heteroskedasticity in the errors. The test regression for the PP tests is

$$\Delta y_t = \beta' d_t + \lambda y_{t-1} + \mu_t \qquad (1)$$

Where μ_t is I(0) and may be heteroskedastic. The PP tests correct for any serial correlation and heteroskedasticity in the errors μ_t by using OLS estimation and modifying the test statistics $t_{\lambda=0}$ and $T\hat{\lambda}$. These modified statistics, denoted Z_t and Z_λ are given by

$$Z_t = \left(\frac{\hat{S}^2}{\hat{\omega}^2}\right)^{1/2} t_{\lambda=0} - \frac{1}{2}\left(\frac{\hat{\omega}^2 - \hat{S}^2}{\hat{\omega}^2}\right)\left(\frac{T.SE(\hat{\lambda})}{\hat{S}^2}\right)$$

$$Z_\lambda = T\hat{\lambda} - \frac{1}{2}\frac{T^2.SE(\hat{\lambda})}{\hat{S}^2}(\hat{\omega}^2 - \hat{S}^2)$$

Given that k lags used in the autocovariances, the Newey-West estimator can be used to yield consistent estimates of the variance parameters,

$$\hat{S}^2 = T^{-1}\sum_{t=1}^{T}\hat{\mu}_t^{\,2}$$

$$\hat{\omega}^2 = \hat{v}_0 + 2\sum_{j=1}^{K}[1 - \frac{j}{(k+1)}]\hat{v}_j$$

where,

$$\hat{v}_j = T^{-1}\sum_{t=j+1}^{T}\hat{\mu}_t\hat{\mu}_{t-j}$$

Estimated values of λ and its standard errors obtained from OLS results from equation (1). The sample variance of the least squres residual $\hat{u}$ is a consistent estimate of σ^2 , and the Newey-West long-run variance estimate of u using $\hat{u}$ is a consistent estimate of ω^2 .

Under the null hypothesis that $\lambda=0$, the Z_t and Z_λ statistics of the PP test have the same asymptotic distribution as ADF t-statistic and normalized bias statistics. One advantage of the PP tests over the ADF tests is that the PP tests are robust to general forms of heteroskedasticity in the error terms u_t. Another advantage is that the user does not have to specify a lag length for the test regression.

4.3: Stationarity test:

More recent researches, DeJong et al (1992a), and Diebold and Rudebusch (1991), detect low power evidences against the standard unit root tests of ADF and PP tests when the data exhibit stable autoregressive with roots near unity or when the data is fractionally integrated. To circumvent shortfalls of unit root tests, our research methodology in this paper includes, beside the unit root tests, stationarity test which test the null hypothesis of stationarity against the alternative of nonstationarity. A result of unit root in the data is concluded if the null hypothesis of ADF and PP tests are not rejected, while the null hypothesis of stationarity test is rejected. On the other hand, if the stationarity test do not reject the null, and the ADF and the PP tests reject the null of unit root, then the conclusion of the random walk hypothesis rejection is re-inforced.

The most comonly used stationarity test is, KPSS test which is due to Kwiatkowski, Phillips, Schmidt, and Shin (1992). To explain this test let y_t , t=1,2,….,T, be the observed series. It is assumed that y_t series can be decomposed into the sum of deterministic trend, a random walk, and stationary error or,

$$y_t = \beta t + r_t + e_t \qquad (1)$$

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

The r_t is I(0) and its initial value (r_0) is treated as fixed and play the same role of an intercept term of the regression equation. Notice that r_t is a pure random walk with innovation variance $\sigma_\varepsilon{}^2$.

The null-hypothesis that y_t is trend stationary is formulated as:

H_0: $\sigma^2{}_\varepsilon = 0$, which implies that r_t 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 (e_t) generated from the regression of y_t 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 test statistic as:

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

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

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

$$\hat{\sigma}^2(l) = T^{-1}\sum_{t=1}^{T} e^2{}_t + 2T^{-1}\sum_{s=1}^{l} w(s,l)\sum_{t=s+1}^{T} e_t e_{t-s} \qquad (3)$$

Where w(s,l) is an optional lag window. KPSS (1991) use the Bartlet window, $w(s,l) = 1 - s/(1+l)$, and they show that the test ststistic in equation (2) 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 (2) is shown as:

$$\hat{\eta}_u \xrightarrow{d} \int_0^1 v(r)^2 dr \qquad (4)$$

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

It should be noted that when testing for level stationarity the residuals, e_t, in equation (2) calculates the regression of y_t on a constant only or $e_t = y_t - \bar{y}$.

For trend stationarity the asymptotic distribution is given by:

$$\hat{\eta}_r \xrightarrow{d} \int_0^1 v_2(r)^2\, dr \qquad (5)$$

Where the second level Brownian bridge $v_2(r)$ is given by:

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

The upper tail critical values of equations (4) and (5) are reported in KPSS(1991) and replicated in the appendix with this study.

The calculated value of KPSS statistic for trend stationarity of KSE is o.018, which is highly insignificant under all significance levels..

4.4: The Variance Ratio Test:

To expose some elements of the Variance Ratio Test theory let x_t denote a stochastic process satisfying the following recursive relation:

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

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

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

4.4.1: The IID Gaussian Null Hypothesis:

Let the null-hypothesis denote the case where innovations are identically distributed normal random variables with variance σ^2 and suppose we obtain (nq+1) observations:

y_0 , y_1 ……y_{nq} of y_t , where both n and q are arbitrary intigers greater than one. Consider the following estimators for the unknown parameters μ and σ^2 :

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

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

The estimator $\hat{\sigma}_a$ is simply the sample variance of the first difference of y_t . Consider the variance of qth differences of y_t which under the null-hypothesis H_1, is q times the variance of first-diffences. By dividing by q we obtain the estimator $\hat{\sigma}_b{}^2\,(q)$ which also converges to σ^2 under H_1, 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 a distinct alternative estimator of σ^2 may 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

$H_r(q)=\frac{\hat{\sigma}_b^{\ 2}}{\hat{\sigma}_a^{\ 2}}-1$, which converges in probability to zero as well. Lo and MacKinlay (1988b) show that $H_r(q)$ possess the following limiting distribution under the null-hypothesis H_1:

$$\sqrt{nq}H_r(q) \sim \quad N(0,\frac{2(2q-1)(q-1)}{3q}) \qquad (6)$$

4.4.2:The Heteroskedstic Null Hypothesis

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

$M_r(q) \sim N(0,v(q))$

Where

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

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

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

Test of the null hypothesis of the heteroskedasticity under the normalized variance ratio, $z_2(q)$ 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 homeskedasticty (equation 6) under the normalized variance ratio can be shown as:

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

5: Results:

5.1: Unit root tests:

Null-hypothesis	Dicky-Fuller Test		Phillips –Perron Test	
	Test Statistic	Asy.Critical value (5%)	Test Statistic	Asy.Critical Value (5%)
$B_1=\lambda=0$	4.9	4.6	7.6	4.6

Since the test statistic values are greater than the critical value, both tests reject the null-hypothesis of unit root.

5.2: Stationarity test:

L	KPSS statistics	Critical values 0.05	0.01
1	0.0173	0.146	0.216
4	0.0176	0.146	0.126
8	0.0182	0.146	0.216

Values of KPSS statistics are highly insignificant at all critical levels, therefore trend stationarity hypothesis can not be rejected. This result, with the unit root tests result, signifies the rejection of the random walk hypothesis.

5.3: The Variance Ratio Test:

q	Z_1	P-value	Z_2	P-value
2	-1.49	0.06	-1.78*	0.03
3	-1.44	0.07	-1.81*	0.03
4	-1.68*	0.04	-2.19*	0.01

The P-values for the variance ratio test statistics of z_2 **,** are siginificant at the 5% significance level, and for z_1 only significant for q greater than 4. The null-hypothesis of random walk is rejected at all significant z values.

6- Concluding Remarks:

In this paper a number of statistical tests have been applied to assess the efficiency performance of Khartoum Stock Exchange Market. Our research results signify the inefficiency of Khartoum Stock Market. The rejection of the random walk hypothesis of KSE implies that successive price changes in individual securities are inter-related. Interdependence of security prices imply that the past history of price series change can be used to predict future price changes. What constitutes a meaningful prediction of future price changes depend on the purpose for which the data are being examined. For example, the investor wants to know whether the history of prices can be used to increase expected gains. In a random walk market, with either zero or positive drift, no mechanical trading rule applied to an individual security would consistantly outperform a policy of simply buying and holding the security. However, it should be noted that, although it is possible to construct models where successive price change are dependent, yet the dependence is not of a form which can be used to increase expected profits.

Since information inadequacy and lack of transparancy could be a major cause of the the factors preventing the efficient transformation of market signals, greater focus could be directed towards disclosure and transparancy requirments, which may require more effective capital market law that stipulates listing procedures, regulatory mechanisms and trading and settlement procedures that can be enhanced by:

1- Securites Exchange Commission (SEC) responsible for the issue of rules, regulations, instructions and enforcement of a capital market law.
2- Securities Deposit Centre responsible of the operations of deposit, transfer, settlements, clearing and registering ownership of securities traded on the exchange.
3- Regulations on brokerage business, on collective investment schemes, and disclosure and transparancy requirments, with sanctions and penalties for vilations.

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Appendix: 1

Upper tail critical values of the KPSS statistic:

Distribution	0.1	0.05	0.025	0.01
$\int_0^1 v(r)^2 dr$	0.347	0.463	0.574	0.739
$\int_0^1 v_2(r)^2 dr$	0.119	0.146	0.176	0.216

Source: KPSS(1992)