E C O N O M I C S B U L L E T I N

An analysis of the efficiency of the foreign exchange market in Kenya

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Abstract

This study examined the Efficiency Market hypothesis in its weak form using run tests, unit root tests and the Ljung-Box Q-statistics. The motivation was to determine whether foreign exchange rate returns follow a random walk. The data covered the period starting January 1994 to June 2007 for the daily closing spot price of the Kenya shillings per US dollar exchange rate. The main finding of this study is that the foreign exchange rate market is not efficient. The results showed that most of the rejections are due to significant patterns, trend stationarity and autocorrelation in foreign exchange returns. This is attributed to both exchange rate undershooting and overshooting phenomena.

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1.0 Introduction

The concept of market efficiency when used with respect to speculative markets means that market prices should fully and instantaneously reflect all information available to market participants (Fama, 1970). Therefore, it should be impossible to earn excess returns to speculation. Also past asset prices should not have any predictive ability. Interest in the foreign exchange markets efficiency goes back to the debate concerning whether, financial prices fully and instantaneously reflect all available information and how this affects economic efficiency.

Three forms of market efficiency can be distinguished based on the information used to form expectations of future prices (Fama, 1991). First, the weak form of efficiency in which security prices reflect all historical information. Second, the semi-strong form of efficiency in which security prices reflect all publicly available information. Third, the strong-form of market efficiency in which, security prices include all private information.

It was Bachelier (1900) who first suggested that asset prices in an efficient market are well described by a random walk and therefore they could be normally distributed. This argument gave birth to the random walk hypothesis (RWH) in which changes in asset prices do not display any pattern. Earlier test of market efficiency, therefore exclusively tested for randomness of asset prices and asset returns. The rationale is that if markets quickly impounded any new information into current asset prices (i.e. the market is efficient) then there could be no pattern in price changes hence asset prices are random.

Though many studies have been done on the efficiency of the foreign exchange markets in developed countries, little is known about these markets in developing economies. Extant literature on market efficiency in Kenya is limited (Kurgat, 1998; Ndunda, 2002; Muhoro, 2005; Kimani, 2007), self-contradictory and fraught with methodological problems (Kimani, 2007). Therefore, it is worth revisiting the issue of efficiency of the foreign exchange markets in Kenya and its implication for business policy.

This study employs a longer period of data and a different methodology to reexamine the efficiency of the foreign exchange rate market in Kenya. The Efficiency Market Hypothesis (EMH) is re-examined using the nominal exchange rate series for the Ksh/US dollar. The US dollar is the most traded currency on the spot market and is the denominator of most business transactions and asset valuations. The data covers the period from January 2, 1994 to June 30, 2007.

The study applied the run tests, unit root tests, and the Ljung-Box (LB) Q-statistics to analyze the efficiency of the foreign exchange market in Kenya. The RWH implies that foreign exchange rate returns follow a unit root process and are not auto-correlated. This study focused on these two features not only due to the fact that not all departures from the RWH can be captured by the unit root test but also because the autocorrelation feature has important implications for exchange rate model. For instance, autocorrelated increments suggest the possibility of either exchange rate overshooting or undershooting.

The results from the run tests show that there exist significant differences between actual and expected numbers of runs. Moreover, there appears to be important patterns in the differences between actual and expected number of runs of different signs. With the exception of the 1-day differencing interval, the differences between actual and expected number of runs are negative for plus and no change runs, and positive for minus runs. This means that the exchange rate has a higher tendency to appreciate than to depreciate. Thus the results suggest the presence of exchange rate undershooting and overshooting. There are also significant patterns in exchange rate returns that can be exploited for profit. The unit root test indicates that foreign exchange rates have unit roots while currency returns are trend stationary. The returns are also autocorrelated.

In summary, the evidence adduced in this study strongly suggests that the foreign exchange rate market in Kenya is not efficient. This is due to the presence of significant patterns in exchange rate returns, serial correlation and trend stationarity. The results also exhibit foreign exchange rate undershooting and overshooting phenomenon. The rest of the paper is organized as follows. Section 2 presents a brief literature review. Section 3 discusses the methodology. Section 4 presents the results of data analysis. Section 5 is the conclusion

2. Empirical Evidence on Spot Market Efficiency in Kenya

Evidence on the efficiency of the foreign exchange market in Kenya is not conclusive. Those studies that have examined this issue have approached it from two perspectives. There are studies that have analyzed the presence of profitable opportunities in the foreign exchange market (Kurgat, 1998; Muhoro, 2005), while others have tested the rationality of market participants (Ndunda, 2002; Kimani, 2007). All these studies agree that foreign exchange markets in Kenya are inefficient. However, they all arrived at this conclusion based on flawed empirical methodologies. Indeed, the evidence adduced by Kurgat (1998) and Muhoro (2005) with respect to the Kshs/US dollar spot market is counterfactual.

Kurgat (1998) found the annual mean return on speculation to be 51 cents per dollar or about 1 percent (using a mean exchange rate of Ksh. 58/US$ for the period). The corresponding returns for the Pound, Tanzanian shilling and Uganda shilling were 2%, 83% and 200%, respectively. Therefore, the rejection of the null hypothesis is mainly due to arbitrage in the last two markets for the Tanzanian shilling and the Ugandan shilling. Also the corresponding p-values for the US dollar, Sterling pound, Tanzanian shilling and Uganda shilling were 0.18, 0.27, 0.06 and 0.09. Thus only the returns on the Tanzanian shilling and the Ugandan shilling are significant.

Muhoro (2005) examined the presence of locational and triangular arbitrage in the currency market. Using data from both the forex bureaus and the commercial banks, she applied the same methodology like Kurgat (1998). On the basis of her analysis she rejects the null hypothesis that the foreign exchange market is efficient. However, a random check of the computed location and triangular arbitrage profits reveals serious logical and computational errors. For instance, using 15/05/2003 data for illustration, in commercial bank sector the highest buying prices for the Euro, US dollar and Sterling pound were Ksh. 82.45, Ksh. 76.35, and Ksh. 119.69, respectively. The corresponding lowest selling prices were Ksh. 77.27, Ks. 66.10 and Ksh. 106.47. This generates arbitrage profits of Ksh. 5.18, Ksh. 10.25 and Ksh. 13.22, respectively, on every unit of currency traded assuming zero transaction costs. However, in Appendix 2 of this study no locational arbitrage is reported for all currencies on this date.

Furthermore, using the following exchange rates as reported in the Daily Nation newspaper of the same date, one Sterling pound = US$ 1.6091, one Euro = US$ 1.1513, and the information above, we find that the triangular arbitrage profit for the Ksh to Euro to US$ to Ksh is Ksh. 81.40; for the Ksh to Sterling pound, to US$ to Ksh is Ksh. 154.83 and for the cycle from Ksh to Euro to pound is Ksh 276. The corresponding figures are, from Appendix 2, for banks Ksh 55.64, Ksh 66.51 and Ksh 54.65, respectively. The mean annual return on location arbitrage for banks are Ksh 0.04 or (0.00004%), 0.06 or (0.00006%) and 0.03 or (0.00003%) for the US$, pound and Euro, respectively, yet the conclusion is that the market is inefficient. While Kimani (2007) finding that foreign exchange rates are integrated of order two, I (2), contradicts available evidence that exchange rates are integrated of order one, I(1) (Noman and Ahmed, 2008).

Therefore, the results of these studies are flawed and the issue of the efficiency of the foreign exchange market in Kenya needs to be re-examined. The current study revisited the question of the weak form of efficiency of the foreign exchange market in Kenya focusing on the Kshs/US dollar spot market. However, it goes further than this by examining the genesis of the inefficiency in the foreign exchange rate market.

2.1 Stationarity of Foreign Exchange Rate Returns

The unit root test is designed to test whether the spot rate (S_t) is difference-stationary (null hypothesis) or trend-stationary (the alternate hypothesis). Though the RWH is contained in the unit root null hypothesis, its primary focus is on the permanent/temporary nature of shocks to the spot rate or exchange rate return. Empirical studies indicate that most macroeconomic time series data follow random walks. For instance, Noman and Ahmed (2008), Baillie and Bollerslev (1989), Meese and Singleton (1982) and Poole (1967) found a unit root process in the exchange rates. If time series variables are non-stationary all regression results with such series will be different from the classical theory of regression with stationary time series. This implies that regression coefficients with non-stationary time series will be misleading. Therefore, it became necessary to establish the level of stationarity or non-stationarity of the spot rate before carrying out further analysis. Kimani (2007) applied the unit root tests to the Ksh/USD spot rate and found evidence for a unit root after differencing the data twice. In this study we also focused on the order of differencing required to achieve stationarity to see whether Kimani (2007) over-differenced the data.

2.2 Serially Correlated Exchange Rate Returns

The use of unit root test for randomness is not sensitive to some departures from the random walk process such as serial correlation. Early empirical studies of the behavior of foreign exchange rates indicate that there is no serial correlation in the data thus exchange rates follow a random walk. The evidence is based on testing for uncorrelated increments in foreign exchange rates. Auto-correlation test is a reliable measure for testing of either dependence or independence of random variables in a series. The serial correlation coefficient measures the relationship between the values of a random variable at time ***t*** and its value in the previous period.

Autocorrelation test provides evidence whether the correlation coefficients for residuals are significantly different from zero. The presence of serial correlation in time series data can be tested using the Ljung-Box Q-statistics (LB), Variance ratio test and the Chow-Denning test – a multiple VR test. This study employed the LB test due to its popularity in econometric literature.

Giddy and Dufey (1975), Cornell and Dietrich (1978), Logue, Sweeny and Willet (1978), and Hsieh (1989) applied the serial correlation test to foreign exchange rate data and found uncorrelated increments in exchange rates. There are several causes of serial correlation in the foreign exchange market such as exchange rate overshooting or undershooting, risk aversion, herding and government intervention. Yet there is little evidence on the causes of failure of the EMH from developing countries. Kimani (2007) argues that autocorrelation could be caused by irrational market participants.

3.0 Empirical Methodology

3.1 Run Tests

A run is a sequence of price changes of the same sign. In the exchange returns, three different types of runs can be identified: positive, negative and zero price changes. The objective of a run test was to determine whether exchange returns are independent and identically distributed **(IID).** This is the strongest postulate of the **EMH**. In this section runs were tested by examining the differences between expected and actual numbers of runs in three ways. First, the total actual number of runs irrespective of sign, and the total expected number were analyzed. Second, the total expected and actual numbers of plus, minus and zero change runs were examined. Thirdly, for runs of each sign the expected and actual numbers of runs of each length were computed.

3.1.1 Actual and Expected Number of Runs

The total expected number of runs of all signs for the Kshs/US$ exchange rates were calculated as follows:

$$m = \left[N(N+1) - \sum_{i=1}^{3} n_i^2 \right] / N \tag{1}$$

Where N is the total number of returns, and n_i are the numbers of returns of each sign. The distribution of m is approximately normal for large N and δ_m the standard error of m is calculated as

$$\delta_m = \left(\frac{\sum_{i+1}^{3} \left[n_i^2 + N(N+1) \right] - 2N \sum_{i+1}^{3} n_i^2 - N^3}{N^2(N-1)} \right)^{1/2} \tag{2}$$

The magnitude of the dependence is measured by the size of the difference between the total actual numbers of runs and the total expected numbers. These differences are standardized in two ways. First, the difference between the actual number of runs, R, and the expected number can be expressed by means of the standardized variable.

$$K = \frac{\left(R + 1/2\right) - m}{\delta_m} \tag{3}$$

The ½ in the numerator is a discontinuity adjustment factor. For large samples K will be approximately normal with mean zero and unit variance. Secondly, it is measured by the $(R-m)/m$ value.

3.1.2 Actual and Expected Number of Runs of Each Sign

If the signs of price variation are generated by random process with probabilities ***P (+)***, ***P (-),*** and ***P (0)*** for the positive, negative and zero exchange returns, the expected number of positive, negative and zero returns is the product of the respective probabilities and the total number of price changes. Positive, negative and zero returns are realized when the exchange rate depreciates, appreciates or is constant, respectively. For large samples, the expected number of plus runs of length ***i*** in a sample of ***N*** returns is approximated by:

$$NP(+)^{i} \tag{4}$$

The expected number of negative and zero return runs of all lengths are calculated in the same manner.

In this section the study focused on the differences between the expected breakdown by sign of the total ***actual*** number of runs and the ***actual*** breakdown of the actual number of signs. The reason is that in most differencing intervals there are differences between the total actual numbers of all signs and the total expected numbers. The above formulae were used to calculate the expected numbers of runs of each sign for all differencing intervals of one four, nine and sixteen days. Moreover, the actual numbers of runs, and the differences between the actual and expected numbers have been calculated. The differencing intervals were limited by the length of the data stream.

3.2 The Unit Root Tests

To examine the issue surrounding non-stationarity and unit roots associated with spot rates, we used an Augmented Dickey-Fuller **(ADF)** test, which allows for serial correction in the error term $\boldsymbol{\varepsilon_{t+k}}$. This was important since unit root tests of spot rates series should take into account any seasonality in the generation of time-series data. The equation used for conducting **ADF** test has the general structure of equation (5).

$$\Delta S_t = \alpha_0 + \beta_1 t + \rho_1 S_{t-1} + \sum_{k=1}^{n} \delta_k \Delta S_{t-k} + \varepsilon_t \tag{5}$$

Where Δ is the first difference operator, ΔS_t = ***St – St-1*** , δ_k are coefficients, β_1 is the coefficient of the time trend for S_t rates, P_1 is the coefficient of the lagged 1st difference of S_t , t is the time trend, ε_t is a white noise error term. In equation (11), if (i) β_1 = 0 and $\rho_1<1$ then the series S_t is stationary; (ii) if β_1 = 0 and $\rho_1 = 1$ then the series is non-stationary, (iii) if $\beta_1 \neq 0$ and $\rho_1<1$ then the series is trend-stationary (i.e. stationary around a deterministic linear time trend).

3.3 The Serial Correlation Tests (Ljung-Box Q-statistics)

One of the ways to test for the presence of autocorrelation is to regress equation (6) and check whether the $\boldsymbol{y_i}$’s, i=1, 2, 3… n are all equal to zero suggests no autocorrelation.

$$\Delta E_t = E_{t-1} + y_1 \Delta E_{t-1} + y_2 \Delta E_{t-2} + y_3 \Delta E_{t-3} + ... + y_n \Delta E_{t-n} + \varepsilon_t \tag{6}$$

Where $\boldsymbol{E}_t$ is the residual from the regression; $\boldsymbol{y_i}$ = coefficient of the lagged residuals, while ΔE_t = $E_t - E_{t-1}$. If autocorrelation is present, this will imply that participants in the foreign exchange market are not rational. Ljung-Box **Q** statistics were used to test for autocorrelations. Ljung-Box Q statistics follows the chi-square distribution with ***m*** degrees of freedom as shown in equation (7).

$$LB = n(n+2)\sum_{k=1}^{m}\left(\hat{p}_k^2 / n-k\right) \equiv x^2 \quad (7)$$

Where $\hat{p}_k^2$ is the autocorrelation coefficients at lag ***k***; and ***n*** = sample size.

4.0 Empirical Results

4.1 Summary Statistics

One implication of the EMH is that exchange returns are normally distributed. The objective of this section is to test the EMH by examining the nature and type of distribution that can best describe the behavior of foreign exchange returns in Kenya from January 1994 to June 2007. Table 1 below provides the summary statistics for returns over the sample period.

The mean returns at all sampling intervals are negative. This implies that on average the exchange rate has been appreciating. The variance of the returns is low on a daily basis compared to the weekly and monthly sampling intervals. Indeed, the variance of exchange returns is highest when data is sampled on a weekly basis. This means that volatility is highest when measured from one week to another compared to daily or monthly intervals. The results also indicate that the returns are positively skewed at the daily and weekly intervals but negatively skewed at the monthly interval. This suggests that the exchange rate has a general tendency to appreciate at longer sampling intervals. The results also demonstrate that exchange returns are highly leptokurtic. This means that there are more extreme movements in exchange rates than one would expect under the assumption of a normal distribution. These extreme returns are more likely at the daily and weekly sampling intervals than at longer horizons. The returns do not conform well to the normal distribution as shown by the Bera-Jaque statistics. The returns are also highly serially correlated as indicated by the LB statistics.

4.2 Run Tests

The results in Table 2 show that there exist significant differences between actual and expected number of total runs. The actual number of runs is greater than the expected number at all differencing intervals. In Table 3, the difference between actual and expected number of runs are negative for plus and positive for minus runs. Therefore this suggests that exchange rate changes are nonlinear and asymmetrical. This means that the foreign exchange rate depreciates less and appreciates more than is expected. The pattern also implies that the exchange rate has a higher tendency to appreciate than to depreciate. However, this behavior pattern declines with the increase in the differencing interval. The returns are also positively auto-correlated. Table 4 shows, for the runs of each sign, the probability of a run of each length and the expected and actual numbers of runs of each length. Evidently, the distribution of the runs by sign and length differ significantly from the normal distribution.

In Table 5 the magnitude of the deviations of actual number of runs from the expected number of runs decline with increasing run length. The number of actual runs for plus sign is less than the expected number of plus runs. While the number of actual runs for minus sign is more than the expected number of plus runs. There is also an important pattern in the magnitude differences. For instance, the differences between actual and expected number of plus and minus runs change sign when the run length exceeds 7 for 1-day and 4-day differencing intervals. Also, the actual number of no change runs exceeds the expected number of runs for 1-day and 4-day differencing intervals and converge to zero for higher intervals.

Table 6 shows the absolute dependence in the total actual and total expected number of runs standardized by the standard deviation and the mean. In large samples K is normally distributed with a zero mean and variance of one. The results show that the actual number of runs is more than three standard deviations above the expected number for almost all run lengths and all differencing intervals. The standard deviations from the mean decline with the increase in run lengths up to seven runs. The deviations of the actual number of runs from the expected number of runs as a proportion of the mean are also very significantly different from zero. The deviations from the mean increase with the differencing interval and the run length.

In conclusion, therefore, the actual breakdown of runs by signs differs very significantly from the breakdown that would be expected if the signs were generated by a random process. Thus the results strongly suggest that significant patterns exist in foreign exchange rate returns that can be exploited for profit by the speculators. Hence the foreign exchange market is not efficient.

4.3 The Results of the Unit Root Tests in Foreign Exchange Rates Market

The results for testing the stationarity of the foreign exchange returns are presented in Table 7 below. The null hypothesis was that the foreign exchange rates are stationary. The alternative hypothesis was that foreign exchange rates are nonstationary (i.e. have a unit root). The decision rule was based on rejecting the null hypothesis if the computed ADF statistics are less than (or greater than in absolute values) than the critical values in Fuller (1976). As a matter of procedure, this test was performed in level form and then in first differences. The ADF was performed with different autoregressive orders until the series was consistent with white noise error terms. To achieve stationarity the spot rate series was differenced once. The results show that the series was non-stationary in levels and stationary in first difference form. Therefore, the Ksh/USD foreign exchange rate is integrated of order one, I (1), while foreign exchange returns are trend stationary. This results contradicts Kimani (2007) finding that the exchange rate is integrated of order two, I (2). In summary, therefore, the foreign exchange rate market is not efficient.

4.4 Uncorrelated Increments

The autocorrelation test is the most commonly used test for dependence among financial data. The results for applying the serial correlation test using Ljung-Box Q statistic are displayed in Table 8. The lag structure was selected to correspond to daily, weekly, bi-weekly, tri-weekly, monthly, one and a half months, 3 months, six months and annual intervals. This reflects the typical decision making horizons for different market participants. For instance, a one-day trading interval is typical of speculators in the market, one-month trading interval is typical of exporters and airlines, six months horizon is typical of the Central Bank and a one-year horizon is characteristic of pension funds. The null hypothesis of no autocorrelation was tested and the results are presented below. The Q-statistic is significant at the conventional levels for all relevant lags. Indeed, the Q-statistic increases with the lag length. The results, therefore, indicate that the exchange returns are not random.

Overall evidence from analysis of data does not support the EMH. The findings are consistent across samples and the entire study period.

5.0 Conclusions

This study examined the RWH using the run tests, Ljung-Box statistics, and the unit root tests. The data covered the period starting January 1994 to June 2007 for the daily closing prices of the Ksh/UD dollar spot rate. The main finding of this study is that the RWH is strongly rejected at the 5% significance level. The results indicate that the rejections are due to autocorrelation in currency returns. The exchange rate tends to appreciate most of the time over the sample period. Therefore failure of the EMH could be due to exchange rate undershooting and overshooting phenomena. The unit root tests showed that the exchange rate data is non-stationary while returns are stationary. Therefore the evidence strongly suggested that the foreign exchange market is not efficient.

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Table 1 Summary Statistics of Returns

	Daily	Weekly	Monthly
Sample size	3382	677	160
Mean	$-6.9x\ 10^{-6}$	-0.00027	-0.00136
Variance	0.005921	8.48	1.11
Skewness	3.51	5.7175	-5.8582
Kurtosis	136.065	107.6955	54.7308
Bera-Jaque	0.0000	0.0000	0.0000
LB (levels)	0.0000	0.0000	0.0000
LB (Squares)	0.0000	0.0000	0.0000

Notes: This table reports the summary statistics for exchange returns for the sample period from January 2, 1994 to June 30, 2006. The data is sampled at the daily, weekly and monthly intervals. The Bera-Jaque (BJ) statistics provides a test for normality of the data. The Ljung-Box (LB) statistics measure the degree of autocorrelation in levels and squares of the returns. The figures for BJ and LB are *p*-values.

Table 2 The Total Actual and Expected Numbers of Runs for 1-, 4-, 8- and 16- Day Differencing Intervals

	Daily	Four-day	Eight-day	Sixteen-day
Actual	3,388	427	214	106
Expected	1,729	216	107	54
Difference	1,659	211	107	52

Notes: This table shows the total actual and expected number of runs at one day, one week (4-day), two weeks (8-day) and one month (16-day) differencing intervals for the sample period from January 1994 to June 2007.

Table 3 Actual and Expected Numbers of Runs for 1-, 4-, 8- and 16- Day Differencing by Sign

	Daily		4-Day		8-Day		16-Day	
Sign	+	-	+	-	+	-	+	-
Actual	1589	1760	191	232	99	115	48	58
Expected	1729	1729	216	216	107	107	54	54
Difference	**-140**	**31**	**-25**	**16**	**-8**	**8**	**-6**	**4**

Notes: This table shows the total actual and expected number of runs by sign at one day, one week (4-day), two weeks (8-day) and one month (16-day) differencing intervals for the sample period from January 1994 to June 2007.

Table 4 Total Expected and Total Actual Distributions of Runs by Length

Length	Plus Runs			Minus Runs			No Change runs		
	Prob.	**Exp.**	**Actual**	Prob.	Exp.	**Actual**	Prob.	**Exp.**	**Actual**
1	0.53	1729	1589	0.48	1729	1760	1.00	39	39
2	0.24	993	916	0.25	993	1075	0.05	0	2
3	0.11	609	552	0.14	609	677	0.00	0	0
4	0.05	387	341	0.08	387	446	0.00	0	0
5	0.02	254	218	0.05	254	301	0.00	0	0
6	0.01	169	140	0.03	169	209	0.00	0	0
7	0.00	114	89	0.07	114	154	0.00	0	0
8	0.02	41	58	0.00	41	31	0.00	0	0
9	0.00	1	38	0.00	1	0	0.00	0	0
10	0.01	18	25	0.00	18	13	0.00	0	0
Total	**1.00**	**4,314**	**3,966**	**1.00**	**4,311**	**4,666**	**1.00**	**39**	**41**

Notes: This table shows the actual and expected number of runs by sign and run length and their probabilities for the sample period from January 1994 to June 2007.

Table 5 Runs Analysis by Sign and by Length (L)

Panel A: 1-Day Differencing Interval

Length	Plus runs			Minus runs			No change runs		
	(1) A	(2) E	(1)-(2) D	(3) A	(4) E	(3)-(4) D	(5) A	(6) E	(5)-(6) D
1	1589	1729	-140	1760	1729	31	39	39	0
2	916	993	-77	1075	993	82	2	0	2
3	552	609	-57	677	609	68	0	0	0
4	341	387	-46	446	387	59	0	0	0
5	218	254	-36	301	254	47	0	0	0
6	140	169	-29	209	169	40	0	0	0
7	89	114	-25	154	114	40	0	0	0
8	58	41	17	31	41	-10	0	0	0
9	38	1	37	0	1	-1	0	0	0
10	25	18	7	13	18	-5	0	0	0
Total	**3,966**	**4,314**	**-348**	**4,666**	**4,314**	**352**	**41**	**39**	**2**

Panel B: 4-Day Differencing Interval

Length	Plus runs			Minus runs			No change runs		
	(1) A	(2) E	(1)-(2) D	(3) A	(4) E	(3)-(4) D	(5) A	(6) E	(5)-(6) D
1	191	216	-25	232	216	16	4	0	4
2	101	120	-19	144	120	24	0	0	0
3	58	73	-15	96	73	23	0	0	0
4	32	43	-11	63	43	20	0	0	0
5	19	28	-9	45	28	17	0	0	0
6	13	19	-6	31	19	12	0	0	0
7	9	14	-5	22	14	8	0	0	0
8	6	6	0	4	6	-2	0	0	0
9	5	1	4	0	1	-1	0	0	0
10	4	4	0	3	4	-1	0	0	0
Total	**438**	**524**	**-86**	**620**	**524**	**96**	**4**	**0**	**4**

Panel C: 8-Day Differencing Interval

Length	Plus runs			Minus runs			No change runs		
	(1) A	(2) E	(1)-(2) D	(3) A	(4) E	(3)-(4) D	(5) A	(6) E	(5)-(6) D
1	99	107	-8	115	107	8	0	0	0
2	52	60	-8	68	60	8	0	0	0
3	25	33	-8	44	33	11	0	0	0
4	12	18	-6	28	18	10	0	0	0
5	6	10	-4	18	10	8	0	0	0
6	4	7	-3	12	7	5	0	0	0
7	2	4	-2	9	4	5	0	0	0
8	0	1	-1	1	1	0	0	0	0
9	0	-	0	0	-	0	0	0	0
10	0	1	-1	1	1	0	0	0	0
Total	**198**	**241**	**-43**	**296**	**241**	**55**	**0**	**0**	**0**

Panel D: 16- Day Differencing Interval

Length	Plus runs			Minus runs			No change runs		
	(1) A	(2) E	(1)-(2) D	(3) A	(4) E	(3)-(4) D	(5) A	(6) E	(5)-(6) D
1	48	54	-6	58	54	4	0	0	0
2	25	30	-5	34	30	4	0	0	0
3	15	19	-4	21	19	2	0	0	0
4	8	11	-3	14	11	3	0	0	0
5	4	7	-3	10	7	3	0	0	0
6	2	4	-2	7	4	3	0	0	0
7	1	3	-2	4	3	1	0	0	0
8	0	1	-1	2	1	1	0	0	0
9	0	-	0	0	-	0	0	0	0
10	0	-	0	0	-	0	0	0	0
Total	**103**	**129**	**-26**	**150**	**129**	**21**	**0**	**0**	**0**

Notes: This table shows the actual and expected number of runs by sign and run length and their difference at 1-day, 4-day, 9-day, and 16-day differencing interval for the sample period from January 1994 to June 2007. A=Actual, E=expected, D=Difference

Table 6 Runs Analysis: Standardized Variables and Percentage Differences

Length	Daily		Four day		Eight day		Sixteen day	
	K	(R-m)/m	K	(R-m)/m	K	(R-m)/m	K	(R-m)/m
1	57.81	0.96	58.50	0.99	20.83	0.97	14.76	0.99
2	45.16	1.01	52.06	1.01	16.62	1.05	11.31	1.00
3	37.78	1.02	46.20	1.02	14.00	1.10	9.62	1.10
4	29.05	1.03	40.75	1.04	12.04	1.19	8.70	1.25
5	23.96	1.04	36.57	1.05	11.14	1.31	8.20	1.40
6	20.18	1.07	33.27	1.07	9.27	1.28	6.72	1.28
7	17.96	1.14	30.17	1.08	7.92	1.25	8.38	1.58
8	11.31	1.15	120.60	7.20	3.30	0.72	-	-
9	-	37.00	-	188.00	-	4.00	-	-
10	7.47	1.10	85.16	6.32	2.61	0.58	-	-

Notes: This table shows the total actual (R) and total expected number of runs (m) and their difference for the sample period from January 1994 to June 2007 standardized by the standard deviation and the mean.

Table 7 Results of the Unit Root Test for the Ksh/USD Spot Rate January 1994 to June 2007

Variable	**Computed Statistic**	**Decision**
S_t	77.2448	Reject H_o
ΔS_t	-1.5847	Accept H_o

Note: Critical values for ADF are as follows: -4.04 at 1% and -3.45 at 5% significance levels (Fuller, 1976: 373, Table 8.5.2)

Table 8 Autocorrelation Test Results

LAG	1	5	10	15	20	30	60	120	240
Q-statistic	277.4	305.5	305.5	332.7	341.9	346.1	374.9	427.5	631.9
P	.000	.000	.000	.000	.000	.000	.000	.000	.000

Notes: The table describes the results of the autocorrelation test at different lag length. The lag length is in days. Q-statistic is the Box-Ljung Q-statistic while P is the probability associated with it.