Efficiency of the Foreign Exchange Market of Papua New Guinea During the Recent Float

Abstract

This paper examines the validity of the efficient market hypothesis (EMH) for the foreign exchange market of Papua New Guinea (PNG) using data on spot exchange rates for four major foreign currencies during the recent float. The unit root test results indicate that all the four exchange rates are random walks supporting the weak–form of the EMH. However, the Johansen multivariate cointegration test, the Granger causality test and variance decomposition analysis provide evidence that there are long-run as well as short-run predictable relationships among the spot exchange rates, refuting the validity of EMH in its semi-strong form. Further, evidence is found that the Australian dollar plays a vital role in driving the movements of exchange rates in PNG. These results have important implications for participants in the foreign exchange market and policy makers in PNG.

Key Words: Efficient market hypothesis, Papua New Guinea, foreign exchange market, Japanese yen, Variance decomposition

JEL Classifications: F31, G14

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After the collapse of the Bretton-Woods system in 1973, most countries around the world adopted a floating exchange rate system. Under this system, the exchange rate for a currency with another currency is determined by the demand for, and supply of, that particular currency. Therefore, as in the case of a fixed exchange rate system, the need for government invention in the foreign exchange market can be avoided or limited as the market clears the excess supply of, or demand for, a currency in determining the exchange rate. One of the major reasons for the adoption of a floating exchange rate system was to remedy the balance of payments crises that some countries had been facing.

Although the fixed exchange rate system of most countries was abolished in 1973 for various reasons, Papua New Guinea (PNG) continued to adhere to it for the Kina, from independence in 1975 untill October 1994. In October 1994, the Kina commenced trading as a floating currency[1] resulting in a reduction in demand for imports, to some extent. However, any increase in domestic demand for imports will adversely affect exchange rates, and hence the balance of payments, unless it is not associated with a proportionate increase in exports. Therefore, one of the policy objectives of PNG has been to manage domestic demand and minimise its adverse effects on imports and external balance. Such a policy will result in optimal exchange rates with the currencies of the trading partners of PNG. In a recent study, Kannapiran (2002) found evidence that domestic demand management policy in PNG must be targeted to maintain external balance and a stable exchange rate.

During the floating exchange rate regime, foreign exchange markets around the world have been subjected to tests of efficiency by many researchers. This increased interest has been due to the important implications that the efficiency of a foreign exchange market has for government authorities and other market participants. If foreign exchange rates are unpredictable, as implied by the efficient market hypothesis originally due to Fama (1970), the need for government intervention in the market is minimal. On the other hand, an inefficient foreign exchange market provides opportunities for profitable foreign exchange transactions for speculators. Participants in an inefficient foreign exchange market can use various devices such as trading rules and statistical techniques to predict the movement of exchange rates. Further, government authorities can determine the best way to influence exchange rates, reduce exchange rate volatility and evaluate the consequences of different economic policies on exchange rates (Pilbeam, 1992).

Although there are a large number of studies examining the efficient market hypothesis (EMH) in relation to developed and certain developing countries, to the knowledge of the author there are no studies examining the efficiency of the foreign exchange market of PNG. The objective of the current study is, therefore, to investigate the efficiency of the foreign exchange market of PNG during the recent floating exchange rate period. The results of such a study will be an important aid to participants in the foreign exchange market as well as to government policy-making bodies such as the Bank of PNG when making informed judgments in relation to the movements of foreign exchange rates.

Overview of the Literature

Efficient market hypothesis (EMH)

The EMH has three forms (Fama, 1970): the weak, semi-strong and strong form. Each version reflects a different degree of information in the prices of financial assets. The weak version of the EMH asserts that the prices of financial assets reflect all the information contained in past prices. Therefore, no person can use past data on the prices of financial assets to predict the future values of such assets. In other words, the prices of financial assets behave randomly, or without any identifiable pattern.

On the other hand, the semi-strong version of the EMH says that the prices of financial assets reflect all publicly available information. In the case of exchange rates, publicly available information would include data releases on interest rates, inflation, exchange rates for currencies other than the one we are concerned with, and other macroeconomic variables. Since exchange rates are expected to rapidly adjust to releases of such information, no person can use publicly available information to predict the movements of exchange rates.

The strong form of the EMH indicates that the prices of financial assets reflect, in addition to the information contained in past prices and publicly available information, inside information. Therefore, even a central bank officer cannot use his or her knowledge of inside information to predict future values of exchange rates. This version of the EMH encompasses both the weak and semi-strong versions.

Empirical tests of the EMH

Since the publication of Fama's seminal work on the EMH, foreign exchange markets, especially those in developed countries, have been extensively subjected to tests of efficiency using different econometric techniques. These techniques are mainly aimed at determining whether (a) a spot exchange rate for a currency behaves as a random walk, (b) the forward rate for a currency is an unbiased predictor of the future spot exchange rate for that currency, and (c) there are cointegrating relationships among several currencies. The first type of tests can be categorised as weak-form efficiency tests whereas the second and third type of tests can be categorised as semi-strong form efficiency tests. Empirical studies using these different methodologies have provided mixed evidence.

The first type of tests were carried out using such techniques as the autocorrelation test, the Ljung-Box Q-statistic, variance ratio tests, technical trading rules and runs tests. For example, Liu and He (1991) used a variance ratio test and Gupta (1981) employed an autocorrelation test, Box-Pierce statistic, runs test, filter rules and cross-correlation tests in studies on weak-form efficiency. In addition, developments in techniques for testing unit root tests provided another methodology to examine the random walk properties of financial time series (see Bleaney (1998) and Baillie and Bollerslev (1989). The second type of tests were performed using the ordinary least squares regression method, particularly before the development of cointegration techniques (see Levich (1978), Frankel (1980, 1982), Edwards (1983), Boothe and Longworth (1986) and Taylor (1988)). After the latter half of the 1980s, there was a significant change in the methodologies employed to test the efficiency of foreign exchange markets and this was due to the development of the bivarite cointegration techniques of Engle and Granger (1987) and the multivariate cointegration techniques of Johansen (1988) and Johansen and Juselius (1990). These techniques were used by researchers to examine the unbiasedness of the forward rate as a predictor of the future spot rate (see, for example, Norrbin and Reffertt (1996), Wesso (1999) and Barnhart *et al*. (1999). In addition, several studies employed cointegration tests to see whether there are long-run co-movements among several exchange rates. Among others, Ballie and Bollerslev (1989), Hakkio and Rush (1989), Lajaunie *et al*. (1996), Masih and Masih (1996), Singh (1997), Sanchez-Fung (1999) and Speight and McMillan (2001) employed this methodology in their studies on the efficiency of foreign exchange markets.

Econometric Procedure and Data

This paper applies unit root tests, the multiple cointegration methodology of Johansen (1991, 1995), Granger (1969) causality tests and variance decomposition analysis to investigate the EMH in relation to the foreign exchange market of PNG. In what follows, these tests are briefly explained.

Unit root tests

Unit root tests are conducted to examine whether spot exchange rates follow random walks in accordance with the weak version of EMH. Unit roots are tested using the Augmented Dickey-Fuller (1979, 1981) (ADF) test and the Phillips-Perron (1988) (PP) test.

Augmented Dickey Fuller test

The Augmented Dickey-Fuller (ADF) test is conducted by estimating the following equation:

$$\Delta x_t = a_0 + b_0 x_{t-1} + \sum_{i=1}^{k} c_0 \Delta x_{t-1} + w_t \qquad (1)$$

where Δ is the difference operator, a_0, b_0 and c_0 are coefficients to be estimated, x is the variable whose unit roots are examined and w is the white-noise error term. Since the ADF test results are sensitive to the choice of the lag length (Thornton and Batten, (1985)), Akaike Information Criterion (AIC) is used to select the optimal lag length of the ADF regression. The test for a unit root using equation (1) consists of testing the null hypothesis that $b_0 = 0$ (or that the series is non-stationary) against the alternative hypothesis that $b_0 < 0$ (or the series is stationary). Dickey and Fuller (1979) proved that the t-statistic of the coefficient b_0 in equation (1) has a non-standard distribution and, therefore, they tabulated critical values for selected sample sizes. Recently, MacKinnon (1996) estimated the response surfaces using their simulation results enabling the calculation of Dickey-Fuller critical values for any sample size and for any number of variables. Therefore, critical values tabulated by MacKinnon are used in drawing inferences with respect to the time series properties of the variables used in this paper.

Phillips-Perron test

The Phillips-Perron (PP) (1988) test suggests a non-parametric method of controlling for higher order autocorrelation in a series. This test is based on the following first order auto-regressive (AR(1)) process:

$$\Delta y_t = \alpha + \beta y_{t-1} + \varepsilon_t \tag{2}$$

where y_t is the variable of interest, Δ is the difference operator, α is the constant, β is the slope and t is a subscript for time. The non-parametric correction is made to the t-ratio of the β coefficient from equation (2) to account for the autocorrelation of ε_t. This correction is based on an estimate of the spectrum of ε_t at zero frequency that is robust to heteroskedasticity and autocorrelation of unknown form. In this paper, this estimation is based on Bartlett kernel. The optimal bandwidth in the PP equation is selected using the Newey-West (1994) method. Critical values tabulated by MacKinnon (1996) are used in making inferences regarding the time series properties of the variables.

Cointegration and Granger causality tests and variance decomposition analysis

Cointegration and Granger causality tests and variance decomposition analysis are used to test the semi-strong version of the EMH. One condition when applying cointegration tests is that the variables entering the cointegrating equation should be integrated of the same order. If the variables are integrated of the same order, the second step is to test for cointegration among the variables of interest. Johansen's multiple cointegration test is based on the following vector autoregression equation:

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + Bx_t + \varepsilon_t \qquad (3)$$

where y_t and x_t are, respectively, a k-vector of non-stationary $I(1)$ variables and a vector of deterministic variables and ε_t is a vector of innovations.

In making inferences about the number of cointegrating relations, two statistics known as the trace statistic and the maximal eigenvalue statistic are used. The trace statistic is determined using the following formula:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \log(1-\hat{\lambda}_i) \qquad r = 0, 1, 2, \ldots, n-1$$

where T is the number of observations and $\hat{\lambda}_i$ is the ith eigenvalue.

The maximum eigenvalue statistic is determined using the following formula:

$$\lambda_{\max} = -T\log(1-\hat{\lambda}_{r+1}) \qquad r = 0, 1, 2, \ldots, n\text{-}2, n\text{-}1$$

To make inferences regarding the number of cointegrating relationships, the trace and maximum eigenvalue statistics are compared with the critical values tabulated in Osterwald-Lenum (1992).

According to Engle and Granger (1987), if two variables are cointegrated, there exists an error-correction model of the following form[2]:

$$\Delta x_t = a_1 + b_1 ect_{1t-1} + \sum_{i=1}^{m} c_1 \Delta x_{t-i} + \sum_{i=1}^{n} d_1 \Delta y_{t-i} + e_{1t} \quad (4)$$

$$\Delta y_t = a_2 + b_2 ect_{2t-1} + \sum_{i=1}^{m} c_2 \Delta y_{t-i} + \sum_{i=1}^{n} d_2 \Delta x_{t-i} + e_{2t} \quad (5)$$

where x_t and y_t are the variables which are cointegrated, Δ is the difference operator, m and n are the lag lengths of the variables[3], ect_{1t} and ect_{2t}[4] are the residuals from the cointegrating equation and e_{1t} and e_{2t} are the white-noise residuals.

The error-correction model opens up another channel of causality through the error-correction term which is ignored in standard Granger causality tests. Therefore, causality can also be tested by examining (i) the statistical significance of the error-correction term by a separate t-test, (ii) the joint significance of the lags of each explanatory variable by an F- or Wald χ^2 test; or by testing (iii) the error-correction terms and lagged term of each explanatory variable simultaneously by a joint F- or Wald χ^2 test.

Granger causality test results can be interpreted as within-sample causality tests and can be used to make inferences about causal relationships within the sample period only. Therefore, to make inferences on causal relationships beyond the sample period, variance decomposition analysis is used. In variance decomposition analysis, variance of the forecast error of a particular variable is partitioned into proportions attributable to innovations (or shocks) in each variable in the system, including its own. If a variable can be optimally forecast from its own lags, then it will have all its forecast variance accounted for by its own disturbances (Sims, 1982).

Data used in the study consist of the natural log values of the monthly nominal exchange rates of the Kina for the Australian dollar (A$), US dollar (US$), Japanese yen (Yen) and UK pound (UKP) for the floating exchange rate period (January 1995 to September 2002). These data were obtained from the website of the Bank of PNG.

Empirical Results

Table 1. Unit root test results for the spot exchange rates

Exchange rate	ADF	PP
Panel A. Levels of exchange rate		
With a constant in the test equation		
A$	-0.751 (0)	-0.679 (2)
US$	-0.416 (0)	-0.381 (1)
Yen	-0.330 (1)	-0.411 (4)
UKP	-0.442 (0)	-0.417 (1)
With a constant and a time trend in the test equation		
A$	-2.797 (0)	-2.800 (2)
US$	-2.488 (0)	-2.538 (3)
Yen	-1.891 (0)	-1.963 (4)
UKP	-2.344 (0)	-2.447 (3)
Panel B. First differences of exchange rate		
With a constant in the test equation		
A$	-10.254 (0)[a]	-10.279 (2)[a]
US$	-10.462 (0)[a]	-10.460 (2)[a]
Yen	-10.213 (0)[a]	-10.190 (4)[a]
UKP	-10.031 (0)[a]	-10.030 (1)[a]
With a constant and a time trend in the test equation		
A$	-10.197 (0)[a]	-10.219 (2)[a]
US$	-10.407 (0)[a]	-10.405 (2)[a]
Yen	-10.173 (0)[a]	-10.153 (4)[a]
UKP	-9.979 (0)[a]	-9.979 (1)[a]

Notes: a implies statistical significance at the one per cent level. A$, US$, Yen and UKP are the spot exchange rates of the Kina in terms of the Australian dollar, US dollar, Japanese yen and UK pound, respectively. Lag lengths used in each unit root test are given within brackets with the unit root test statistics. The lag length criteria used are Akaike Information Criterion and the Newey-West method using Bartlett kernel for the ADF test and PP test respectively.

Table 1 reports results of unit root tests for the four exchange rates using ADF and PP tests. The unit root tests were performed including a constant and a constant and a linear time trend in the test equations. The results for the levels of exchange rates reported in Panel A of the table indicate that all four exchange rates accept the null hypothesis that exchange rates have unit roots. These results indicate that the exchange rates follow random walks indicating that the foreign exchange market of PNG is weak-form efficient.

Because the levels of the exchange rates are not stationary, the first differences of the exchange rates were examined to see whether they are stationary or reject the null hypothesis of a unit root. The results reported in Panel B of the table show that the null hypothesis of a unit root is overwhelmingly rejected for the first differences of all four exchange rates at the one per cent level of significance. Since the first differences of all the exchange rates are stationary or integrated of order one, it is possible to proceed to the next step of testing for cointegration among the four exchange rates.

Table 2. Johansen and Juselius test results for cointegration among the four exchange rates

Null Hypothesis	Trace Statistics	5% Critical Value	1% Critical Value	Maximal Eigen Value Statistics	5% Critical Value	1% Critical Value
$r = 0$	75.811[a]	53.12	60.16	32.079[b]	28.14	33.24
$r \leq 1$	43.732[a]	34.91	41.07	27.792[a]	22.00	26.81
$r \leq 2$	15.940	19.96	24.60	12.987	15.67	20.20
$r \leq 3$	2.952	9.24	12.97	2.952	9.24	12.97

Notes: a and b imply statistical significance at the one and five per cent level, respectively. Five lags were included in the vector autoregression determined by the likelihood ratio. The Pantula principle selected the cointegration equation with no deterministic trend (restricted constant). Critical values given in columns five and six were obtained from Osterwald-Lenum (1992).

Table 2 reports the Johansen and Juselius test to examine whether there is any long-run co-movement or cointegration among the four exchange rates. Two test statistics, trace and maximum eigenvalue, are used to examine the cointegrating properties among the currencies. The values of the trace test statistic are shown in column two of the table with five and one per cent critical values in columns three and four, respectively. The trace statistic results are significant at the one per cent level for the first two null hypotheses shown in column one of the table. In other words, trace test results show that there are two cointegrating relationships among the four currencies. Similar results are provided by the maximum eigenvalue test statistics reported in column five of the table together with their critical values in columns six and seven, respectively. These results indicate that the foreign exchange market of PNG is not efficient in the semi-strong form as the movement of a particular exchange rate is related to the movement in the other exchange rates.

Table 3. Temporal causality test results based on the vector-error correction model

Dependent variable	Short-run causality, Chi-square statistics				Error-correction term, *t*-statistics	
	ΔA$	ΔUS$	ΔYen	ΔUKP	ECT1	ECT2
ΔA$	-	8.885	4.336	4.173	0.166	-0.886
ΔUS$	1.914	-	2.474	3.423	0.300	-0.376
ΔYen	3.440	11.908[b]	-	11.986[b]	1.869	-0.185
ΔUKP	2.488	8.543	5.107	-	1.791	-1.810

Notes: b implies statistical significance at the five per cent level. Two error-correction terms were included in the error-correction models as there were two cointegrating relationships among the four exchange rates. ECTs are the estimated t-statistics testing the null hypotheses that each ECT is statistically significant. The number of lags in the VECM was selected using the likelihood ratio test.

The cointegration tests are meant to detect the long-run co-movements among a set of non-stationary variables. The short-run dynamics among cointegrated variables can be examined using vector error-correction models. Therefore, vector error-correction models were estimated for the four exchange rates and estimation results are reported in Table 3. The significance of the Chi-square test statistics for the hypothesis that all the lags of a particular exchange series are zero in the vector error-correction model for a currency indicates a causal relationship. A causal relationship is also indicated by a significant *t*-statistic for the error-correction term. The results show that there are two causal relationships from the US dollar and the UK pound to the Japanese yen. The error-correction terms are not statistically significant in any of the error-correction models. Therefore, the identified causal relationships are of a short-run nature.

Table 4. Variance decomposition results for the spot exchange rates

Months	Relative variance in	Percentage of forecast variance explained by innovations in			
		A$	US$	YEN	UKP
1	A$	100.00	0.00	0.00	0.00
12		92.11	4.58	3.11	0.19
24		91.58	3.79	3.84	0.79
36		92.29	3.42	3.39	0.90
1	US$	68.75	9.40	0.00	21.85
12		66.83	15.35	0.84	16.98
24		68.67	13.23	0.85	17.26
36		71.78	12.01	0.67	15.53
1	YEN	60.46	0.17	25.12	14.25
12		78.54	5.35	12.08	4.03
24		86.71	3.91	6.43	2.95
36		89.62	3.70	6.44	2.24
1	UKP	66.15	0.00	0.00	33.84
12		76.09	10.63	0.49	12.79
24		75.97	10.62	0.62	12.79
36		76.77	10.31	0.59	12.33

Notes*:* Figures in the first column refer to months after a once-only shock. Cholesky ordering for the variance decomposition was log(A$), log(UKP), log(US$) and log(YEN). Variance decompositions for the months 1, 12, 24 and 36 only, are reported. Variance decomposition results for the other months are available from the author upon request. All figures in columns three to eight have been rounded to two decimal places.

Table 4 reports the results of variance decomposition analysis for each exchange rate used in the analysis. Column one shows the months for which percentage variance decompositions are shown in columns three to six for the currencies shown in column two. The Granger causality test shows only the in-sample causal relationships whereas the variance decomposition analysis reveals out-of-sample causal relationships. According to the results reported in columns three to six, out of the four exchange rates only the Australian dollar exchange rate is exogenous as most of its variance at different forecast horizons is accounted for by itself. The US dollar exchange rate and the Japanese yen exchange rate account for less than five per cent of the variance of the Australian dollar exchange rate at any horizon. The percentage variance of the Australian dollar exchange rate explained by the Japanese yen is very small (less than one per cent) at any horizon.

When the US dollar exchange rate is considered, more than sixty per cent of its variance is explained by the Australian dollar at the four forecast horizons considered. The US dollar and the UK pound exchange rates together, account for more than twenty five per cent of the variance of the US dollar at all the forecast horizons considered. These results indicate that the movements of the US dollar exchange rate are caused mainly by the other exchange rates, other than Japanese yen exchange rate which accounts for less than one per cent of the variance of the US dollar exchange rate, at all the forecast horizons considered.

The Australian dollar exchange rate itself accounts for more than sixty per cent of the variability of the yen exchange rates at all forecast horizons. An interesting feature of the yen exchange rate is that the longer the forecast horizon, the larger the amount of variation explained by the Australian dollar exchange rate. However, the US dollar exchange rate accounts for a smaller amount of the variation in yen exchange rates than the yen exchange rate itself, so does the UK pound exchange rate, at all forecast horizons. The results for the UK pound exchange rate are similar to those for the US dollar exchange rate. Overall, the results indicate that the Australian dollar is the major currency causing the movements in other exchange rates in PNG.

Conclusions and Policy Implications

This paper examines the validity of the efficient market hypothesis to the foreign exchange market of a developing country, such as PNG. Unit root test results provide strong evidence that the spot exchange rates of PNG follow random walks. These results are consistent with the weak version of the efficient market hypothesis which asserts that the current prices of financial assets are unpredictable from their history. However, the results of cointegration and Granger causality tests and variance decomposition analysis provide evidence against the validity of the semi-strong form of the efficient market hypothesis which asserts that prices of financial assets cannot be predicted using publicly available information. Further, variance decomposition analysis shows that the Australian dollar is the major currency that drives the movements of other exchange rates in PNG. These results indicate that participants in the foreign exchange market and policy-making authorities can predict the movement of a particular spot exchange rate from the movement of other exchange rates.

The above results have important implications for both the participants in the foreign exchange market of PNG and policy-making bodies such as the Bank of PNG. Participants in the foreign exchange market of PNG can engage in speculative activities such as buying and selling foreign currencies to make profits. However, they should consider the transaction costs involved before engaging in such speculative activities. Policy-making bodies can determine the best way to influence the exchange rates and limit exchange rate volatility. Further, an inefficient foreign exchange market enables policy makers to better evaluate the consequences of alternative economic policies on exchange rates.

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Notes

[1] From October 1994, the exchange rate of the Kina with the US dollar has been the closing rate set by the foreign exchange auction. Exchange rates of the Kina with the other currencies are obtained by crossing the US dollar/Kina exchange rate with the mid-point of the closing buying and selling rates at 4.00 pm, PNG time.

[2] When there are more than two variables, the lags of each variable appear as independent variables in each error-correction equation.

[3] There are several criteria used to select the optimal number of lags to be included in the regression equations such as AIC, BIC, FPE, HQC, and likelihood ratio test. Out of these, the likelihood ratio test is used to select the optimal number of lags of the variables in the error-correction model.

[4] As Engle and Granger (1987) and Miller and Russek (1990) point out, more than one lag of the error-correction term is unnecessary. The effects of additional lagged error-correction terms are already captured in the distributed lags of x_t and y_t.