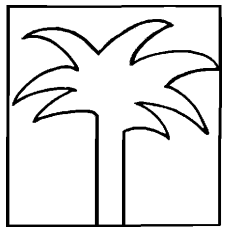

Is the PNG foreign exchange market efficient?

Guneratne B. Wickremasinghe

This paper examines the validity of the efficient market hypothesis (EMH) for the PNG foreign exchange market. Empirical tests support the EMH in its weak form. However, various tests provide evidence that there are predictable long and short-run relationships among the spot exchange rates, refuting the validity of the EMH in its semi-strong form. Further, there is evidence that the Australian dollar plays a key role in movements of exchange rates in Papua New Guinea.

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Following the collapse of the Bretton Woods system of exchange rates in 1973, a few countries adopted floating exchange rate regimes.[1] By the mid 1990s, the number of countries that had floated their currencies had expanded considerably. Under a floating system, the exchange rate for a currency is determined by the demand for, and supply of, that particular currency. Therefore, unlike under fixed exchange rate systems, the need for government intervention in the foreign exchange market can be avoided or limited, as the market clears the excess supply of, or demand for, the currency. Floating exchange rate systems were adopted in order, among other things, to avoid recurring balance of payments crises.

Papua New Guinea, like many other developing countries, maintained a fixed rate currency regime from independence in 1975 until October 1994. In October 1994, in the wake of a fiscal crisis that resulted in the loss of almost all of Papua New Guinea's foreign reserves, the kina was floated,[2] resulting in a at least partial reduction in demand for imports. Any increase in demand for imports will adversely affect the exchange rate and the balance of payments, unless it is associated with a similar increase in exports.

One of the PNG authorities' prime policy objectives, therefore, has been to manage domestic demand and minimise its adverse effects on imports and the external balance (Kannapiran 2002:91).[3] Such a policy will result in optimal exchange rates with the currencies of Papua New Guinea's major trading partners. Kannapiran (2002) found evidence that domestic demand management policy in Papua New Guinea must be targeted at maintaining external balance and a stable exchange rate.

Since floating exchange rate regimes have become more widely used, foreign exchange markets around the world have been subjected to tests of efficiency by many researchers. This 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 (EMH) (originally formulated by Fama 1970), the need for government intervention in the market is minimal. On the other hand, an inefficient foreign exchange market provides speculators with opportunities for profitable foreign exchange transactions. 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 use this information to 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).

To the author's knowledge, there has been no test of the EMH with respect to Papua New Guinea's foreign exchange market. Therefore, the objective of this study was to investigate the efficiency of the foreign exchange market since the kina was floated. The results of the study should be an aid to participants in the foreign exchange market as well as to government policymaking bodies, such as the Bank of Papua New Guinea, when making judgments with respect to movements of foreign exchange rates.

Overview of the literature

The efficient market hypothesis

The EMH has three forms (Fama 1970): weak, semi-strong and strong. Each form of the hypothesis reflects different views about the amount of information reflected 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.

The semi-strong version of the EMH states that the prices of financial assets reflect all publicly available information. In the case of exchange rates, publicly available information includes releases of information about interest rates, inflation, and exchange rates for other currencies, as well as information about other macroeconomic variables. Since exchange rates are expected to adjust rapidly to releases of such information, no one can use publicly available information to predict the movements of exchange rates.

The strong form of the EMH states that the prices of financial assets reflect, in addition to the information contained in past prices and publicly available information, 'inside' information. Therefore, in this case, even central bank officers cannot use their knowledge of inside information to predict future values of exchange rates. This form of the EMH encompasses both the weak and semi-strong forms.

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 various econometric techniques. These techniques are mainly aimed at determining whether a spot exchange rate for a currency behaves as a random walk; the forward rate for a currency is an unbiased predictor of the future spot exchange rate for that currency; and there are cointegrating relationships amongst currencies. The first type of test is categorised as a weak-form efficiency test, whereas the second and third types are categorised as semi-strong form efficiency tests. Studies using these different statistical techniques have provided mixed evidence.

The weak-form efficiency tests have been carried out using statistical techniques such as the auto-correlation 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. Developments in statistical techniques for testing unit root tests have provided another methodology for examining the random walk properties of financial time series (see Bleaney 1998; Baillie and Bollerslev 1989).

The second type of test has been performed using ordinary least squares regression—particularly before the development of cointegration techniques (see Levich 1978; Frankel 1980, 1982; Edwards 1983; Boothe and Longworth 1986; Taylor 1988). In the second half of the 1980s there was a significant change in the techniques employed to test the efficiency of foreign exchange markets due to the development of the bivariate 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, studies employed cointegration tests to see whether there are long-run co-movements among exchange rates. Among others, Baillie 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 technique 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 PNG foreign exchange market. These tests are briefly explained below.

Unit root tests

Unit root tests are used to examine whether spot exchange rates follow a random walk 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[4]

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

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, t is a subscript for time, 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), the 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 Dickey-Fuller simulation results, enabling the calculation of Dickey-Fuller critical values for any sample size and for any number of variables. Therefore, critical values tabulated in 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.

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

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 for applying cointegration tests is that the variables in 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.

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

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.

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

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

According to Engle and Granger (1987), if two variables are cointegrated, there exists an error-correction model of the following form[5]

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

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

where x_t and y_t are the variables that are cointegrated, Δ is the difference operator, m and n are the lag lengths of the variables,[6] ect_t[7] denotes 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 the statistical significance of the error-correction term by a separate t-test; the joint significance of the lags of each explanatory variable by an F or Wald χ^2 test; or by testing 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 about 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–September 2002). These data were obtained from the *Quarterly Economic Bulletin* of the Bank of Papua New Guinea.

Empirical results

Table 1 reports results of unit root tests for the four exchange rates using ADF and PP tests. The unit root tests were performed by including only a constant in the test equations, as the tests indicated that the model with a constant was preferred to the model with a constant and a time trend. This was true for all four exchange rates. The results for the levels of exchange rates reported in Panel A of the table indicate that the null hypothesis that exchange rates have unit roots is accepted for all four exchange rates. These results suggest that the exchange rates follow random walks and that the foreign exchange market of Papua New Guinea 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, it is possible to proceed to the next step of testing for cointegration among the four exchange rates.

Table 2 reports the Johansen and Juselius test of whether there is any long-run co-movement or cointegration among the four exchange rates. Two test statistics, the 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, the 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 PNG foreign exchange market is not efficient in the semi-strong form

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)*	–10.279 (2)*
US$	–10.462 (0)*	–10.460 (2)*
Yen	–10.213 (0)*	–10.190 (4)*
UKP	–10.031 (0)*	–10.030 (1)*
With a constant and a time trend in the test equation		
A$	–10.197 (0)*	–10.219 (2)*
US$	–10.407 (0)*	–10.405 (2)*
Yen	–10.173 (0)*	–10.153 (4)*
UKP	–9.979 (0)*	–9.979 (1)*

Notes: * 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 the Akaike Information Criterion and the Newey-West method using the Bartlett kernel for the ADF test and PP test, respectively. F-tests indicated that the preferred data generating process for the four exchange rates is represented by the model with a constant. Therefore, the time trend was not included in the test equations (Enders 1995:222–24).

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

Null hypothesis	Trace statistics	5 per cent critical value	1 per cent critical value	Maximal eigenvalue statistics	5 per cent critical value	1 per cent critical value
r = 0	75.811*	53.12	60.16	32.079**	28.14	33.24
r ≤ 1	43.732*	34.91	41.07	27.792*	22.00	26.81
r ≤ 2	15.940	19.96	24.60	12.987	15.67	20.20
r ≤ 3	2.952	9.24	12.97	2.952	9.24	12.97

Notes: * and ** 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 were obtained from Osterwald–Lenum (1992).

as the movements in a particular exchange rate are related to movements in the other exchange rates.

Cointegration tests are used 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 the 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 statistically significant in two of the error-correction models. These results indicate that the identified causal relationships for the yen / kina exchange rate are of short-run and long-run nature while that for the UK pound exchange rate is of a long-run nature.

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

When the US dollar / kina exchange rate is considered, more than 60 per cent of its variance is explained by the Australian

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[*]	1.869[**]	0.185
ΔUKP	2.488	8.543	5.107	-	1.791[**]	1.810[**]

Notes: * and ** imply statistical significance at the five and ten per cent levels, respectively. 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.

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	-	-	-
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	-	-	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.

dollar / kina exchange rate at the four forecast horizons considered. The US dollar / kina and the UK pound / kina exchange rates together account for more than 25 per cent of the variance of the US dollar / kina exchange rate at all forecast horizons considered. These results indicate that the movements of the US dollar / kina exchange rate are caused mainly by the other exchange rates—other than the Japanese yen / kina exchange rate, which accounts for less than one per cent of the variance of the US dollar / kina exchange rate at all forecast horizons considered.

The Australian dollar / kina exchange rate accounts for more than 60 per cent of the variability of the yen / kina exchange rate at all forecast horizons. An interesting feature of the yen / kina exchange rate is that the longer the forecast horizon, the larger the amount of variation explained by the Australian dollar / kina exchange rate. However, the US dollar / kina exchange rate accounts for a smaller amount of the variation in the yen / kina exchange rate than the yen / kina exchange rate itself; and so does the UK pound / kina exchange rate, at all forecast horizons. The results for the UK pound / kina exchange rate are similar to those for the US dollar / kina exchange rate. Overall, the results indicate that the Australian dollar is the major currency causing the movements in other exchange rates in Papua New Guinea.

Conclusions and policy implications

This paper examines the validity of the efficient market hypothesis for the foreign exchange market of Papua New Guinea. Unit root test results provide strong evidence that the spot exchange rates 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. These results suggest that participants in the foreign exchange market and policymaking authorities can do better than a coin toss in predicting the movement of a particular spot exchange rate from the movement of other exchange rates.

These results have implications for both the participants in the foreign exchange market and policymaking bodies such as the Bank of Papua New Guinea. Participants in the foreign exchange market stand some chance of making a profit from engaging in speculative activities such as buying and selling foreign currencies. However, they should consider the transaction costs involved before engaging in such speculative activities.

For their part, policymaking bodies can use this information to determine the best way to influence exchange rates and limit exchange rate volatility. Further, an inefficient foreign exchange market allows policy makers to better evaluate the consequences of economic policies on exchange rates. However, a strong qualification is in order. The results of this study should be used cautiously as the kina primarily trades against the US dollar, while the other currencies are very thinly traded.

Notes

[1] For example, in 1983 Australia became the tenth country to adopt a floating exchange rate system.

[2] From October 1994, the exchange rate of the kina with the US dollar was the closing rate set by the foreign exchange auction. Exchange rates of the kina with other currencies are obtained by crossing the US dollar / kina exchange rate with the mid-point of the closing buying and selling rates at 4pm, PNG time.

[3] In 1994, the PNG government was forced by the fiscal crisis to introduce a stabilisation program to restore internal and external balance.

[4] The test equation with a constant is compared with the test equation with a constant and a time trend in order to select the better data generating process. This comparison is based on the ϕ_3 statistic of Dickey and Fuller (1981).

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

[6] Several criteria are 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.

[7] 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.

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