EFFICIENCY OF FOREIGN EXCHANGE MARKETS: A DEVELOPING COUNTRY PERSPECTIVE

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Abstract

This study tests weak and semi-strong form efficiency of the foreign exchange market in Sri Lanka using six bilateral foreign exchange rates during the recent float. Weak-form efficiency is examined using unit root tests while semi-strong form efficiency is tested using co-integration and Granger causality tests and variance decomposition analysis. Results indicate that the Sri Lankan foreign exchange market is consistent with the weak -form of the Efficient Market Hypothesis. However, the results provide evidence against the semi - strong version of the Efficient Market hypothesis. These results have important implications for government policy makers and participants in the foreign exchange market of Sri Lanka.

Key Words: Efficient market hypothesis, Sri Lanka, foreign exchange market, Japanese yen, Variance decomposition

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1. INTRODUCTION

Efficient market hypothesis (EMH) that is originally due to Fama (1965) asserts that in an efficient market, prices always fully reflect available information. EMH has three forms: weak, semi-strong and strong reflecting different degrees of information. When a market is weak-form efficient, its prices reflect all the information available in the past history of prices or returns of foreign currencies. In a semi-strong form efficient market prices of financial assets instantly reflect publicly available information. On the other hand, in a strong-form efficient market, prices of financial assets reflect even inside information. Accordingly, in an efficient market, participants cannot use (i) past prices or returns of a financial asset, (ii) publicly available information or (iii) information available to the insiders of the market to devise any rule to beat the market consistently. Strong form of the EMH encompasses both weak and semi-strong versions of the EMH.

Since the publication of Fama's seminal work, foreign exchange markets especially in developed countries, have been extensively subjected to the tests of efficiency using different econometric techniques (see, Cumby and Obstfeld, 1984; Taylor, 1988; Edwards, 1983; Hakkio and Rush, 1989; Taylor and MacDonald, 1989; Singh, 1997; Serletis, 1997). However, since of late there have been several studies in this area using data from developing countries as well (see, Masih and Masih, 1996; Sarwa, 1997; Los, 1999). These studies provide mixed evidence. Whether a foreign exchange market is efficient and what model best predicts exchange rate movements have policy implications of enormous importance (Pilbeam, 1992). If the foreign exchange market is efficient, the need for government intervention is minimal. On the other hand, an inefficient foreign exchange market provides opportunities for profitable foreign exchange transactions. Participants in an inefficient foreign exchange market can use various devises such as trading rules and statistical techniques to predict the movement of exchange rates. Further, the government authorities can determine the best way to influence exchange rates, reduce exchange rate volatility and evaluate the consequences of different economic policies.

To the knowledge of the author, there are no previous empirical studies on the applicability of EMH to Sri Lankan foreign exchange market. The objective of this paper is to test the efficiency of the Sri Lankan foreign exchange market during the recent floating exchange rate regime. Forward exchange rates are not published by the Central bank of Sri Lanka as the market for forward contracts is not yet well developed. Therefore, the scope of the study is limited to the efficiency of the spot foreign exchange market. Weak-form efficiency is tested using unit root tests. Semi-strong form efficiency is examined using three techniques: cointegration, Granger causality and variance decomposition analysis. Test of strong-form efficiency is a topic for future research.

The remainder of the paper is organized as follows: Section 2 sets out the econometric methodology used. Section 3 then discusses the data and empirical results of the study and Section 4 concludes the paper.

2. ECONOMETRIC METHODOLOGY

Empirical tests of foreign exchange market efficiency have been carried out using different econometric techniques. These methodologies have mainly aimed at determining whether (a) a spot exchange rate behaves as a random walk (Liu and He, 1991; Bleaney, 1998), (b) forward exchange rate is an unbiased predictor of future spot exchange rate (Norrbin and Refferett, 1996; Wesso, 1999; Barnhart et al., 1999; Zacharatos and Sutcliff, 2002) or (c) whether there is a cointegrating relationship among a set of spot exchange rates (1996; Masih and Masih, 1996; Sanchez-Fung, 1999; Speight and McMillan, 2001).

This paper adopts Engle and Granger (1987) (EG) bivariate and Johansen (1991, 1995) multivariate cointegration tests. These procedures are carried out in two steps. The first step in the analysis is to test for the order of integration of the variables. Order of integration is the number of times variables have be differenced before they become stationary. A condition to apply both of the above tests is that the variables entering the cointegrating equation should be integrated of the same order. To test the degree of integration of the variables, two well-known tests are used. The first test is the Augmented Dickey-Fuller (1979, 1981) (ADF) test and the second test is the Phillip-Perron (1988) (PP) test. Unit root tests provide evidence on whether the exchange rates follow random walks. Therefore, they are also a test of the weak-form of the EMH.

According to Engle and Granger (1987), if two variables are cointegrated, there exists a cointegrating relationship between them. In the EG method, cointegration is tested by regressing one variable on the other and testing whether the residuals of the estimated regression equation are stationary. In this paper, ADF, PP, and CRDW (Cointegration Regression Durbin-Watson) test are used to test the stationarity of the residuals obtained from the bivariate cointegration equations.

The Johansen multiple cointegration test is based on the following vector autoregression equation.

$$y_t = A_1 y_{t-1} + \ldots + A_p y_{t-p} + Bx_t + \varepsilon_t \tag{1}$$

where y_t is a k-vector of non-stationary $I(1)$ variables, x_t is 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 trace statistic and maximal eigenvalue statistic are used. The trace statistic tests the null hypothesis that there are at most r cointegrating vectors against the alternative hypothesis of r or more cointegrating vectors. Meanwhile, the maximal eigenvalue statistic tests r cointegrating vectors against the alternative of $r+1$ cointegrating vectors. To make inferences regarding the number of cointegrating relationships, trace and maximum eigenvalue statistics are compared with the critical values tabulated by Osterwald-Lenum (1992).

If two variables are cointegrated, there exists an error-correction model of the following form (Engle and Granger, 1987):

$$\Delta x_t = a_1 + b_1 ect_{1t-1} + \sum_{i=1}^{m} c_1 \Delta x_{t-i} + \sum_{i=1}^{n} d_1 \Delta y_{t-i} + e_{1t} \tag{2}$$

$$\Delta y_t = a_2 + b_2 ect_{2t-1} + \sum_{i=1}^{m} c_2 \Delta y_{t-i} + \sum_{i=1}^{n} d_2 \Delta x_{t-i} + e_{2t} \tag{3}$$

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, ect_{1t} and ect_{2t} are the residuals from the cointegrationg equations 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 that is ignored in standard Granger causality tests. Therefore, causality can also be tested by examining the statistical significance of (i) the error-correction term by a separate t-test, (ii) by testing the joint significance of the lags of each explanatory variable by an F or Wald χ^2 test; or (iii) by a test of error-correction terms and lagged terms of each explanatory variable simultaneously by a joint F or Wald χ^2 test.

Granger causality test results can be used to test causality within the sample period only. Therefore, to make inferences on causality beyond the sample period, the variance decomposition analysis is used. In the variance decomposition analysis, the 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)

3. DATA AND EMPIRICAL RESULTS

Data used in this paper consist of average monthly nominal spot exchange rates for Japanese yen (JPY), the UK pound (GBP), the US dollar (USD), French franc (FRF), Indian rupee (INR) and German mark (DM) for the period January 1986 to November 2000. They were obtained from the Central Bank of Sri Lanka.

Table 1 about here

Table 1 reports the results of the ADF test for unit roots in the six real exchange rates for levels and the first differences of the natural log values. Interestingly all the exchange rates under consideration are not stationary in their levels and become stationary when they are first differenced. Level of significance of the ADF statistics for all currencies is one percent. These results are consistent with the weak form of the EMH that says financial time series behave as random walks. In other words, past exchange rates cannot be used to predict future exchange rates. Therefore, the participants in the foreign exchange market cannot devise any statistical technique to gain from foreign exchange market transactions consistently.

Table 2 about here

Table 2 reports the results of the PP test for a unit root in the six real exchange rates. The PP test also produces results similar to those of ADF test, except for the German mark exchange rate. However, the ADF regression for this currency has a lower AIC (Akaike information criterion) value. Therefore, this variable can be considered as having a random walk on the basis of the ADF test results. The level of significance of the PP statistics is one percent for all the currencies. These results again confirm the results of the ADF test indicating that the foreign exchange rates in Sri Lanka behave as random walks providing support for the weak-form of the EMH.

One requirement of the EG and Johansen techniques is that for there to be a cointegrating relationship, variables under consideration should be integrated of the same order. Therefore, all the exchange rates being integrated of the same order allows us to carry out EG bivariate cointegration test as well as the Johansen multiple cointegration test.

Table 3 about here

Table 3 reports the results of EG bivariate test for cointegration. In column one all the possible pairs of currencies that can be used to test for cointegration are shown. The first currency shown in each pair has been regressed on the second currency of the same pair to obtain the residuals on which ADF, PP and CRDW tests were performed. Column three of the table reports the ADF test statistics to test for the stationarity of residuals from each regression equation. According to the results, nine cointegration equations (30%) have whitenoise residuals when ADF test is used. This means that there is a cointegrating relationship between the currencies in each of these pairs. The co-movement between currencies indicates that one of the currencies in the pair can be predicted from the other currency. Therefore, such co-movements indicate a violation of the semi-strong form EMH. If a foreign currency market is efficient in the semi-strong form, exchange rates at a particular point in time reflect all the available information. Available information includes information available in exchange rates other than the one with which are concerned.

Column four of the table reports the PP test statistics to test whether the regressions of pairs of currencies in column one contain statinary residuals or whether currencies in each pair are cointegrated. The results are consistent with ADF test results except that one additional pair of currencies is cointegrated (Japanese yen and Indian rupee when the former is regressed on the latter).

The last column of the table reports the results of CRDW test for cointegration between each pair of currencies. This test indicates that none of the pairs of currencies is cointegrated. These results are consistent with the semi-strong form of the EMH. However, since ADF and PP tests are more suitable tests of cointegration than CRDW, their results can be accepted as revealing the true cointegrating properties.

Table 4 about here

Johansen's test results for each possible pair of currencies are reported in Table 4. Results reported for trace and maximum eigen value tests respectively in columns five and six indicate that there are only two conintegrating relationships. That is, between German mark and French franc and Sterling pound and Japanese yen. The cointegrating relationship between German mark and French franc is significant at the one percent level and that between the sterling pound and the Japanese yen is significant at the five percent level. These results indicate that around 98% (28 pairs out of 30) of the exchange rate pairs are not cointegrated. Therefore, these results provide strong evidence that the Sri Lankan foreign exchange market is efficient in the semi-strong sense.

Table 5 about here

Table 5 reports the Johansen multivariate test for the cointegration among the six exchange rates. The trace statistic reveals that there is one cointegrating relationship among the six exchange rates. Since the trace statistic takes into account all of the smallest egenvalues, it possesses more power than the maximum eigenvalue statistic (Kasa, 1992; Serletis and King, 1997). Further, Johansen and Juselius (1990) recommend the use of the trace statistic when there is a conflict between these two statistics. Therefore, this result indicates that there is a long-run co-movement among these six exchange rates. In other words, the value of any currency out of the six currencies can be predicted using the values of the other currencies. This is a violation of the efficiency of the foreign exchange market in its semi-strong form.

Table 6 about here

Temporal causality test results reported in Table 6 indicate five bivariate causal relationships. Results show two causal relationships from the UK pound and the US dollar to Indian rupee, one causal relationship from the UK pound to Japanese yen, one causal relationship from Indian rupee to the US dollar and one causal relationship from Japanese yen to French franc. The two causal relationships from the UK pound and the US dollar to Indian rupee are strong with a significance level of one percent. The causal relationships from Sterling pound to Japanese yen and from Indian rupee to the US dollar are significant at the five percent level. However, the causal relationship from the Japanese yen to French franc is significant only at the ten percent level. The error-correction term is not significant in any of the error-correction models. These results indicate that the identified causal relationships are of a short-run nature. Existence of causal relationships indicates the predictability of one exchange rate from one or more of the other exchange rates. Therefore, these results provide evidence against the semi-strong form of the EMH.

Table 7 about here

Table 7 reports the results of variance decomposition analysis. This analysis was used to supplement the results of Granger causality test results to examine the out-sample causality. Results reported in columns three through eight explain how much of a spot exchange rate's own shock is explained by movements in its own variance over the forecast horizon (i.e. 48 months).

According to the results reported in Table 7, the US dollar and Indian rupee explain up to 77% and 69% of their respective variances even after 48 months following the once-only shock. After 36 months and 48 months following the once-only shock more than 50% of the variance in Japanese yen is explained by the other currencies with the US dollar and the Indian rupee explaining most of the variance of the Japanese yen. As far as the French franc is concerned, most of its variance is accounted for by the German mark at all the forecast horizons considered. Even one month after the once-only shock, 94% of the French franc's variance is explained by the German mark.

When the Sterling pound is considered, around 48% of its variance is accounted for by the German mark at the one month forecast horizon in addition to the balance being accounted by its once-only shocks to the variance. At the other horizons, the US dollar and the German mark together explain most of the forecast variance of the UK pound. For example, after 36 months after a once-only shock 46% and 14% of the forecast variance of the UK pound is explained respectively by variances of the US dollar and those of the German mark

The German mark emerges as the only currency whose forecast variance after a month forecast horizon is totally accounted for by itself. At the other horizons, most of its variance is explained by the US dollar and the Japanese yen.

Above results indicate that the forecast variance of one exchange rate is explained by others revealing causal relationships between currencies. Therefore, these results do not support the applicability of the semi-strong form of the EMH to Sri Lanka. Such causal relationships can be used to predict the future value of one currency from the past values of one or more of the other currencies.

4. CONCLUSIONS

This study examines the weak and semi-strong form efficiency of the foreign exchange market in Sri Lanka using monthly data for six currencies for the period January 1986 to November 2000. While unit root tests are used to test the weak-form of the efficient market hypothesis, semi-strong form of the efficient market hypothesis is investigated using cointegration, Granger causality and variance decomposition analysis.

Results of unit root tests indicate that all the six exchange rates are random walks. These results support the efficient market hypothesis in its weak-form. Implications of these results are that the participants in the foreign exchange market in Sri Lanka cannot devise some rule or technique that can be used to predict future movements of an exchange rate from its past values.

However, the cointegration and Granger causality tests and variance decomposition analysis provide evidence against the semi-strong version of the EMH. They indicate that the movement of one or more exchange rates can be predicted from the movements of the other exchange rates. Therefore, the participants in the foreign exchange market can engage in profitable transactions both in the short and long-run.

The results of the study have implications for the government policy- making bodies as well as for the participants in the foreign exchange market. The government can make informed decisions on exchange rates, take actions to reduce exchange rate volatility and evaluate the consequences of various economic policies for exchange rates. Participants in the foreign exchange market can devise various trading rules or techniques to make abnormal profits from transactions in the foreign exchange market. Testing the similarity of findings with high frequency data would be a topic for future research.

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Table 1
ADF Test Results for Unit Roots

Currency	Level		First Differences	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
DM	-2.834 (4)	-1.736 (4)	-6.779 (3)[a]	-7.262 (3)[a]
GBP	-2.006 (7)	-2.592 (2)	-9.545 (1)[a]	-9.606 (1)[a]
FRF	-2.488 (4)	-1.566 (4)	-6.701 (3)[a]	-7.081 (3)[a]
INR	-1.420 (1)	-1.542 (1)	-10.137 (0)[a]	-10.136 (0)[a]
JPY	-1.438 (6)	-2.310 (11)	-7.683 (5)[a]	-7.736 (5)[a]
USD	-0.138 (2)	-2.198 (2)	-8.343 (1)[a]	-8.320 (1)[a]

Notes:

1. a implies significance at the 1% level.
2. DM, GBP, FRF, INR, JPY and USD denote the nominal exchange rates for German mark, Sterling pound, French franc, Indian rupee, Japanese yen and the US dollar respectively.
3. Augmented Dickey-Fuller (ADF) statistic is obtained by $\Delta x_t = a_0 + b_0 x_{t-1} + \sum_{i=1}^{k} c_0 \Delta x_{t-1} + w_t$ where Δ is the difference operator, a_0, b_0 and c_0 are coefficients to be estimated, x is the variable whose time series properties are examined and w is the whitenoise error term.

4. The lags of the dependent variable used to obtain white-noise residuals are determined using Akaike Information Criterion (AIC).
5. The null and the alternative hypotheses are respectively $b_0 = 0$ (series is non-stationary) and $b_0 < 0$ (series is stationary).
6. As the coefficient b_0 has a non-standard distribution, it is compared with critical values tabulated by Mackinnon (1991).

Table 2
PP Test Results for Unit Roots

Currency	Level		First Differences	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
DM	-3.136[a]	-1.996	-9.218[a]	-9.449[a]
GBP	-1.817	-2.672	-10.127[a]	-10.168[a]
FRF	-2.664	-1.703	-9.843[a]	-10.016[a]
INR	-1.363	-1.444	-10.052[a]	-10.044[a]
JPY	-2.013	-2.975	-9.411[a]	-9.418[a]
USD	-0.081	-2.153	-7.516[a]	-7.494[a]

Notes:

1. a implies significance at the 1% level.
2. See note 2 for Table 1 for details of notations in column 1.
3. The Phillips-Perron (PP) test suggests a non-parametric method of controlling for higher order autocorrelation in a series and is based on the following first order auto-regressive (AR(1)) process: $\Delta y_t = \alpha + \beta y_{t-1} + \varepsilon_t$ where Δ is the difference operator, α is the constant, β is the slope and y_{t-1} is the first lag of the variable y. This paper uses Newey-West (1987) method.
4. The null and the alternative hypotheses tested are the same as for the ADF test.
5. Figures in brackets indicate the number of lags of the dependent variable used in the PP regression to obtain whitenoise residuals. Lag truncation for Bartlett kernal is 4 for all the currencies for levels and first differences. The truncation lags were determined using Newey-West method (1994).

Table 3
Engle/Granger Bivariate Cointegration Test Results

Dependent variable	Independent variable	ADF Test Statistic	PP Test Statistic	CRDW Test Statistic
DM	GBP	-1.409 (1)	-1.546	0.035
	FRF	-3.310 (3)[b]	-4.252[a]	0.118
	INR	-3.157 (1)[b]	-3.087[b]	0.072
	JPY	-1.759 (1)	-1.423	0.056
	USD	-1.941 (1)	-2.030	0.052
GBP	DM	-1.073 (1)	-1.042	0.036
	FRF	-1.225 (3)	-1.043	0.041
	INR	-1.718 (2)	-1.892	0.043
	JPY	-1.881 (1)	-1.801	0.053
	USD	-3.059 (1)[b]	-3.030[b]	0.122
FRF	DM	-3.153 (3)[b]	-4.105[a]	0.118
	GBP	-1.583 (3)	-1.345	0.040
	INR	-2.902 (1)[b]	-2.848[c]	0.074
	JPY	-2.044 (3)	-1.501	0.060
	USD	-1.873 (3)	-1.723	0.062
INR	DM	-2.834 (1)[b]	-2.679[b]	0.083
	GBP	-2.012 (1)	-1.828	0.052
	FRF	-2.719 (1)[c]	-2.579[c]	0.085
	JPY	-2.330 (1)	-2.225	0.076
	USD	-1.658 (1)	-1.518	0.054
JPY	DM	-1.352 (1)	-1.018	0.054
	GBP	-1.722 (1)	-1.811	0.050
	FRF	-1.705 (3)	-1.266	0.059
	INR	-2.242 (1)	-2.286[c]	0.065
	USD	-2.675 (1)[c]	-2.916[b]	0.066
USD	DM	-1.103 (1)	-1.028	0.046
	GBP	-2.972 (1)[b]	-2.670[c]	0.115
	FRF	-0.979 (1)	-0.907	0.056
	INR	-1.053 (1)	-0.788	0.038
	JPY	-2,342 (1)	-2.462	0.062

Notes:

1. a, b and c imply significance at the 1%, 5% and 10% level, respectively.
2. See note 2 for Table 1 for details of notations in columns 1 and 2.
3. Column one and two report respectively the dependent and independent variables of each cointegration equation. Lags of the dependent variable in the ADF regressions were selected using AIC. Figures in brackets against ADF statistics in column three are the number of lags of the dependent variable used to obtain whitenoise residuals. Truncation lag for each PP regression was 4 and was selected using the Newey-West method. One, five and ten percent critical values for the CRDW test are 0.29, 0.20 and 0.16 respectively (Engle and Yoo, 1987).

Table 4
Johansen Cointegration Test Results for each possible pair of currencies

Pairs of Currencies	Number of Lags in VAR	Trend Assumption	Null Hypothesis	Trace Statistic	Maximal EigenValue Statistic
DM/GBP	2	1	$r = 0$	16.376	13.225
			$r \leq 1$	3.152	3.152
DM/FRF	4	1	$r = 0$	30.155[a]	21.098[a]
			$r \leq 1$	9.057	9.057
DM/INR	2	3	$r = 0$	18.012	12.548
			$r \leq 1$	5.464	5.464
DM/JPY	5	2	$r = 0$	12.559	10.723
			$r \leq 1$	1.836	1.836
DM/USD	3	2	$r = 0$	9.235	9.220
			$r \leq 1$	0.015	0.015
GBP/FRF	2	1	$r = 0$	13.969	11.659
			$r \leq 1$	2.310	2.310
GBP/INR	6	2	$r = 0$	13.004	10.050
			$r \leq 1$	2.954	2.954
GBP/JPY	5	2	$r = 0$	8.888	4.844
			$r \leq 1$	4.043[b]	4.043[b]
GBP/USD	3	2	$r = 0$	0.370	9.911
			$r \leq 1$	0.459	0.459
FRF/INR	2	1	$r = 0$	19.508	13.729
			$r \leq 1$	5.778	5.778
FRF/JPY	5	2	$r = 0$	11.844	9.069
			$r \leq 1$	2.775	2.775
FRF/USD	3	2	$r = 0$	7.756	7.732
			$r \leq 1$	0.023	0.023
INR/JPY	2	1	$r = 0$	17.733	13.817
			$r \leq 1$	3.916	3.916
INR/USD	3	2	$r = 0$	3.253	3.246
			$r \leq 1$	0.007	0.007
JPY/USD	7	2	$r = 0$	6.482	6.336
			$r \leq 1$	0.146	0.146

Notes:
1. a and b imply significance at the 1% and 5% level, respectively.
2. See note 2 for Table 1 for details of notations in column 1.
3. The deterministic components are selected using the Pantula principale suggested by Johansen (1992). In the trend assumption column, 1 denotes no deterministic trend (restricted constant), 2 denotes linear deterministic trend, and 3 denotes linear deterministic trend (restricted).
4. Lag lengths in vector autoregressions were selected using Likelihood Ratio (LR) test.
5. Critical values for the Trace and Maximal Eigen value test were obtained from Osterwald-Lenum (1992).

Table 5
Johansen Test Results for Cointegration among the Six Currencies

Null Hypothesis	Trace Statistics	5% Critical Value	1% Critical Value	Maximal Eigen Value Statistics	5% Critical Value	1% Critical Value
$r = 0$	98.702[b]	94.15	103.18	37.114	39.37	45.10
$r \leq 1$	61.588	68.52	76.07	28.353	33.46	38.77
$r \leq 2$	33.233	47.21	54.46	15.959	27.07	32.24
$r \leq 3$	17.273	29.68	35.65	11.762	20.97	25.52
$r \leq 4$	5.511	15.41	20.04	5.236	14.07	18.63
$r \leq 5$	0.275	3.76	6.65	0.275	3.76	6.65

Notes:

1. b implies significance at the 5% level.
2. See notes for Table 4 for details on selection of the trend components, trace and eigenvalue statistics and critical values.
3. Four lags were included in the vector autoregression determined by the likelihood ratio. Pantula principle selected the cointegration equation with a linear deterministic trend.

Table 6
Temporal Causality Results Based on the Vector Error-Correction Model (VECM)

Dependent Variable	Short-run Causality, Chi-square-statistics						Error-correction term, *t*-statistics
	Δ JPY	Δ USD	Δ INR	Δ FRF	Δ GBP	Δ DM	ECT[$\varepsilon_{1,t-1}$]
Δ JPY	-	3.260	1.531	1.106	10.561[b]	2.307	0.298
Δ USD	2.013	-	9.572[b]	3.246	6.140	4.207	0.050
Δ INR	1.258	13.102[a]	-	2.979	17.286[a]	3.141	0.233
Δ FRF	8.272[c]	7.144	1.342	-	0.445	6.298	0.754
Δ GBP	3.398	4.588	2.501	2.708	-	3.341	1.049
Δ DM	7.378	7.558	0.928	3.454	0.962	-	0.468

Notes:

1. a, b and c imply significance at the 1%, 5% and 10% level, respectively.
2. Δ indicates the first difference. See note 2 for Table 1 for the details of other notations in column 1.
3. Only one error-correction term was included in the error correction model as there was only one cointegrating relationship among the six currencies. ECTs are the estimated t-statistics testing the null hypothesis that ECTs are each statistically significant. Number of lags in the VECM was selected using the likelihood ratio test.

Table 7.

Results of Variance Decomposition of Exchange Rates

Months	Relative variance in	Percentage of forecast variance explained by innovations in					
		ΔJPY	ΔUSD	ΔINR	ΔFRF	ΔGBP	ΔDM
1	ΔJPY	73.99	0.00	0.13	1.05	0.22	24.61
12		66.72	11.66	3.02	6.02	0.66	11.92
24		56.64	20.65	8.39	5.26	0.61	8.45
36		48.45	28.15	11.06	4.58	0.78	6.97
48		42.09	35.00	11.42	4.03	1.43	6.02
1	ΔUSD	0.08	84.33	9.10	1.44	2.29	1.86
12		0.72	91.23	1.34	1.09	5.12	0.50
24		2.08	85.20	0.70	0.71	10.48	0.84
36		2.84	80.79	0.65	0.66	13.86	1.21
48		3.37	77.29	0.89	0.73	16.15	1.58
1	ΔINR	0.00	0.00	94.37	3.06	0.00	2.57
12		1.21	0.62	87.56	2.93	4.69	2.99
24		4.77	0.47	80.18	3.64	6.08	4.86
36		7.77	0.50	73.40	4.26	7.23	6.84
48		9.57	0.46	69.05	4.68	8.10	8.13
1	ΔFRF	0.00	0.00	0.00	5.87	0.00	94.13
12		12.81	23.34	1.94	3.51	3.61	54.80
24		13.75	26.99	7.77	4.69	4.03	42.77
36		13.22	27.58	12.42	5.06	3.77	37.95
48		12.86	28.12	15.14	5.15	3.53	35.20

Table 7 (*continued*)

1	ΔGBP	0.00	0.00	0.03	0.94	50.00	48.29
12		7.97	23.95	1.26	0.36	40.60	25.86
24		7.75	39.47	2.34	0.27	32.93	17.25
36		6.17	46.16	2.85	0.34	30.80	13.69
48		5.53	49.42	3.24	0.50	29.65	11.66
1	ΔDM	0.00	0.00	0.00	0.00	0.00	100.00
12		9.46	20.35	2.30	6.23	3.67	57.98
24		10.47	23.23	9.00	7.13	4.56	45.61
36		10.33	23.37	14.26	7.24	4.48	40.01
48		10.31	23.53	17.35	7.18	4.31	37.33

Notes:

1. Figures in the first column refer to months after a once-only shock. Cholesky ordering for the variance decomposition was log(DM), log(FRF), log(INR), log(GBP), log(JPY), and log(USD).
2. See note 2 for Table 1 and 6 for details of notations in column 2.
3. Variance decompositions for the months 1, 12, 24, 36, and 48 only are reported. All figures in columns three through eight have been rounded to two decimal places.