FOREIGN EXCHANGE MARKETS: AN ERROR CORRECTION MODEL ANALYSIS

IBM Wiyasha
Sekolah Tinggi Pariwisata Bali, email: ibwiyasha@yahoo.com

Abstract

This study aims at investigating the behavior of foreign exchange rate markets in Indonesia using 1350 daily observations. Another objective of this study is to examine the structural stability due to Bali bombing chapter I and II. The markets being investigated are USD, AUD, SGD, and YEN; all relative to rupiah. The ECM is applied to investigate the behavior of the markets aforementioned. The findings of this study are that the markets are co integrated and there is a long term equilibrium relationship among them. Using the Chow test, this study finds that there is no structural stability in the markets after Bali bombing chapter I and II.

Keywords: foreign exchange rate, structural stability, equilibrium

Abstrak

Penelitian ini bertujuan untuk menguji perilaku pasar mata uang asing di Indonesia dengan menggunakan 1350 pengamatan harian. Tujuan lain penelitian ini adalah untuk menguji kestabilan struktural pada pasar mata uang asing akibat bom Bali I dan II. Pasar mata uang asing yang diteliti adalah nilai tukar USD, AUD, SGD, dan YEN terhadap rupiah. Model Koreksi Kesalahan (ECM) diterapkan untuk menguji perilaku pasar mata uang asing tersebut. Temuan penelitian ini mengungkapkan bahwa pasar mata uang asing tersebut berkointegrasi serta terjadi hubungan ekuilibrium jangka panjang antar pasar mata uang asing. Hasil uji Chow penelitian ini mengungkapkan bahwa tidak terjadi kestabilan struktural pada pasar mata uang asing dimaksud sebagai dampak dari bom Bali I dan II.

Kata kunci: *foreign exchange rate, structural stability, equilibrium*

1. Research Background

Exchange market is one of the interesting subjects in money markets. This market deals mainly with the exchange of monetary unit amongst countries. Indirectly this market measures the power of purchase amongst the countries involved (Breuer, 1994). Extant studies on foreign exchange rate markets have already been undertaken by plenty of researchers, Clostermann and Schnatz (2000), Lajaunie and Naka (1994), Diebold et al. (1994), and Baillie and Bollerslev (1994) to mention a few. Those aforementioned studies applied the error correction model (ECM) in analyzing and forecasting the exchange rate markets.

The ECM approach in studying the exchange market reveals the short run and long run dynamics of the currencies. The ECM approach also applied in

other fields like in promotions, in M_1 and M_2, international trades, Purchasing Power Parity, stock indexes, and so forth. The interesting properties of the ECM approach are that the error adjusted for short run and as well for long run equilibrium, eliminates the problems of spurious regressions, and identifies if two times series variables are co integrated.

Diebold et al. (1994) investigate the co integration and exchange rates dynamics of seven nominal daily spot exchange rates: the Canadian dollar (CD), French Franc (FF), Deutsche Mark (DM), Italian Lire (LIR), Japanese Yen (YEN), Swiss Franc (SF), and British Pound (BP). All currency denoted relative to US dollar. Their study lends support to Granger's claim that one should not expect to find co integration in assets markets

Baillie and Bollerslev (1994) also investigated the seven above exchange markets studied by Diebold et al. (1994) with the emphasis on the co integration, fractional co integration, and exchange rates dynamics. Their empirical findings are that allowing an intercept in the co integrating regression, the test statistics do not reject the null hypothesis of a unit root. Study on economics variables applying ECM methodology in Indonesia, to the best of my knowledge, are still a few. Price and Insukindro (1994) and Radianto and Insukindro (1995) are amongst scholars conducted studies applying the ECM.

This study aims at investigating the behavior of the foreign exchange rate markets in Indonesia. Specifically, this study analyses the US dollar (USD), Japanese yen (YEN), Singaporean dollar (SGD), and Australian dollar (AUD) exchange markets. All markets are expressed relative to Indonesian rupiah (IDR). In other words, this study investigates if each market integrates each other and if each error in prediction could last for a certain magnitude to equilibrium.

This study differs from others since this study investigates if the parameter stability exists in the period of 2002 to 2003 and 2005 to 2006. These two periods are chosen since in October 12 2002 was Bali bombing chapter 1 happen and in October 1 2005 Bali bombing chapter 2 happen. These two tragedies are suspected to influence the foreign exchange markets in Indonesia, so that it is reasonable to investigate their parameters stability. This paper also aims at investigating if exchange markets are in accordance with the Efficient Market Hypothesis. In EMH it will be difficult to convince that today's price due to the influence of yesterday's. The rest of this paper is organized as follows: next section will be literature review; section 3 will deal with research methods, and section 4 with result and discussion.

2. Literature Review and Hypothesis Development

Baillie and Bollerslev (1994) conducted study on the foreign exchange market to examine if foreign exchange markets were well characterized by I(1) and as martingales distributions. To prove the above statement they applied co integration and fractional co integration using seven foreign exchange markets relative to USD. The data used was daily nominal bid prices for 1245 observations from March 1, 1980 through January 28, 1985. They concluded that foreign exchange market's deviation from co integrating relationships due to the markets possessed long memory and may possibly be well described as a

fractionally integrated process. This finding implies that the influence of shocks to the equilibrium exchange rates may only vanish at very long horizon.

Diebold et al. (1994) investigated the co integration and exchange dynamics of seven foreign exchange market relative to USD. This study applied data from Baillie research with 1245 daily observations. The model formulated using error correction model with main emphasizes on martingale and variance differences model. The findings of this study supports that martingale model was superior to variance differences in its predictive power on the out of sample exercises.

Breuer (1994) assessed the evidence of purchasing power parity (PPP) in international trade would tend to prevail in the absence of trade imbalances, speculation, central bank intervention, and other impediments to trade. She applied the co integration formula and ECM to test the PPP. The findings of her study are as follows. First, there was a weak distinction between short run and long run PPP. Second, in the ultra long run all temporary fluctuation in the exchange rate would offset each other. Thus, the role of coefficient restrictions in PPP's original conception has been disregarded.

Lajaunie and Naka (1994) examined the Tokyo exchange market to see if the behavior of the market would be in line with the Efficient Market Hypothesis (EMH). They applied the co integration and ECM and using the asks of the daily closing prices for the British Pound, Japanese Yen, Deutsche Mark, and Canadian Dollar from the Bank of Tokyo for the period from October 1 1986 to April 1991. Thus, the length of the observations was 1105 daily exchange rates. The findings of this study confirm that the Tokyo exchange market is in line with the EMH.

Mehra's study (1991) concerned with one aspect of money demand, M_2 in the US. In his study he emphasizes the choice of either log form or first difference specification in M_2 estimation still questioned. In an attempt to cope with these approaches, he then integrates the approach of co integration and ECM. He specifies the US M_2 demand using co integration model and ECM in log natural form. Quarterly data that spans the period 1953Q1 to 1990Q4 is used in this study. This study reveals the following. First, the unit root test shows that real M_2, real GNP, and real Consumption are non stationary at their level form. Second, co integration test shows that M_2 and GNP were co integrated, implying that these variables had long run equilibrium. Third, this study finds parameter stability using chow test with breakpoints covering the period 1970Q4 to 1980Q4. Finally, the ECM with real consumer spending as a short run scale variable provides more accurate out of sample forecasts of M_2 growth than does the model with real GNP.

Clostermann and Schnatz (2000) investigates the medium to long term forces driving the real euro-dollar exchange rate in 11 European countries. Applying co integration approaches four factors are identified as fundamental determinants of the real euro-dollar exchange rate: the international real interest rate differential, relative prices in the traded and non-traded goods sectors, the real oil price and the relative fiscal position. In their study a single error correction model outperforms multivariate models and seems to be best suited

to analyze and forecast the behavior of the euro-dollar exchange rates in the medium-term perspective.

Elia Radianto and Insukindro (1995) analyzing the effects of Regional Gross Domestic Product, interest rate and labor force, and monetary policy on private investment (under the PMA and PMDN). The data for this study are economic variables IRR, PDRB, RDT, AK, and DR from the period of 1975 to 1992. To achieve the research objective mentioned above, partial adjustment model (PAM) and ECM are applied. The findings of their study that error correction term is statistically significant, indicating that there is long- run equilibrium relationship amongst the variables aforementioned.

Price and Insukindro (1994) investigated the behavior of the demand for Indonesian narrow money. Variables examined in this study are currency held by the public, demand deposits, gross domestic real income, time and savings deposit returns, and returns on foreign assets proxies by the LIBOR. All variables are integrated of order one. This study also finds that the coefficients on the error correction terms are of plausible magnitude and very well determined. The forward looking model analyzed in this study shows better predictive performance compared to error correction specification. This is due to that the error correction model may be the reduced form of the full forward-looking system.

3. Research Methods

In this section theory on unit root, co integration, and ECM will be discussed. Data series used in this study are daily exchange rate ask price of closing prices from the Bank of Indonesia, the Indonesian central bank. The foreign exchange rates market examined in this study are USD, AUD, SGD, and Japanese Yen. All data series are quoted relative to rupiah, the Indonesian currency. For example in January 1 2002, 1 USD = Rp 9,925, 1 AUD = Rp 5,502, 1 SGD = Rp 5,362, and 1 Japanese Yen = Rp 74.79. The data studied from January 1 2002 to June 30 2007, thus 1350 daily observations were analyzed.

Unit root is very common for time series data. If unit root exists in a data series then the consequence of these data in regression analysis that a spurious one as a result. To see if a data series contains unit root, a test should be conducted using the following (Thomas, 1997: 376).

$$X_t = \alpha + \varphi X_{t-1} + \mu_t$$

Model above should be differenced to achieve stationary.

$$\Delta X_t = \alpha + \varphi^* X_{t-1} + \mu_t$$

where:

$\Delta X_t = (X_t - X_{t-1})$

$\varphi^* = \varphi - 1$

Using ordinary least square the value of φ^* could be derived. If it exceeds the critical value, the null hypotheses of non stationary rejected.

Co integration test is also conducted in this study. Suppose:

$$Y_t = \beta_1 + \beta_2 X_t + \varepsilon_t$$
$$\varepsilon_t = Y_t - \beta_1 + \beta_2 X_t$$

Quoting Engle and Granger, Breuer (1994) stated that a set of non-stationary series, integrated of the same order, $X_t = \alpha + \varphi X_{t-1} + \mu_t$, to be co integrated when some linear combination of them produce a series that is stationary. Simply stated, if a set of non-stationary series share common trends so that the trends cancelled out when linearly combined, they are co integrated. Using $\varepsilon_t = Y_t - \beta_1 + \beta_2 X_t$, if ε_t is linear combination of $Y_t - \beta_1 + \beta_2 X_t$ at order I(0), then both variable X and Y are co integrated. Two steps should be done to conduct co integration test. First, run co integration regression for model $Y_t = \beta 1 + \beta_2 X_t + \varepsilon_t$. Then do unit root test for the residuals from co integration regression $Y_t = \beta_1 + \beta_2 X_t + \varepsilon_t$, using the formula underneath:

$$\Delta\mu_t = \Theta\mu_{t-1} + \Sigma i \eta i \, \Delta\mu_{t-1i} + \varepsilon$$

When null hypothesis H0: $\Theta = 0$ rejected, then the residuals were stationary. Both variables X and Y were co integrated as result. Error Correction Model is applied in this study to examine the behavior of foreign exchange market. The ECM only applies if the data series are co integrated and no spurious regression due to unit root. Error Correction Model is within the general category of VAR systems but explicitly incorporate certain information about the existence of unit roots and the presence of co integrating among the variables (Phillips, 1998). The long run equilibrium among foreign exchange market could be derived as follows:

$$USD = a_0 + a_1 AUD + a_2 SGD + a_3 YEN + \varepsilon$$

$$\Delta USD_t = a_0 + a_1 \Delta AUD_t + a_2 \Delta SGD_t + a_3 \Delta YEN_t + a_4(USD_{t-1} + AUD_{t-1} + SGD_{t-1} + YEN_{t-1}) - Resid_{t-1}$$

$\Delta USD_t = (USD_t - USD_{t-1})$, other currency applies the same formula, and -1 stands for lag one period. From $\Delta USD_t = a_0 + a_1 \Delta AUD_t + a_2 \Delta SGD_t + a_3 \Delta YEN_t + a_4(USD_{t-1} + AUD_{t-1} + SGD_{t-1} + YEN_{t-1}) - Resid_{t-1}$, a_1, a_2, and a_3 are short term shock of each currency to USD, where a_4 is long term equilibrium relationship among currencies in the model. The residuals lag_1 is included in the model to investigate if long term equilibrium relationship exists among the variables. Residuals series derived by running model $USD = a_0 + a_1 AUD + a_2 SGD + a_3 YEN + \varepsilon$, and included in model $\Delta USD_t = a_0 + a_1 \Delta AUD_t + a_2 \Delta SGD_t + a_3 \Delta YEN_t + a_4(USD_{t-1} + AUD_{t-1} + SGD_{t-1} + YEN_{t-1}) - Resid_{t-1}$.

Since the data used in this study are daily data, auto correlation should be investigated. The disturbance (ε) of $X_t = \alpha + \varphi X_{t-1} + \mu_t$, above should be investigated for auto correlation. Time series data normally produce auto correlation on the disturbance which will spill over from one time period to another (Thomas, 1997: 296). To test the auto correlation on the data the Durbin Watson statistics are used.

Parameter stability of the model is tested using Chow test. The Chow test is conducted to see if parameter magnitude in foreign exchange markets in Indonesia not influenced by Bali Bombing chapter 1 and 2 tragedies. To conduct the Chow test samples are partitioned into two periods; April 2002 to March 2003 and April 2005 to March 2006. Each of those periods is also partitioned into two. Parameter of periods April to September 2002 compared to October 2002 to March 2003. Another test applied for periods of April to September 2005 compared to October 2005 to March 2006. Chow formula applied to test parameter stability as follow (Gujarati, 1995: 264).

$$F = \frac{S_1/k}{S_2/(n_1 + n_2 - 2k)}$$

Where S_1 and S_2 are sum of squares residuals of regression 1 and 2, and n_1, n_2, are number of observations of regression 1 and 2 and; while k is the parameter estimated in the model. If the F observed value exceeds the critical F value at the chosen level of α, reject the null hypotheses of structural stability.

4. Result and Discussion

This section deals with descriptive statistics, auto correlation, unit root test results, co integration results, ECM results, and structural stability results.

Table 1. Descriptive Statistics of the Variables in the Models

	USD	AUD	SGD	YEN
Mean	8,632.48	6,040.39	5,148.45	74.86
Median	8,595	6,224.35	5,224.96	73.73
Maximum	10,300	7,730.15	6,118.21	92.83
Minimum	7,665	4,461.96	4,378.88	64.28
Std. Deviation	497.25	860.23	389.80	5.68
t-statistics	637.87	257.99	485.30	483.93
Skewness	0.549	-0.327	-0.194	0.505
Observations (days)	1,350	1,350	1,350	1,350

From Table 1 shows analysis of AUD exchange market was relatively more volatile compared to the other three. It departed from its mean on average 14.24 % during the observations, while USD 5.6%, SGD and Yen 7.6 %. The auto correlation of residuals of model USD = $a_0 + a_1$AUD + a_2SGD + a_3YEN + ε, can be verified from Table 2.

Table 2. The Auto Correlations of Residuals

lag	Correlation	t-stat.	lag	Correlation	t-stat.	lag	Correlation	t-stat.
1	0.97	35.78	30	0.61	3.71	60	0.30	1.52
5	0.91	11.68	35	0.57	3.29	65	0.24	1.23
10	0.83	7.67	40	0.52	2.87	70	0.19	0.96
15	0.77	5.99	45	0.47	2.53	75	0.15	0.76
20	0.71	4.92	50	0.42	2.22			
25	0.66	4.23	55	0.36	1.88			

The residuals of model $USD = a_0 + a_1AUD + a_2SGD + a_3YEN + \varepsilon$, were highly auto correlated. This means that the shock of the previous period spills over severely to the next one. This condition diminishes using lags until 52 periods. Stated differently, data series in model $USD = a_0 + a_1AUD + a_2SGD + a_3YEN + \varepsilon$, has unit root. Unit root test applying the Augmented Dickey Fuller test shows the following results.

Table 3. Unit Root Tests Result ADF t-statistics

Exchange market	Level	Difference 1
USD	-2.702***	-8.737*
AUD	-0.638	-3.632*
SGD	-1.003	-5.087*
YEN	-1.552	-4.654*

Note: *: significance at 1 %. ***: significance at 10 %.

Table 3 could infer that only data series of USD is stationary at 10 % significance, while the other three AUD, SGD, and YEN contained unit root at their level and stationary in difference 1. This finding suggests that except for USD that integrates at order I(0), the other three markets integrate at order I(1). The trend components of the markets have no effects after differenced once. Co integration test using Johansen procedures shows the following result.

Table 4. Co Integration Results, Johansen Procedures

No of CE	Log likelihood	Akaike I .C.	Eigen value	1 % critical v.
r =1	-20,327.92	18.990	0.007	35.65
r =2	-20,322.92	18.995	0.005	20.04
r =3	-20,319.24	19.002	0.000	6.65

Note: CE: Cointegrating Equation. I.C.:Information Criteria. v.:value

Results of co integration using Johansen procedures lead us to conclude that exchange markets are co integrated simultaneously. Each market is stationary after first difference as shown in Table 3. These findings of being stationary of each market lead us to infer that they are also co integrated.

The results of ECM are as follows:

$$\Delta USD_t = -75825.72 - 0.492\Delta AUD_t + 1.607\Delta SGD_t - 41.94\Delta YEN_t + 58.47USD_{t-1}$$
$$(2.8E+11) \quad (0.039) \quad (0.106) \quad (3.974) \quad (3.78)$$
$$[-2.7E-07] \quad [-12.72] \quad [15.12] \quad [-10.55] \quad [15.46]$$
$$+ 33.38AUD_{t-1} - 87.82SGD_{t-1} - 2984.96YEN_{t-1} - 58.50Resid_{t-1}$$
$$(2.16) \quad (5.68) \quad (193.05) \quad (3.78)$$
$$[15.47] \quad [-15.47] \quad [-15.46] \quad [-15.47]$$

where:
Figures in ( ) and [ ] are standard errors
t-statistics respectively
Adjusted R^2: 0.68

Statistically, model $\Delta USD_t = a_0 + a_1\Delta AUD_t + a_2\Delta SGD_t + a_3\Delta YEN_t + a_4(USD_{t1} + AUD_{t-1} + SGD_{t-1} + YEN_{t-1}) - Resid_{t-1}$, explains 68 % variance in the

model. All variables are statistically significant at 1 %. In short-term relationship only SGD positively related to USD. While on the other hand AUD and YEN negatively related to USD. For long-term relationship, SGD and YEN negatively related to USD. All variables in the model exhibit long term equilibrium relationship shown by statistically significant $Resid_{t-1}$ variable.

Structural stability between periods of April-September 2002 compared to October 2002-March 2003. Each observations last for six months. Six months are considered an appropriate time lag to recover from shock like Bali bombing I and II attacks. The result of Chow test at 5 % for Bali Bombing I is F4.242 = 34.1918, while the critical value of F4.242 = 2.37. Since the observed F value exceeding the critical value, we could reject the hypothesis that the exchange markets for the two periods i.e. before and after Bali Bombing I are the same. The second structural stability test is also conducted covering the periods of April to September 2005 compared to October 2005 to March 2006. The result of Chow test at 5 % for Bali Bombing II is F4.240 = 21.67. The critical value of F4.240 = 2.37. Again, since the observed F value exceeding the critical value, one could reject the hypothesis that the exchange markets for periods before and after Bali Bombing II are the same. To support this structural stability tests, exchange rates movements for each currency are included in the appendix as Figures 1a-1d and Figures 2a-2d. These structural findings support that the markets react to such tragedy.

This study aims at examining the behavior of exchange rate markets in Indonesia. The markets under study were USD, AUD, SGD, and YEN. All markets are quoted to rupiah. The ECM is applied to study the behavior of the markets mentioned above. The findings of this study that data series of the market co integrated at order I(1). This finding lends to support of Lajaunie and Naka's that long term relationship among the markets violate the Efficient Market Hypothesis. The results of ECM show that in the short-run AUD and YEN are negatively related to USD. For long-term relationship on the other hand, SGD and YEN negatively related to USD. Each market in the model exhibits long-term relationship. This fact is indicated by the $Resid_{t-1}$ which is statistically significant.

The Chow tests for structural stability for Bali bombing I and II show that markets reacted to such tragedy. The implications of these findings that money market investors could infer the short term and long term equilibrium when joining the foreign exchange market in Indonesia. Another implication is that investors should be aware of money market respond to such thing like the Bali bombing attacks.

This study does not examine the effects of each currency's depreciation against rupiah which may influence the results of data trends in the model. Another limitation of this study is that it does not formulate the forward looking of the ECM. Based on those limitations it is suggested that the future research should cover the examination of the effects of depreciation against rupiah on data trends in the model and formulate the forward looking of the ECM.

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Appendixes

Rupiah Depreciation Against USD, AUD, SGD, and YEN Currency USD

Time	Exchange rate (Rp)	Depreciation (%)
1 Jan 02	9,925	0
1 Jul 02	8,195	-17.43
1 Jan 03	8,468	-14.68
1 Jul 03	7,745	-21.97
1 Jan 04	8,074	-18.65
1 Jul 04	8,889	-10.44
1 Jan 05	9,560	-3.68
1 Jul 05	9,260	-6.70
1 Jan 06	8,560	-13.75
1 Jul 06	8,665	-12.70
1 Jan 07	8,600	-13.35
1 Jul 07	8,554	-13.81

Currency AUD

Time	Exchange rate (Rp)	Depreciation (%)
1 Jan 02	5,201.69	0
1 Jul 02	4,590.84	-11.74
1 Jan 03	4,768.33	-8.33
1 Jul 03	5,210.84	0.20
1 Jan 04	6,067.61	16.65
1 Jul 04	6,200.97	19.21
1 Jan 05	7,042.85	35.40
1 Jul 05	7,049.64	35.53
1 Jan 06	6,553.54	25.99
1 Jul 06	6,431.16	23.64
1 Jan 07	6,935.04	33.32
1 Jul 07	7,251.23	39.40

Currency SGD

Time	Exchange rate (Rp)	Depreciation (%)
1 Jan 02	5,361.39	0
1 Jul 02	4,639.90	-13.46
1 Jan 03	4,858.29	-9.38
1 Jul 03	4,401.07	-17.91
1 Jan 04	4,780.63	-10.83
1 Jul 04	5,179.16	-3.40
1 Jan 05	5,650.79	5.40
1 Jul 05	5,495.22	2.50
1 Jan 06	5,446.68	1.59
1 Jul 06	5,473.44	2.09
1 Jan 07	5,661.62	5.60
1 Jul 07	5,579.91	4.08

Currency YEN

Time	Exchange rate (Rp)	Depreciation (%)
1 Jan 02	74.79	-0-
1 Jul 02	68.48	-8.44
1 Jan 03	71.22	-4.77
1 Jul 03	64.76	-13.41
1 Jan 04	75.68	1.19
1 Jul 04	82.18	9.88
1 Jan 05	80.17	7.19
1 Jul 05	83.48	11.62
1 Jan 06	74.82	0.00
1 Jul 06	75.59	1.07
1 Jan 07	73.14	-2.21
1 Jul 07	69.40	-7.21

Note: The basis point to calculate depreciation of each currency against rupiah is the rate of January 1, 2002 for each respective currency.

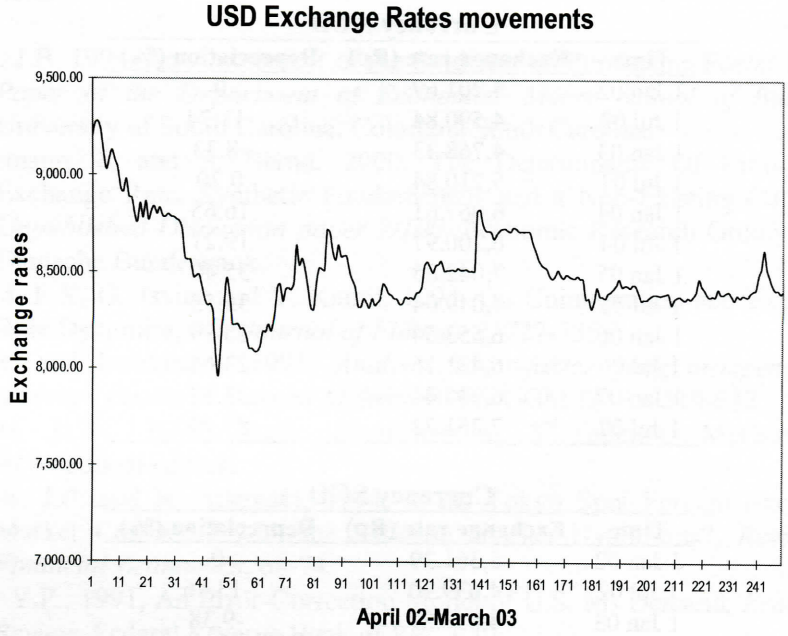

Figure 1a. USD Exchange Rates Movements period of April 02 - March 03 for Period Bali Bombing I

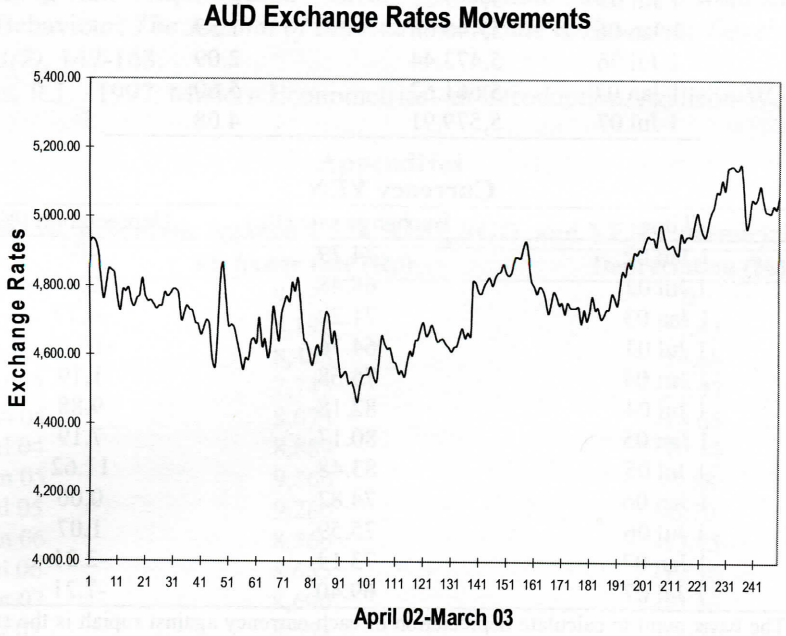

Figure 1b. AUD Exchange Rates Movements period of April 02 - March 03 for Period Bali Bombing I

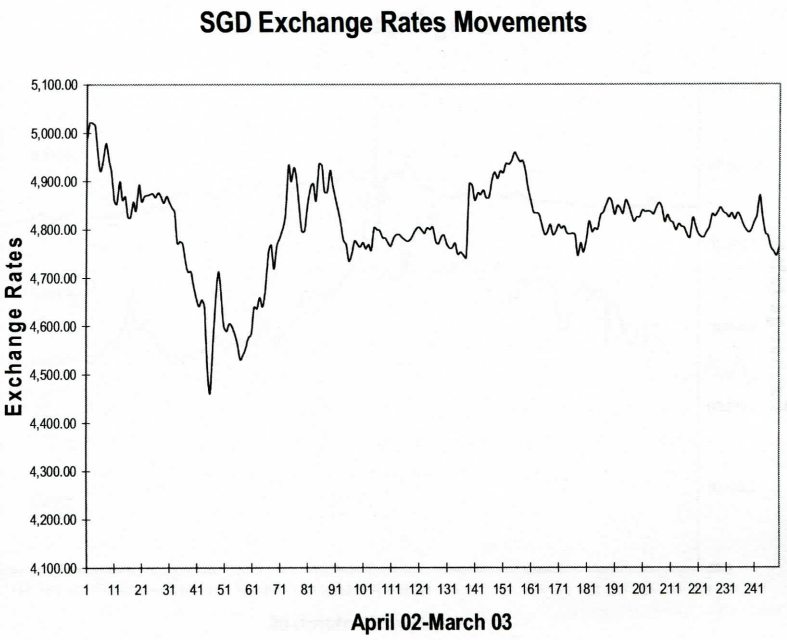

Figure 1c. SGD Exchange Rates Movements period of April 02 - March 03 for Period Bali Bombing I

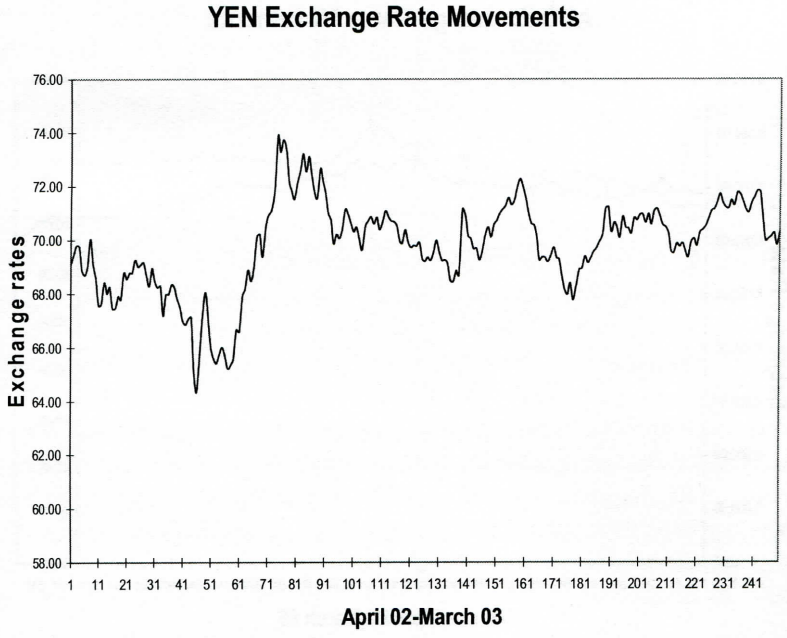

Figure 1d. YEN Exchange Rates Movements period of April 02 - March 03 for Period Bali Bombing I

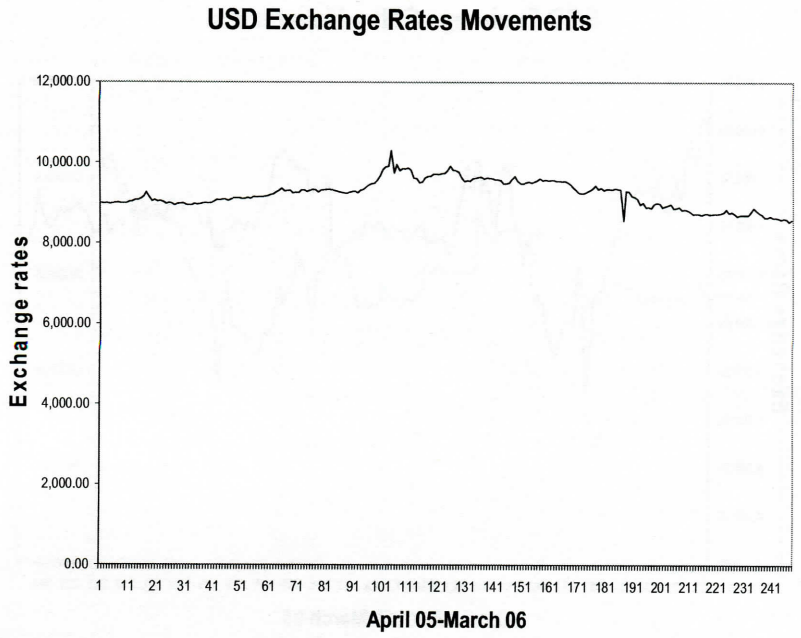

Figure 2a. USD Exchange Rates Movements period of April 05 - March 06 for Period Bali Bombing II

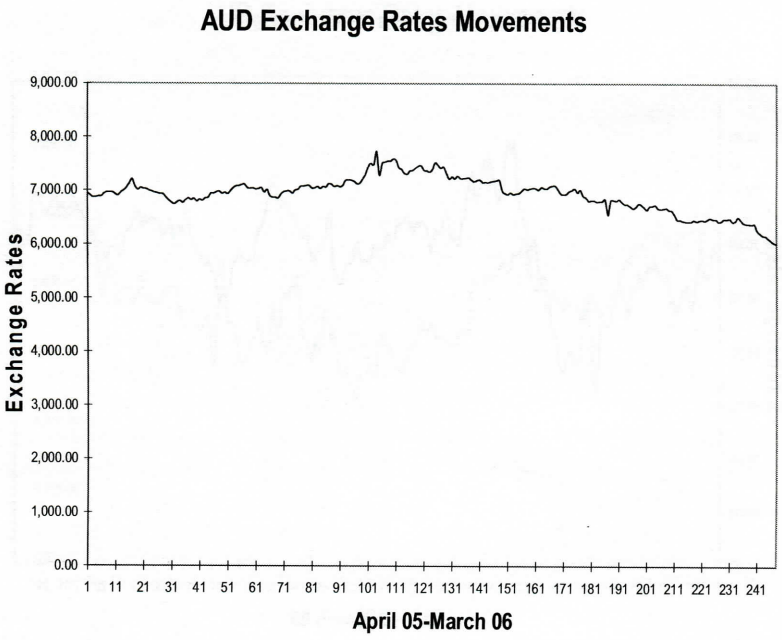

Figure 2b. AUD Exchange Rates Movements period of April 05 - March 06 for Period Bali Bombing II

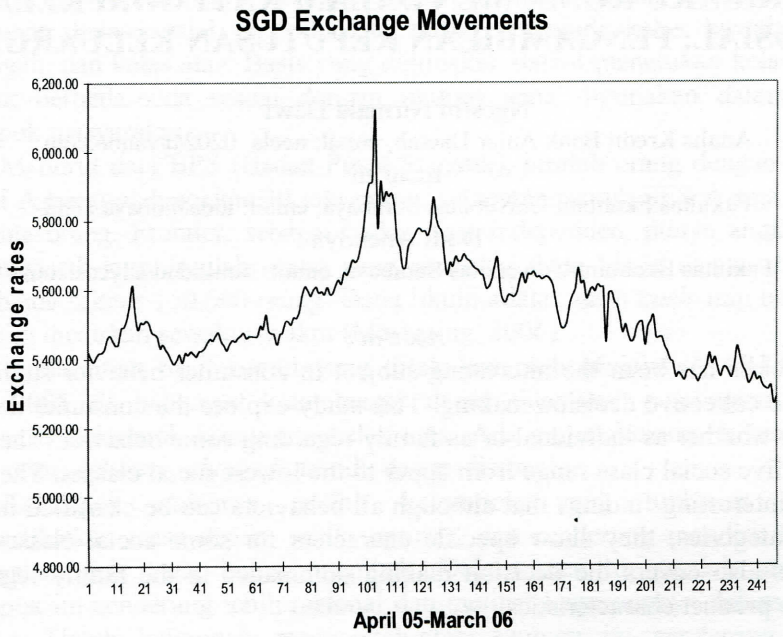

Figure 2c. SGD Exchange Rates Movements period of April 05 - March 06 for Period Bali Bombing II

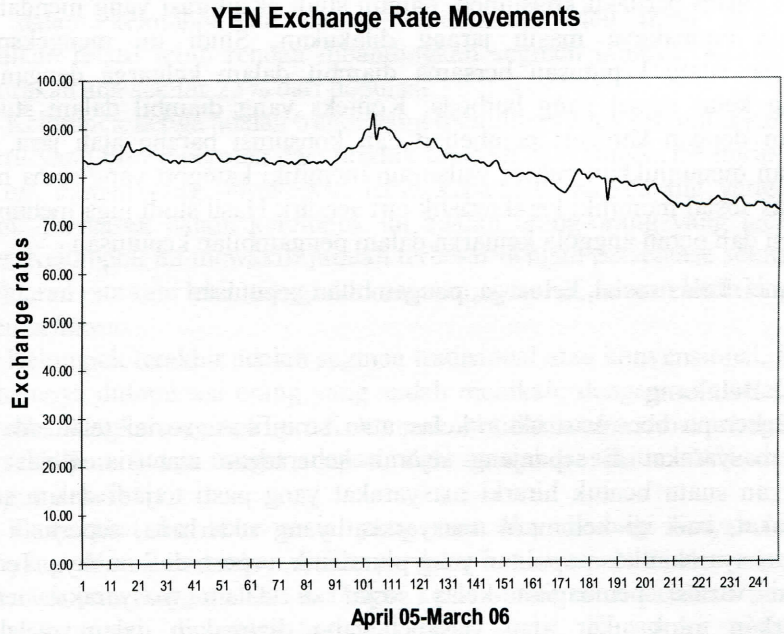

Figure 2d. YEN Exchange Rates Movements period of April 05 - March 06 for Period Bali Bombing II