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Revisiting the Unit Root Hypothesis and Structural Break: Asia and Emerging Economies Foreign Exchange Markets

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Abstract: This study examines the stationary of ten Asian and for emerging Foreign Exchange (FX) rates during the 1990s. The paper employs the Augmented Dickey-Fuller (ADF) unit root test to the following FX rates: Hong Kong Dollar (HKD) Japanese Yen (JPY), South Korean won (KRW) new Taiwan dollar (TWN), Chinese Renminbl (CHR), Indonesia Rupiah (IDR), Malaysian Ringgit (MYR), Singapore Dollar (SGD), Thai Bhat (THB), Philippines Peso (PHP), Argentine Peso (AGP), the Brazilian Real (BRR), Mexican Peso (MXP) and Russian Rouble (RUR). Structural break is taken into account for series found to be non-stationary using the[1] test. The results show that exchange rate series were found to be non-stationary except for the Chinese Renminbi, Mexican and Argentina pesos. Furthermore, the robustness test indicates that the ADF test is robust across different data frequencies for most series we examined finally; we find the choice of structural break data is crucial in testing that stationary for most series examined.

Key words: Unit root, stationarity, structural-breaks JEL classification: G10, G15

INTRODUCTION

It has been well-documented that non-statinarity has several important implications in analyzing time series data[2-4,5] suggests the Ordinary Least Square (OLS) regression technique becomes invalid when applied the variables that are non-stationary. Regressing non-stationary variable results in high R2 and significant t-statistics but the results are economically meaningless, a symptom known as "spurious" regression. This is because OLS estimates in such regression do not converge to contents and therefore, the usual t and f ratio test statistics do not have the limiting distributions thus generating spurious inferences[3].

Visual inspections of the autocorrelation function are the simplest form of determining whether time series is non-stationary. The most commonly used formal tests of stationarity are the Augmented Dickey-Fuller (ADF) unit root test. However,[1] suggests that widespread evidence of unit roots in many long-run macroeconomic time series may be due to structural change in their deterministic trend function. The omission of structural change variables from an ADF equation can bias the ADF test statistic and lead towards the non-rejection of a unit root. Hence,[1] developed a formal procedure to test for unit roots in the presence of a onetime structural change with dummy variables.

Previous empirical research on stationery has been conducted using major Foreign Exchange (FX) rates and report strong evidence of a unit root in nominal exchange rates examined[6]. Found that the logarithm of weekly nominal exchange rate is difference stationary and has since become the cornerstone in the empirical testing of stationary of time series data. Recent research by[7-9] also strong evidences of unit roots in nominal exchange rate studies[10]. Compare the difference stationary of nominal exchange rate for United Kingdom, Canada, Germany, France, Italy and Japan from 1973-1996 using monthly and quarterly data in logarithmic form. The authors found that quarterly exchange rates tend to have a unit root compared to monthly exchange rates. Their findings imply that quarterly data are less volatile than monthly data[11]. Test unit roots of very high frequency spot exchange rate series (against USD) for Canadian Dollar, French France, German Mark, UK pound, Swiss France and Japanese yen from 1983-1987. Using multiple unit root tests such as the dickey and pantula test, solo LM unit root test, dickey-fuller tests and Phillips-Perron tests, the authors found that all the daily and hourly exchange rate series have a unit root.

Recognizing that one of the reasons that inconclusive results are found in many previous unit root tests is the regime shift or break in the time series as suggested by[1-12] conduct unit root tests in the nominal exchange rate series using ADF with structural break. The authors used the method developed by[1] and extended by[13], who treats the break point as unknown. Contrary to[1], [12] found that the null hypothesis of a unit root for the spot exchange rate variable is not rejected when structural break is taken into account[14]. Found similar results using the ADF and[1] tests in the Malaysian exchange rate series from 1980-1994. The author concludes that the nominal exchange rate is non-stationary in both test and the structural break in 1985 (the exogenous event of intervention of G-5 in the foreign exchange market) did not bias the ADF test towards rejecting unit root.

From the above-mentioned studies, two explanations have been offered to explain the existence of a unit root in nominal exchange rates are as follows. First, the random walk property (non-stationary) of exchange rates is a natural outcome of efficient financial markets where prices fully reflect all available information. Under this theory, the condition for market efficiency implies that exchange rates change unpredictably and hence is described by a random walk. Another explanation is that the random walk carries strong implications for identifying the kinds of shocks that have driven exchange rates as most of these shocks have been expected to be permanent[15].

Most studies cited above mainly focus on the nominal exchange rate in major currencies. Little has been examined on the Asian and emerging markets. The Asian and emerging FX rates can behave differently from the major currency rates due to differences in the FX regimes and government policies. In addition, a few currency crises occurred during the 990’s greatly affect the Asian and emerging FX rates. This therefore leads to our main research questions:

- Are the Asian and emerging FX rates unit root?
- Taking into account of structural break, are the Are the Asian and emerging FX rates unit root?

This study examines the stationary of ten Asian and for emerging FX rates during the 1990s. The paper employs the Augmented Dickey-Fuller (ADF) unit root test to the following FX rates: Hong Kong Dollar (HKD), Japanese yen (JPY), South Korean Won (SKW), the New Taiwan dollar (TWN), Chinese Renminbl (CHR), Indonesia Rupiah (IDR), Malaysian Ringgit (MYR), Singapore Dollar (SGD), Thai Baht (THB), Phillipines peso (PHP), Argentine Peso (AGP), the Brazilian Real (BRR), Mexican peso (MXP) and the Russian rouble (RSR). Structural breaks are also taken into account for series found to be non-stationary using the[1] test. These structural breaks are chosen in accordance to the following crises: 1994 Mexican, 1997 Asian, 1998 Russian and 1999 Brazilian financial crises. Finally, the study also conducts the robustness of the ADF and Perron tests to the different data frequencies and different structural breaks.

Augmented Dickey Fuller test (ADF): The ADF and Phillips-Perron tests are the two most commonly used for stationary tests. The ADF test is a parametric approach to correct for autocorrelated errors by adding higher-ordered lagged terms to the model[16]. Unlike the ADF test, the Phillips-Perron test is a non-parametric approach, which does not take into account the extra terms in the data generating process (adding them to the regression model) but include a non-parametric correction to the t-statistic to account for the presence of autocorrelation[17].

The statistical performance of the ADF test depends on two-specification problems: firstly, the inclusion of the constant term and the time trend in the estimating equation and secondly, the specification of the number of lag terms[18]. It is important to use a regression equation that mimics the actual data-generating process. If the intercept or time trend is inappropriately omitted, the power of the test can go to zero generating meaningless results. On the other hand, extra repressors increase the absolute value of the critical values and results in not rejecting the null of a unit root[19].

The ADF unit root test for the exchange rate series in this study is expressed as follows:

$$\Delta y_i = \alpha_0 + \gamma \Delta y_{i-1} + \sum_{i=2}^{\rho} \beta_i \Delta y_{i-1+t} + \varepsilon_t \qquad (1)$$

Where:

$$\gamma = -\left(1 - \sum_{i=1}^{\rho} \alpha_i\right)$$

$$\beta_i = \sum_{i=1}^{\rho} \alpha_i$$

In order for the exchange rate series not to be integrated by more than 1, the ADF unit root test using first difference exchange rate series will be estimated based on the following model:

$$\Delta^2 y_i = \alpha_0 + \gamma \Delta y_{i-1} + \sum_{i=2}^{\rho} \beta_i \Delta^2 y_{i-1+t} + \varepsilon_t \qquad (2)$$

Where:

$$\gamma = -\left(1 - \sum_{i=1}^{\rho} \alpha_i\right)$$

$$\beta_i = \sum_{i=1}^{\rho} \alpha_i$$

In equations 1 and 2 y, represents the natural logarithm of foreign exchange rates against US dollar, $\alpha 0$ is the intercept term, γ is the coefficient of interest in the unit root test, β, is the parameter of the lagged first difference of yt to better represent the path-order autoregressive process and εt is the white noise error term[20]. Found that exchange rates do not exhibit a time trend. Hence, time trend is omitted from equations (1) and (2).

Using Microfit to compute the selection criterion by maximizing the value of log-likelihood function of the corresponding model, this study selects the value of the Akaike Information Criterion (AIC) or Schwartz Balyesian Criterion (SBC). If these two information criteria are in conflict, the optimal lag length, p, between the suggested lag lengths will be chosen.

In both cases, the null hypothesis of the unit root test is, i.e. { } the sequence contains a unit root process (non-stationarity) while the alternative hypothesis indicates that the series is a stationary process. We reject the null hypothesis of the unit root if the t-statistics of is smaller than the 95% dickey-fuller critical value, given in[21], implying that the series is stationary.

Perron (1989) test: Importance of structural break test: It has been empirically tested that time series macroeconomic data have unit roots[22]. However,[1] challenged Nelson and pleasures findings by suggesting that widespread evidence of uniting roots in many long-run macroeconomic time series may be due to structural change in their deterministic trend function. The omission of structural change variables from an ADF equation can bias the ADG test statistic and lead towards the non-rejection of a unit root[1]. Developed a formal procedure to test for unit roots in the presence of a one time structural change with dummy variables[1]. Findings reversed nelson and plosser conclusions in 10 out of the 13 series examined. Perron finding suggests that most macroeconomic variables are not characterized by unit root processes rather; they appear to be trending stationary processes coupled with structural break. Furthermore Perron assumes that the stock market crash of 1929 and dramatic oil price increase of 1973 were exogenous shocks having permanent effects on the mean of most macroeconomic variables. The crashes induced at one-time fall in the mean otherwise macroeconomic variables appear to be trending stationary.

In contrast to[1] findings,[23] incorporated an endogenous break point into their model specification. The authors failed to reject the unit root hypothesis at the 5% level for four of the ten Nelson-Plosser series. They found inferences related to unit roots are sensitive to the number of assumed structural breaks. The ADF unit root test is further extended to allow for the possibility of having a structural break at an unknown date[13] and allowing for multiple structural breaks for a long time series[24, 25].

Model specification: This study employs the “crash” model described in[1] to test for unit root with structural break on the foreign exchange rate series in the 1994 Mexican, 1997 Asian, 1998 Russian and 1999 Brazilian, financial crises. The exchange rate series are assumed as a one-time jump in the level of the unit root process. The following model is employed:

$$y_i = \alpha_0 + \mu_i D_i + \alpha_i y_{i=1} + \sum_{i=2}^{\rho} \beta_i \Delta^2 y_{i-1} + \varepsilon_t \quad (3)$$

where, DL =1 for all t beginning in time of breaks and otherwise.

Following[20], the time trend is omitted from the equation (3) since the exchange rate series do not exhibit time trends. To overcome the problem of autocorrelation, the test will be re-run until the coefficient of the lag is insignificant at the 5% level and that the error term approximate white noise. The Lagrange Multiplier (LM) test of residual serial correlation is also used for this purpose. A p-value from the LM statistic of less than 0.05 indicates the need for extra difference terms to be included in the model.

Structural break is identified when there is a sudden increase or decrease in the exchange rate series plots. A dummy variable of 0 is assigned to the pre-structural break data and 1 for the date of the structural break. Each exchange rate series in the data set has a different structural break date. For example the Asian exchange rage series, the structural break occurs on 2 July 1997 for Thai baht, 3 July 1997 for Malaysian ringgit, 4 July 1997 for Singapore dollar, 1 October 1997 for South Korean won, Taiwan new dollar, Indonesian rupiah and 7 November 1997 for Philippines peso. The structural break for Hong Kong dollar occurs at a later stage on 3 April 1999. As for the non-Asian exchange rate series, a structural break occurs on 20 December 1994 for Argentina and Mexican pesos, 18 August 1998 for Russian rouble and 14 January 1999 in the Brazilian real marking the beginning of the Brazilian crisis. There is no structural break for the Japanese yen and Chinese Renminbi for the full sample data set.

The model (in equation 3) has the null hypothesis of a unit root against the alternative hypothesis of a one-time change in the intercept of a trend stationary process. The parameters of interest in the regression equation are α_1, i.e. the $\{y_t\}$ sequence contains a unit root (non-stationary) if $\alpha 1 = 1$.

The test involves estimating equation (3) using OLS to obtain the t-statistic of $\alpha 1$. The λ is calculated as the sample size before the structural break. The value of λ is used to identify the critical value from the table simulated by[1].

Data: The exchange rate series used in this study is the natural logarithm of the daily exchange rate against the US dollar for the fourteen currencies. This includes the Hong Kong Dollar (HKD), Japanese Yen (JPY), South Korean Won (SKW), Taiwanese New Dollar (TWD), Chinese Renminbi (CHR), Indonesian Rupiah (IDR), Malaysian Ringgit (MSR), Philippine Peso (PHP), Singapore Dollar (SGD), Thal Bath (THB), Argentine Peso (AGP), the Brazilian Real (BRR), Mexican Peso (MXP) and Russian Rouble (RSR). All exchange rate series are the daily middle exchange rate (the average of the bid and ask rate) obtained from Data Stream. Daily data are chosen to examine the short-term and long-term movements of the exchange rate series despite the inherent constraints (high volatility) associated with high-frequency data ([26,27] for the rationale in using the daily exchange rate).

The data set consists of 2086 observation for each exchange rate series (except for the Brazilian real) from 3 January 1994 to 31 December 2001. The sample period for Brazilian real series commence on 1 July 1994 to 31 December 2001. The beginning date of the sample period is chosen based on data availability. The full sample is then divided into the following seven sub-samples:

Pre 1994-Mexican crisis: 3 January 1994
To 19 December 1994
1994 Mexican crisis: 20 December
1994 to 29 December 1995
Post 1994-Mexican crisis: 1 January 1996
To 1 July 1997
1997 Asian crisis: 2 July 1997 to
14 August 1998

1998 Russian crisis: 17 August 1998
To 12 January 1998
1999 Brazilian crisis: 13 January
1999 to 31 December 1999
Post crisis: 3 January 2000
To 31 December 2001

The break point of the crises is based on the plots of the exchange rate series, which have been used in similar studies[28,29]. For example the 1994 Mexican crisis began on the 20 December 1994 when the Mexican peso experienced devaluation[28]. Similarly, the break point of the Asian crisis is on 2 July 1997 when the Thai Baht is devalued[29]. The Russian crisis commences on 17 August 1998 when the Russian defaulted their payment on short-term domestic debt and long-term external debt[29] and finally 13 January 1999 marked the beginning of the Brazilian crisis when the real initiated its transition to a floating exchange rate regime[30].

In general, the Asian exchange rate series are more volatile during the 1997 Asian crisis while the Argentina and Mexican pesos show a significant shift at the beginning of the 1994 Mexican crisis (Fig. 2). The model is tested with time trend but found to be insignificant for all exchange rate series involved.

RESULTS

Table 1 describes the summary statistics for the natural logarithm of nominal exchange rate series. The Russian rouble series has the largest range (difference between maximum and minimum) of 3.19, followed by Indonesian rupiah, 2.077, Mexican peso, 1.23 and Brazilian real, 1.22. The rest of the exchange rate series have a range of less than 1. The Russian rouble exhibits the highest standard deviation (0.9410), followed by Indonesian rupiah (0.6887) while the Hong Kong and Singapore dollars have the lowest standard deviation close to zero.

Table 1: Summary statistics for the natural logarithm of nominal exchange rate series

Exchange rate series	HKD	JPY	KRW	TWN	CHR	IDR	MYR
Maximum	2.0541	4.9914	7.5807	3.5582	2.1647	9.7259	1.6919
Minimum	2.0441	4.3954	6.6278	3.2250	1.7579	7.6487	0.8906
Range	0.0100	0.5960	0.9529	0.3332	0.4068	2.0772	0.8013
Mean, μ	2.0483	4.7167	6.9235	3.3958	2.1200	8.4407	1.1767
Standard Deviation, σ^2	0.0033	0.1107	0.2295	0.1001	0.0175	0.6887	0.2416
Skewness, σ^3	0.7798	-0.2411	0.1925	0.0250	-7.3924	0.0509	0.3049
Kurtosis-3, σ^4	-0.9378	0.1925	-1.3210	-1.5569	173.741	-1.8067	-1.1106
Coefficient of Variation, ρ	0.0016	0.0235	0.0332	0.0295	0.0083	0.0816	0.2053
Number of observations	2086	2086	2086	2086	2086	2086	2086
Exchange rate series	SGD	THB	PHP	AGP	BRP	MXP	RUP
Maximum	0.1671	4.0378	4.0028	0.0033	1.0251	2.3604	3.4111
Minimum	0.3289	3.1739	3.1591	-0.0131	-0.1906	1.1330	0.2207
Range	0.2882	0.8639	0.8437	0.0164	1.2157	1.2274	3.1904
Mean, μ	0.4597	3.4916	3.5327	-0.0004	0.2819	2.0147	2.2141
Standard Deviation, σ^2	0.0915	0.2240	0.2613	0.0007	0.3487	0.3334	0.9410
Skewness, σ^3	0.0744	0.0028	0.1636	-8.4164	0.4692	-1.6171	-0.0199
Kurtosis-3, σ^4	-1.5402	-1.6757	-1.5320	130.929	-1.2341	1.4322	-1.3434
Coefficient of Variation, ρ	0.1990	0.0699	0.0740	1.8180	1.2368	0.1655	0.4250

Note: We collect data from datastresan from 3 January 2994 to 31 December 2001 for fourteen exchange rate series examined except for Brazilian areas where we collect data from 1 July 1994 to 31 December 2001 (earlier data is not available). The fourteen exchange rate series includes Hong Kong dollar (HKD), Japanese yen (YPY), South Korean Won (KRW), Taiwan new dollar (TWN), Chines Renminbi (CHR), Indonesian rupiah (IDR) Malaysian Ringgit (MYR), Singapore dollar (SGD), the bath (THB) Philippines peso (PHP), Argentina peso (AGP), Braziffan real (BRR) Mexican peso (MXP) and the Russian rouble (RUR)

The Taiwan new dollar, Thai baht and Russian Rouble series have skewers close to zero and are likely to be normally distributed. Other exchange rate series is founded to have scans of either positive or negative. For example, the Chinese Renminbi and Argentina peso series have very high negative scans as compared to other series.

The Chinese Renminbi and Argentina peso series also have high positive kurtosis, indicating a “peaked” distribution. This is because both currencies are pegged to the US dollar. Other exchange rate series have small negative kurtosis, a “flat” distribution, except for Japanese yen since they have small frequent change in the exchange rate.

The ADF test for the level and first difference in the full sample data are first estimated followed by[1] unit root test with structural break in each of the exchange rate series using a dummy variable. Following this, the ADF test for each exchange rate series in first differences for all seven sub-samples are estimated (i.e., Pre-1994 Mexican, 1997 Asian, 1998 Russian, 1999 Brazilian crises and Post crisis period).

Unit root test for the full sample: The results of ADF unit root tests of the individual exchange rate series (Table 2). The results show that among the Asian exchange rate series, the null of a unit root is not rejected for all series in levels except for the Chinese Renminbi at 5% significance level. Among the non-Asian exchange rate series, the null of unit root for the Brazilian real and Russian rouble series are also not rejected. These results are not surprising as nominal exchange rate series are usually found to be non-stationary and non- mean reverting.

When the ADF unit root test was the estimated first difference, the null hypothesis of unit root was rejected for all the exchange rate series. Thus the Hong Kong dollar, Japanese yen , South Korean won, Taiwan New dollar, Indonesian rupiah, Malaysian Ringgit, Singapore dollar, Thai Baht, Philippines peso, Brazilian real and Russian rouble exchange rate series were integrated of order 1.

Unit root test with structural break for the full sample: Using[1] unit test with structural break, this study found substantially similar results to those without structural break (Table 3). The Chenese Renminbi, Argentina and Mexican pesos series are excluded from the unit root test because they are found to be stationary. The results from the ADF tests indicate that 11 out of the 14 exchange rate series examined are non-stationary. Similarly, using[1] test for the 11 series examined, it is found that, the null hypothesis of a unit root cannot be rejected in almost every case and all series examined are non-stationary.

The results are consistent to[10,11] findings that nominal exchange rate non-stationary. However, it contradicts[1] suggest that the conventional Augmented Dickey Fuller test is biased when there is a structural break. These exchange rate series are non-stationary process rather than trend stationary series with a structural break.

Unit root test for the seven sub-samples: Table 4 summarizes the results of the augmented dickey fuller test for each sub sample. The results showed that the null hypotheses of a unit root are not rejected most exchange rate series but are rejected for all first difference exchange rate series in all seven sub-samples. This indicates that most of these exchange rate series examined contain unit root but are stationary on first difference. Hence, they are integrated of order 1. The null hypothesis of unit root is rejected in the sub-sample using level data, which includes the Hong Kong dollar, Chinese remember, Thai Bhat, Argentina peso, Mexican peso and Russian ruble. The Argentine peso series is estimated to be I (0) for seven sub-sample except during post-Mexican and Russian crisis period. The Japanese yen, South Korean won, Taiwanese New dollar, Malaysian Ringgit, Philippines peso, Singapore dollar and Brazilian real are I (1) across the seven sub-samples.

Robustness test on different frequencies: To examine the robustness of the unit root test on different frequencies, the unit root test with and without structural break were estimated for the full sample data using daily, weekly and monthly data. Table 5 shows the results from the ADF unit root test, using daily, weekly and monthly data.

Table 2: Augmented dickey –fuller unit root test (full sample)

Exchange	Test statistics ---------- Level data	first difference data	1(d)
Asian currency series:			
Hong Kong dollar	-0.41	-11.56	1(1)
Japanese Yen	-1.28	-26.86	1(1)
South Korean won	-1.60	-6.87	1(1)
Taiwan new dollar	-0.82	-7.41	1(1)
Chinese renminbi	-0.90	-9.31	1(0)
Indonesian rupiah	-0.90	-9.31	1(1)
Malaysian ringgit	-1.23	-30.28	1(1)
Singapore dollar	-0.54	-7.85	1(1)
Thai baht	-1.00	-8.52	1(1)
Philippines peso	-0.27	-7.92	1(1)
Non-asian currency series:			
Argentina peso	-5.47*	-10.58	1(0)
Brazillian real	-0.76	-6.58	1(1)
Mexican peso	-2.89	-8.76	1(0)
Russian rouble	-1.31	-7.49	1(1)

Notes: The full sample period is from 3 January 1994 to 31 December 2001 consisting of 2086 daily observations for each series except for Brazilian real. The Brazilian real series is from 1 July 1994 to 31 December 2001 (earlier data not available).Similar results were found using daily, weekly and monthly data except for Argentina pesos, which are I (1) when monthly data is used. Using Monte Carlo experiments,[31] find that over a substantial range of values, power depends more on the span of data rather than on the number of observations.
The level data column reports test statistics of γ from $\Delta y_t = a_0 + \gamma \Delta y_{t-1} + \sum_{1+2}^{\rho} \beta_i \Delta^2 y_{t=1+1} + \varepsilon_i$ and the first difference data column reports the test statistics of γ from $\Delta^2 y_t = a_0 + \gamma \Delta y_{t-1} + \sum_{1+1}^{\rho} \beta_i \Delta^2 y_{t=1+1} + \varepsilon_i$
The 1 (d) column indicates whether the exchange rate series is integrated of order 0, 1 (0) or integrated of order 1,1 (1). The 95% critical value for the augmented dickey-fuller statistics is-2.8634 *indicates significance at the 5% level.

This explains the reasons for finding similar results when running the unit root test using daily and weekly data over the same time span.

Table 6 shows the result from the[1] unit root test with structural break using 3 different frequency data-daily, weekly and monthly on the full sample set. When the structural break is taken into account, the results are the same regardless of data frequency type.

As for the sub-sample unit root test, the 1994 Mexican and 1997 Asian crises were chosen to test for robustness. Table 7 shows similar results are obtained when daily and weekly data are used. During the 1994 Mexican crisis, the results are similar except for the Philippine peso, Mexican peso and Russian rouble, which are I (0) when daily data is used and I (1) when weekly data is employed. On the other hand, during the 1997 Asian crisis, the only difference is that the Thai Baht is I (0) using daily data and I (1) using weekly data. For monthly data, the unit root test in Table 7 shows that most of the series are I (1) with a few others integrated of order more than one. These results are questionable due to the low power of the unit root test since only a small number of observations are available for each sub sample. For example, the number of observations during the 1994 Mexican and 1997 Asian crises are 12 and 14, respectively and the results differ from those using daily and weekly data.

Robustness test:

Comparison of Augmented dickey-fuller unit root test (Full and sub-samples): Dividing the full sample data set into sub samples has some effects on the ADF unit root test results.

Table 3: [1] unit root test (full sample with structural break)

Exchange rate series	Time of structural break	Test statistics	1 (d)
Asian exchange rate series:			
Hong Kong dollar	03/04/1999	339.2180	1(1)
Japanese Yen	None	-1.2840	1(1)
South Korean Won	01/10/1999	377.4737	1(1)
Taiwan new dollar	01/10/1999	576.3064	1(1)
Chinese renminbi	-	-	-
Indonesian rupiah	01/10/1999	423.17892	1(1)
Malaysian ringgit	03/07/1999	443.6243	1(1)
Philippines peso	07/11/1997	580.4141	1(1)
Singapore dollar	04/07/1997	517.5781	1(1)
Thai baht	02/07/1997	457.3714	1(1)
Non-asian exchange rate series:			
Argentine peso	-	-	-
Brazllian real	14/01/1999	660.8789	1(1)
Mexican peso	-	-	-
Russian rouble	18/08/1998	829.3528	1(1)

Notes: The full sample period is from 3 January 1994 to 31 December 2001 consisting of 2086 daily observation for each series except for Brazilian real. The Brazilian real series is from 1 July 1994 to 31 December 2001 (earlier data not available). The Chinese renminbl, Argentina peso and Mexican peso are excluded from this because they are found to be stationary. The[1] test is run here to examine whether structural break will cause series that are found to be I (1) in section 3.6.1 will in fact be I (0) after the structural break is taken into account. The numbers reported in the third column is the test statistics of α_I of the[1] model $y_i = a_0 + \gamma \Delta y_{i=1} + \sum_{1+2}^{\rho} \beta_i \Delta^2 y_{t=1+1} + \varepsilon_i$

The time of structural break is chosen based on visual based on visual inspection of data and plot on the exchange rate. The critical value is obtained from the critical value table simulated by[1]. None of the series is able to reject the critical value at 1% or 5% level.

For example, some of the exchange rate series are I (0) when the full sample data set is used but appear to be I (1) in certain sub-samples (see Table 8). This includes the Chinese Renminbi, Argentine peso and Mexican peso. On the other hand, some exchange rate series which are I (1) when tested in the full sample, are shown to be I (0) in certain subs-samples. This is evidenced in the Hong Kong dollar, Thai Baht and Russian rouble series.

This mix results of I (0) and I (1) when the sub-samples were tested could be due to the full sample is separated into smaller sub samples. Since we break the full sample into sub periods based on dates of critical events, that is, dates when currency crises broke out, some of the volatility contained in the full sample has been removed. Thus, when testing sub samples for unit root, the exchange rate series might be I (0) for certain sub periods even though they are found to be I (1) when tested with full sample data.

For a series that are found to be I (0) with the full sample data but I (1) in a certain sub sample, a possible explanation is that the unit root ADF test is more sensitive to smaller breaks, which appear to be more significant when the time period for unit root test is shorter. In addition, testing unit root for the sub sample also reduces the power of the unit root test since the test is higher with a longer span of data[19].

The ADF unit root tests are quite robust since the results are similar to data of different frequency-daily, weekly and monthly. However, when testing for unit roots in sub samples using monthly data, some of the series appears to be integrated of more than order 1, which contradicts to previous findings the nominal exchange rate are usually characterized by an I (1) process. The monthly data might be unreliable if the number of observations is too small. Some of the series are also sensitive to the time period chosen.

Robustness test on Perron (1989) unit root test using different time interval: Table 9 shows the results from the[1] unit root test for the exchange rate series using different time interval. The Chinese Renminbi, Argentine and Mexican pesos exchange rate series which are I (0) in full sample data are excluded from the test. Different time intervals were chosen for each exchange rate series to see if they have an impact on the unit root results. Overall, the results show that all exchange rate series are I (1).

Table 4: Augmented dickey-fuller unit root test for sub sample data set

Exchange rate series	Pre-mexican crisis 3.Jan 94-19 Dec 94 Test Statistics	1 (d)	Mexican crisis 20 Dec 94-29 Dec 95 Test statistics	1 (d)	post-mexican crisis I Jan 96-1 July 97 Test statistics	1 (d)	Asian crisis 2 July 97-14 Aug 98 Test statistics	1 (d)	Russian crisis 17 Aug 98-12 Jan 99 Test statistics	1 (d)	Brazilian crisis 13 Jan 99-31 Dec 99 Test statistics	1 (d)	Post crisis 3 Jan 00-31 Dec 01 Test statistics	1 (d)
Asian exchange rate series:														
HKD	4.2278	1(0)	-2.9124	1(0)	1-.9825	1(1)	-2.5047	1(1)	-2.3685	1(1)	-0.4862	1(1)	-4.4408	1(0)
JPY	-2.4040	1(1)	-06809	1(1)	-1.5388	1(1)	-0.6224	1(1)	-1.5592	1(1)	-0.2168	1(1)	-0.8606	1(1)
KRW	-0.3699	1(1)	-1.7181	1(1)	0.0977	1(1)	-1.4000	1(1)	0.0635	1(1)	-1.2225	1(1)	-0.1994	1(1)
TWN	-1.2052	1(1)	-1.7181	1(1)	0.0977	1(1)	-14103	1(1)	-1.1593	1(1)	0.1150	1(1)	-0.1994	1(1)
CHR	0.8263	1(1)	-0.5319	1(1)	-1.7773	1(1)	-1.4103	1(0)	-1.0938	1(1)	-2.4165	1(1)	-3.2165	1(1)
IDR	-2.2903	1(1)	-1.3166	1(1)	-1.3166	1(1)	-0.5632	1(1)	-1.0761	1(1)	-1.4708	1(1)	-2.4165	1(1)
MYR	-0.8209	1(1)	-1.3166	1(1)	-2.0291	1(1)	-2.0024	1(1)	-0.9108	1(1)	-1.2143	1(1)	-	-
PHP	1.5747	1(1)	-1.8443	1(1)	-0.0989	1(1)	-1.3975	1(1)	-0.0874	1(1)	-0.6870	1(1)	-1.6034	1(1)
SGD	-1.1141	1(1)	-2.0797	1(1)	-1.6924	1(1)	-1.7526	1(1)	-2.0874	1(1)	-1.6020	1(1)	-2.371	1(1)
Non-Asian exchange rate series:														
AGP	-4.1730	1(0)	-3.9961	1(0)	-2.3750	1(1)	-4.4094	1(0)	-2.2609	1(1)	-4.4703	1(0)	-1.2113	1(0)
BRR	-1.2748	1(1)	-1.2792	1(1)	0.0248	1(1)	0.3910	1(1)	-0.2127	1(1)	-4.4703	1(1)	-1.0353	1(1)
MXP	-2.0177	1(1)	-2.6491	1(0)	-1.2091	1(1)	-0.2429	1(1)	-3.9386	1(0)	-3.5723	1(0)	-2.4286	1(1)
RUR	0.7452	1(1)	-3.1221	1(0)	3.6089	1(0)	0.6788	1(1)	-1.9900	1(0)	-1.9481	1(1)	-1.6850	1(1)

Notes: The numbers are the test statistics of γ from the ADF regressions using level data. The 1(d) column reports whether the exchange rate series is integrated of order 0, 1(0) or integrated of order 1, 1(1). Critical values are obtained from December 1991 and indicate significance at eh 5% level for ADF test. When first difference data are used. The test is always significant at 95% for all series and all periods except for Malaysian during the post when it is prggted against the US dollar.

Table 5: Robustness test: Augmented dickey-fuller unit root test (full sample)

Exchange rate series	Daily data Test-statistics	1(d)	Weekly data Test-xstatistics	1(d)	Monthly data Test-statistics	1(d)
Asian exchange rate series:						
Hong Kong dollar	-0.41	1(1)	0.07	1(1)	0.11	1(1)
Japanese Yen	-1.28	1(1)	-1.32	1(1)	-1.58	1(1)
South Korean won	-1.60	1(1)	-1.07	1(1)	-1.40	1(1)
Taiwan new dollar	-0.82	1(1)	-0.49	1(1)	-0.58	1(1)
Chinese renminbi	-4.66	1(0)	-4.39	1(0)	-2.98	1(0)
Indonesian rupiah	-0.90	1(1)	-0.83	1(1)	-0.98	1(1)
Malaysian ringgit	-1.23	1(1)	-1.05	1(1)	-1.10	1(1)
Singapore dollar	-0.54	1(1)	-0.07	1(1)	0.04	1(1)
Thai baht	-1.00	1(1)	-0.89	1(1)	-1.-8	1(1)
Philippines peso	-0.27	1(1)	-0.48	1(1)	0.28	1(1)
Non-asian exchange rate series:						
Argentine peso	-5.47	1(0)	-6.42	1(0)	-0.-8	1(1)

Table 5: Continue

Brazllian real	-0.76	1(1)	-0.61	1(1)	-0.21	1(1)
Mexican peso	-2.89	1(0)	-2.92	1(0)	-4.59	1(0)
Russian rouble	-1.31	1(1)	-1.28	1(1)	-1.25	1(1)

Notes: The full sample period is from 3 January 1994 to 31 December 2001 for each series except for Brazilian real. The Brazilian real series is from 1July 1994 to 31 December 2001 (earlier data not available). The number of observations for each individual series is 2086 for daily data, 418 for weekly data and 96 for monthly data. The numbers are the test statistics of γ from:

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Using first difference data.
The 1 (d) column indicates whether the exchange rate series is integrated of order 0, 1 (0) or integrated of order 1,1 (1). The 95% critical value for the augmented dickey-fuller statistics is-2.8634 indicates significance at the 5% level.

Table 6: Robustness test-[1] unit root test structural break (full sample)

Exchange rate series	Daily data Test-statistics	1(d)	Weekly data Test-statistics	1(d)	Monthly data Test-statistics	1(d)
Asian exchange rate series:						
Hong Kong dollar	339.218	1(1)	70.43	1(1)	28.97	1(1)
Japanese Yen	-1.2840	1(1)	-1.32	1(1)	-1.58	1(1)
South Korean won	377.4737	1(1)	181.23	1(1)	14.32	1(1)
Taiwan new dollar	576.3064	1(1)	107.47	1(1)	16.46	1(1)
Chinese renminbi	-	-	-	-	-	-
Indonesian rupiah	423.1892	1(1)	77.92	1(1)	19.48	1(1)
Malaysian ringgit	443.6243	1(1)	83.16	1(1)	20.00	1(1)
Singapore dollar	517.5781	1(1)	81.35	1(1)	17.61	1(1)
Thai baht	457.3714	1(1)	83.75	1(1)	20.32	1(1)
Philippines peso	580.4114	1(1)	144.93	1(1)	37.11	1(1)
Non-Asian exchange rate series:						
Argentine peso	-	-	-	-	2.67	1(1)
Brazllian real	646.38	1(1)	121.08	1(1)	18.35	1(1)
Mexican peso	-	-	-	-	-	-
Russian rouble	802.39	1(1)	219.37	1(1)	41.08	1(1)

Notes: The full sample period is from 3 January 1994 to 31 December 2001 for each series except for Brazilian real. The Brazilian real series is from 1 July 1994 to 31 December 2001 (earlier data not available). The number of observations for each individual series is 2086 for direct data, 418 fir weekly data and 96 for monthly data. The Chinese Renminbi Argentina peso and Mexican peso are excluded from this test if they are found to be 1 (0) in table 3. The[1] test is run here to examine whether structural bresl will cause series that are found to be 1 (1) will in fact be 1 (0) after a structural break no to account. The numbers reported in the third column is the text statistics of a of the[1] model:

$$y_i = a_0 + \gamma \Delta y_{i=1} + \sum_{1+2}^{\rho} \beta_i \Delta^2 y_{t=1+1} + \varepsilon_i$$

The time of structural break is chosen based on visual based on visual inspection of data and plot on the exchange rate. The critical value is obtained from the critical value table simulated by[1]. None of the series is able to reject the critical value at 1% or 5% level.

Table 7: Robustness test: Augmented dickey fuller unit root test on Mexican crisis and Asian crisis (sub periods)

	Mexican crisis period 20 Dec 1994-29 Dec 1995			Asian crisis period 2 July 1997-14 August 1998		
Exchange rate series	Daily data	weekly data	monthly data	daily data	weekly data	monthly data
Number of observations	269	54	12	293	59	14
Asian exchange rate series:						
Hong Kong dollar	1(0)	1(0)	> 1(1)	1(1)	1(0)	1(1)
Japanese Yen	1(1)	1(1)	> 1(1)	1(1)	1(1)	>1(1)
South Korean won	1(1)	1(1)	> 1(1)	1(1)	1(1)	>1(1)
Taiwan new dollar	1(1)	1(1)	> 1(1)	1(1)	1(1)	1(1)
Chinese Renminbi	1(1)	1(1)	> 1(1)	1(0)	1(1)	1(1)
Indonesian rupiah	1(1)	1(1)	1(1)	1(1)	1(1)	>1(1)
Malaysian Ringgit	1(1)	1(1)	1(0)	1(1)	1(1)	1(0)
Singapore dollar	1(1)	1(1)	> 1(1)	>1(1)	1(1)	>1(1)
Thai Baht	1(1)	1(1)	>1(1)	1(1)	1(1)	>1(1)
Philippines peso	1(1)	1(1)	> 1(1)	1(1)	1(1)	>1(1)
Non-Asian Exchange rate series:						
Argentine peso	1(0)	1(0)	> 1(0)	1(0)	1 (0)	1(1)
Brazilian real	1(1)	1(1)	1(1)	1(1)	1(1)	1(1)
Mexican peso	1(1)	1(1)	> 1(1)	1(1)	1(1)	>1(1)
Russian rouble	1(0)	1(1)	> 1(0)	1(1)	1(1)	1(1)

Notes: Mexican crisis period and Asian crisis period are chosen to text for robustness of the ADF unit root test for sub-samples. 1 (d) column summarizes whether the exchange rate series is integrated of order 0, 1 (0), integrated of order 1,1 (1) or integrated of more than order 1, > 1 (1)

Table 8: Robustness test: Comparison of augmented dickey fuller unit root test

	In full sample	in sub samples	
Exchange rate series	1(d)	Number of 1(0)	Number of 1(1)
Asian exchange rate series:			
Hong Kong dollar	1(1)	3	4
Japanese yen	1(1)	0	7
South Korean won	1(1)	0	7
Taiwan new dollar	1(1)	0	7
Chinese Renminbi	1(0)	2	5
Indonesian rupiah	1(1)	0	7
Malaysian Ringgit	1(1)	0	6
Singapore dollar	1(1)	0	7
Thai bath	1(1)	0	7
Non-Asian exchange rate series:			
Philippine peso	1(0)	5	2
Argentine peso	1(1)	2	7
Brazilian real	1(1)	3	4
Total		16	81

Notes: The full sample period is from 3 January 1994 to 31 December 2001 consisting of 2086 daily observation for each series except for Brazilian real. The Brazilian real series is from 1 July 1994 to 31 December 2001 (earlier data not available). The 1 (d) column indicates whether the exchange rate series is integrated of order 0, 1 (0) or integrated of order 1,1 (1). Sub samples column refers to the seven sub samples. The date of crisis as determined based on visual inspection of plots and data and from prior literature.

Table 9: Robustness test-[1] unit root test (different sample period)

Exchange rate series	Sample period	Time of break	1(d)
Hong Kong dollar	30/03/1999-30/03/2001	10/08/2000	N/A
	15/04/1999-30/03/2001	27/10/2000	N/A
Japanese yen	30/06/1997-29/06/2001	18/08/1998	NA
	20/08/1997-29/06/2001	24/08/1998	1(1)
South Korean won	25/09/1997-29/09/2001	23/12/1997	1(1)
	01/01/1998-28/09/2001	29/09/1998	NA
Taiwan new dollar	25/09/1997-28/09/2001	13/01/1998	1(1)
	15/01/1997-28/09/2001	15/06/1998	N/A
Chinese renminbi	-	-	-
Indonesian rupiah	25.09.1997-28/09/2001	23/01/1998	1(1)
	20/03/1998-28/09/2001	17/06/1998	NA\
Malaysian ringgit	30/06/1997-29/06/2001	23/01/1998	N/A
	03/07/1997-29/06/2001	28/10/1998	N/A
Singapore dollar	30/06/1997-29/06/2001	12/01/1998	1(1)
	15/01/1998-29/06/2001	11/06/1998	N/A
Thai bath	30/06/1997-29/06/2001	26/011998	1(1)
	02/07/1997-31/10/2001	23/09/1999	N/A
Philippine peso	03/11/1997-31/10/2001	09/01/1998	1(1)
	15/11/1997-31/10/2011	21/09/1998	N/A
Argentine peso	-	-	-
Brazilian real	11/01/1999-31/12/2001	04/03/1999	1(1)
	10/03/1999-31/12/2001	24/09/2001	1(1)
Mexican	-	-	-
Russian rouble	14/08/1998-31/12/2001	04/03/1999	1(1)
	18/08/1998-31/07/2001	01/02/1999	1(1)

Notes: The Chinese Renminbi, Argentine and Mexican pesos are excluded from this test because they are found to be stationary using a full sample test. The[1] test is run here to examine whether structural break will cause series that are found to be 1 (1) in full sample will in fact be 1 (0) after the structural break is taken into account. The numbers reported in the third column are the test statistics of a1 of the[1] model:

$$y_i = a_0 + \gamma \Delta y_{i=1} + \sum_{1+2}^{\rho} \beta_i \Delta^2 y_{t=1+1} + \varepsilon_i$$

The time of structural break is chosen based on visual based on visual inspection of data and plot on the exchange rate. The critical value is obtained from the critical value table simulated by[1]. None of the series is able to reject the critical value at 1% or 5% level. N/A indicates that there is not a significant structural break found when shorter time interval is investigated. Therefore, the[1] tests are not applicable in these cases.

However, the robustness test shows with the structural break data changes, smaller jumps inside the time period appear to be more obvious when shorter time period is taken into account. For some of these exchange rate series, no significant structural break is found when investigating shorter time interval. Therefore, the[1] unit root test is not applicable. In general, the robustness test illustrates that with the structural break date change, smaller jumps inside the time period appear to be more obvious. As a result, the findings may incorrectly conclude that there is a structural break when there is not.

CONCLLUSION

The study examines the unit root tests on exchange rate series from Asia and emerging economies foreign exchange markets. The results from the full sample data using the ADF test indicates that most nominal exchange rate series contain unit root except for the Chinese Renminbi, Argentina and Mexican pesos. Other series are found to be non-stationary and are integrated of order 1 because they are stationary on first difference.

Similar results are obtained when structural similar results are obtained when structural break is taken into consideration. The ADF unit root test for each of the individual series for all seven sub-samples are also estimated. The results show that most of the exchange rate series are integrated of order 1 with a few exceptions. This implies that the series that are I (1) have to be first difference. The findings contrast Perron’s suggest that the conventional augmented dickey fuller test is biased when there is a structural break. However, the findings are consistent with[12,14] findings, which take a structural break into account who found similar results when assuming that there is no structural break.

The results from the ADF unit root tests have to be interpreted with caution since unit root tests have the problem of size distortion and low power[32]. First presented Monte Carlo evidence of the size distortion problems of the commonly used unit root test, that is the actual size of a test in small samples is very different from the size of the test indicated by asymptotic theory. The author found that the different from the distribution reported by dickey and fuller if the underlying distribution contains a moving-average component[33]. Monte Carlo simulation shows that the power of the ADF test is very low, that is the ADF unit root tests do not have the power to distinguish between a unit root and near unit root process. The[1] test is found to be insensitive to the data frequencies but is sensitive to the time interval chosen. This is because the jumps that are found to be significant in the full period appear to be insignificant when shorter time interval is investigated. This limitation suggests the Philip-Perron modified unit root test and the modified ADF test (the ADF-GLS test) as the solutions to the problems of size and power of the conventional unit root test.

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