Weak-Form Efficiency of Foreign Exchange Market in the Organisation for Economic Cooperation and Development Countries: Unit Root Test

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Abstract

This paper will look at the weak-form efficiency of the foreign exchange market in thirty (30) Organization for Economic Cooperation and Development (OECD) countries. We employ Augmented Dickey-Fuller (ADF), Philip-Perron (PP) and Kwiatkowski-Phillips-Schmidt-Shin analysis to examine for the unit root. Using weekly data for the period 2000 to 2007, the results for weak-form efficiency using ADF and PP tests indicate that the exchange rates studied follow random walks. The current value of the exchange rate cannot be predicted using its past values. In addition, the OECD foreign exchange market consistent with the weak-form of the Efficient Market Hypothesis.

Keywords: Foreign exchange (Forex), OECD countries, Market efficiency, Unit-Root test

1. Introduction

The foreign exchange market refers to the organizational setting within which individuals, businesses, governments, and banks buy and sell foreign currencies and other debt instruments. Only a small fraction of daily transactions in foreign exchange actually involve trading of currency.

A country will practice either one of a fixed exchange rate system, a floating exchange rate system or somewhere in between. When conducting purchases and sales of foreign currencies, one party promises to pay a stipulated amount of currency to another party or customer on an agreed-upon date.

The exchange rate of a country can be determined through either;

i. monetary approach that emphasizes on a system of market-determined exchange rates, in which movements in currency value plays a primary role in restoring equilibrium between money demand and money supply; or

ii. financial asset approach through the capital and equity market.

This paper will look at the foreign exchange market efficiency in the Organization for Economic Cooperation and Development (OECD) countries which comprises 30 countries. The OECD was formed in 1961 as an expansion of the Organization for European Economic Co-operation (OEEC). The OEEC developed strategies for restructuring Europe after World War II. Conversely, the OECD expanded its reach and included not only European countries, but also Canada, Mexico, Australia, New Zealand, Japan, Korea, and the United States.

The OECD consists of like-minded countries, with the 30 member states all sharing a commitment to democratic government and a market economy, group in a forum to discuss, develop and refine economic and social policy. Members compare experiences, seek answers to common problems, and work to coordinate domestic and international policies to help members and non-members deal with an increasingly globalised world. The organization is internationally recognized as a reliable and comprehensive source of comparable economic and social data.

The OECD's goals are to promote economic stability and democracy in its member countries and in developing countries. One of the main methods that the OECD uses to analyze countries is collecting and publishing statistics on social and economic issues. These statistics are reviewed by governments and during OECD meetings to address how best to foster OECD goals.

The OECD also has influence over the issue of sustainable development. The OECD looks for solutions that allow for current economic growth without negatively impacting the economic growth and survival of future generations.

The primary motivation of the paper arises from the fact that the majority of empirical studies reject market efficiency and rational expectations in foreign exchange market statistically. The studies of these have also been greeted with much suspicion. The findings of market efficiency tests are often ambiguous, as researchers are unable to discern whether the rejection of market efficiency is due to irrationality, misspecification of expected returns, or a risk premium. This study is to determine the weak-form efficiency by performing the unit-root test for each variable using ADF, PP and KPSS. The basis of the analysis is foreign exchange market efficiency, estimated on weekly data from 2001 to 2007.

The paper proceeds as follows: Section 2 presents a literature reviews, Section 3 discus the methodology while Section 4 presents the empirical results and finally conclusion.

2. Literature Review

2.1 Efficient Market Hypothesis

Although the efficient market hypothesis (EMH) is usually applied to the stock market, it can also be used to show the foreign exchange rates, like stock price. The weak form tests of market efficiency states that it is impossible to predict future prices by analyzing prices from the past. The current price is a fair one that considers any information contained in the past price data thus technical analysis is of little use. Run tests can be employed with its main assumption that there should be no pattern in the time series of returns. Three theories of time series behavior of prices can be found in the literature (Cuthbertson & Nitzsche, 2005):

(i) The fair-game model

This model is based on the behavior of average returns'

$$E(\varepsilon_{j,t+1}) = E[\, r_{j,t+1} - E(r_{j,t+1}|\Omega)] = 0 \qquad \text{Eq (2.1)}$$

A fair game means that, on average, across a large number of samples, the expected return, r, on a security equals its actual return.

(ii) The Martingale of sub-martingale model

It is also a fair game, where tomorrow's price, p, is expected to be the same as today (the expected return is zero)

$$E(P_{j,t+1}|\,\Omega) = P_{j,t}, \qquad \text{Eq (2.2)}$$

while the sub-martingale model is a fair game with positive returns

$$E(P_{j,t+1}|\,\Omega) > P_{j,t} \qquad \text{Eq (2.3)}$$

(iii) The random walk model

The simplest form version is the independently and identically distributed increments case, in which the dynamics of prices, p, are given by the equation:

$$P_t = \mu + P_{t+1} + \varepsilon_t \qquad \varepsilon_t \sim IID\,(0, \sigma^2) \qquad \text{Eq (2.4)}$$

2.1.1 The random walk model

The efficient market hypothesis can also be applied to the foreign exchange market, to show that it generally follows a random walk model.

Hypothesis:-

H_o: Prices follow random walk (efficient),

H_A: Market is not efficient.

If the random walk hypothesis holds, the weak form of the EMH must hold, but not vice versa (Cuthbertson & Nitzsche, 2005). Thus the evidence supporting the random walk model is the evidence of market efficiency. This test will be implemented to confirm the efficient market view that the exchange rates are not predictable and follow random walk.

2.2 Review of empirical evidence

The extensive literature underlines two major points relevant to examine the efficiency of foreign exchange market. These include variable selection and representation, and framework chosen.

Kasman & Ayhan (2007) investigates the relationship between exchange rates (nominal and real) and foreign exchange reserves in Turkey, using monthly data over the period 1982:1 to 2005:11. Detailed unit root tests of Zivot and Andrews (1992) are performed by them to establish the order of cointegration of the data series, to check whether in the presence of a structural break in the data, the series are integrated of order one, besides conventional ADF test. The empirical results from conventional cointegration test suggest that there is no long-run relationship between exchange rates and foreign exchange reserves. However, the Gregory and Hansen (1996) cointegration test, when performed to test whether there is a long-run relationship between exchange rates and foreign exchange reserves taking account of the possibility of instability in long-run relations, provide evidence of significant long-run relationship between foreign exchange rates and real exchange reserves.

Another different method developed in statistical physics to test the market efficiency of the financial time series are being used by Oh et al. (2007) which investigates the relative market efficiency in financial market data, using the approximate entropy (ApEn) method for a quantification of randomness of time series. The writers use the global daily foreign exchange market indices for 17 countries during two periods from 1984 to 1998 and from 1999 to 2004 in order to study the efficiency in various foreign exchange markets around the market crisis and employ the apron to quantify market efficiency in the foreign exchange markets.

Kang (2008) applies a new cointegration method called Search method, which is very different from those derived from conventional MLE (maximum likelihood estimation) or OLS (ordinary least square) methods. It demonstrates that using OLS method is inadequate when finding cointegration relationship. Tests have been done to the foreign exchange rates of G-7 countries i.e. Japanese Yen, German Mark, British Pound, French Franc, Italian Lira and the Canadian Dollar against US Dollar, to estimate cointegration relationship for the period March 1973 to December 2001. The method searches numerically, by strictly following the definition of the cointegration, a particular linear combination of non-stationary series in order to make it a stationary series. The ADF test is used to find unit root and monthly data retrieved from St Louis Federal Reserve Bank database, FRED, for the flexible exchange rate period. Each of the rates has one unit root at the 5% significant level, either at lag length of two or of four, consistent with the findings in the literature, when the conventional OLS and MLE methods fail to find.

Simulations show that either source can cause ADF and Engle & Granger tests to find substantial spurious cointegration at empirically possible values of fractional integration order and variable magnitude. When the biases are combined, even at moderate values, tests overwhelmingly find spurious cointegration (Kellard, 2006).

Kim and Ratti (2006) obtained daily data for the exchange rate, interest rate, credit spread, stock index, and banking sector stock index for five crisis countries – Thailand, Indonesia, Malaysia, Korea and the Philippines for this research, they employed the data across VAR and VECM models using ADF, EG. The test results indicate a rise in interest rate, associated with significant exchange rate depreciation of THB, PHP and KRW.

Lo and Lee (2005) acknowledge that the evidence of autocorrelation (price dependency) in daily/weekly asset returns provides no conclusive evidence against the market efficiency hypothesis since the holding period of actual speculative positions maybe less than a day. It examines whether this electronic inter-dealer market demonstrates the weak-form efficiency property based on pattern of autocorrelation in the rate of return's existence and consistency of autocorrelation pattern that allows dealers to take profit from it.

Wickremasinghe (2004) examines the weak efficiency of the foreign exchange market in Sri Lanka using monthly data for six currencies (pairs) for the period January 1986 to November 2000. The paper conducts ADF and PP tests for weak form and Johansen cointegration, Granger causality and variance decomposition analysis tests for semi-strong form and show inconsistent results. Results of unit root tests indicate that all six exchange rates are random walks which support the EMH in its weak-form while the later tests are against the semi-strong version of the EMH.

Wu and Chen (1998) investigates panel unit-root test of Im et al. (2003) to examine the stationarity of forward primer and interest rates differentials. In comparison to Crowder (1994), the research increases the span of the data by jointly testing for a unit root across a large number of currencies. Result show that the null hypothesis of existing unit root in the forward premium can be rejected based on the panel unit-root test and the interest differentials are found stationary. The reason for these findings may be due to the higher power of the panel unit-root test from the weighted symmetric (WS) estimator than that for the conventional unit-root tests of ADF. Thus, the paper supports the hypothesis of foreign exchange market efficiency.

3. Methodology

For the purpose of the study the unit root tests are applied, namely Augmented Dickey-Fuller (ADF), Phillip-Perron (PP) and (KPSS) tests. The ADF and PP tests are based on the null hypothesis that a unit root exists in the time-series while the KPSS is based on the reverses null hypothesis of a unit root exists.

3.1 Unit Root Tests and Orders of Integration

The cointegration tests requires that the series to have the same order of integration. Thus, the first step in cointegration analysis is to determine the order of integration of the series using the unit root test. Three procedures for detecting unit roots are employed here, that is ADF, PP and KPSS tests. In conducting the DF test, it was assumed that the residual term ε_t was uncorrelated. But in case the ε_t are correlated, Dickey and Fuller have developed a test known as ADF test. For series with a unit root which I(1), results should show that each variable is non-stationary at level and attains stationary after first differencing. Consequently, two tests should be performed, one at level and another at first difference.

3.1.1 Augmented Dickey Fuller

There are several unit root tests available in the literature to determine the order of integration of the individual series. However, in this study used Augmented Dickey Fuller test (ADF) which was proposed by Said and Dickey (1984).

For this purpose, after taking logs, the test of stationary as well as unit root test will be carried out using the Augmented Dickey-Fuller (ADF) tests for all the respective variables. Before that, it is important to note that, the error term is correlated. Thus technically, ADF test is conducted by 'augmenting" the proceedings equation by adding the lagged values of the dependent variables Δg_t (Gujarati, 2003).

To illustrate the use of Dickey Fuller tests, consider first an AR (1) process:

$$y_t = \mu + \rho y_{t-1} + \varepsilon_t \qquad \text{Eq (3.1)}$$

Where μ and ρ are parameters and ε_t is assumed to be white noise. y is a stationary series if -1 < ρ < 1. If ρ = 1, y is a non-stationary series (a random walk with drift); if the process is started at some point, the variance of y increase steadily with time and goes to infinity.

If hypothesis of a stationary series can be evaluated by testing whether the absolute value of ρ is strictly less than one. DF tests take the unit root test as the null hypothesis: $\rho = 1$. Since explosive series do not make much economic sense, this null hypothesis is tested against the one-sided alternative: $\rho < 1$. The test is carried out by estimating an equation with y_{t-1} subtracted from both sides of the equation:

$$\Delta y_t = \mu + \gamma y_{t-1} + \varepsilon_t \qquad \text{Eq (3.2)}$$

Where $\gamma = \rho - 1$ and the null and alternative hypothesis are

$$H_0 : \gamma = 0, H_1 : \gamma < 0 \qquad \text{Eq (3.3)}$$

While it may appear that performing a t-test on the estimated γ can carry out the test, the t-statistic under the null hypothesis of a unit root test does not have the conventional t-distribution. Dickey Fuller (DF) showed that the distribution under the null hypothesis is nonstandard, and stimulated the critical values for selected sample sizes.

In general, by testing null hypothesis against alternative, the unit root test can be rejected if the t-test statistic is negatively less than the critical value tabulated. The significant level for all critical value is 5%.

3.1.2 Phillips-Perron Unit Root Test

While the ADF test corrects for higher order serial correlation by adding lagged differenced terms the right-hand side, the PP test makes a correction to the t-statistic of the γ coefficient from the AR(1) regression to account for the serial correlation in. The correction is nonparametric since use an estimate of the spectrum of the ε at frequency zero that is robust to heteroscedasticity and autocorrelation of unknown form. The asymptotic distribution of the PP t-statistic is the same as the ADF t-statistic critical values.

3.1.3 KPSS Unit Root Test

Consequently, many economists have argued against using the standard unit root tests and proposed using other powerful tests, such as tests that can be used to test the null of stationarity against the alternative of non-stationarity. A number of tests have been developed; the most popular one is the KPSS test developed by Kwiatkowski,

For example, if the null of stationarity is accepted (rejected) and the null of non-stationarity is rejected (accepted), it confirmed that the series is stationary (non-stationary). Conversely, we don't have confirmation if both nulls are accepted or both are rejected.

The KPSS test statistic is given by

$$L\hat{M} = T^{-2}\sum_{t=1}^{T} S_t^2 / s^2(l), \qquad \text{Eq (3.4)}$$

where S_t is the partial sum of deviations of residuals from the sample mean,

$s^2(l) = T^{-1}\sum_{t=1}^{T}\hat{\varepsilon}_t^2 + \left(\frac{2}{T}\right)\sum_{s=1}^{l} w(s,l)\sum_{t=s+1}^{T}\hat{\varepsilon}_t\hat{\varepsilon}_{t-s}$ is a consistent estimator of the long run variance (σ^2) of the regression error, l is a lag truncation parameter, and $w(s,l) = 1-[s/(l+1)]$ is an optional weighting function (Bartlett weights) used to smooth the sample auto covariance function, which ensures that $s^2(l)$ is non-negative (Newey and West, 1987). The number of lags truncation in the KPSS test is selected automatically by Newey and West Band with using Bartlett Kernal Spectral estimation method. The null hypothesis of stationary is accepted if the value of the KPSS test statistic is less than it critical value.

4. Empirical Results

This section presents the empirical results of the statistical analysis of unit root tests to investigate the relationship between the co-integrating properties of foreign exchange rates in the OECD countries.

In this paper, the Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski-Phillips- Schmidt-Shin (KPSS) tests to examine for the unit root.

The null hypothesis for the ADF and PP tests postulate that series has a unit root, thus it is non-stationary. Whereas for the KPSS test, the null hypothesis is the opposite of the ADF and PP test. The unit root tests are conducted at level and first difference, both inclusive of testing with and without trend. These tests provide an easy method for determining whether a series is stationary. Importantly the results of unit root tests will also establish whether the series are integrated of the order, a pre-requisite for cointegration test. As reported in previous studies, most macroeconomics and financial series are expected to contain a unit root and thus are integrated of order one [that is, ~ I (1)].

The results of the ADF, PP and KPSS tests in the level are reported in Table 1. All variables are expressed in natural logarithm except for AUD and NZD, for a more precise analysis.

The ADF test indicates that for all variables exceed the critical value tabulated in MacKinnon (1991) at the five percent significance level except for CHF at constant without trend for spot, 3-month, 6-month and 1-year, CZK at constant with trend for spot, 3-month and 6-month, DKK, MXN and SEK at constant without trend for spot, and TRY at constant with trend for spot.

The t-statistics based on PP test are also shown in Table 1. The PP test indicates that for all variables, except for CHF at constant without trend for spot, 3-month, 6-month and 1-year, CZK at constant with trend for spot, 3-month, 6-month and 1-year, DKK at constant without trend for spot and 1-year, MXN at constant without trend for spot, 3-month and 1-year, SEK at constant without trend for spot and 6-month and TRY at constant with trend for 1-year, the t-statistics without the trend exceed the critical value tabulated in MacKinnon (1991) at the five percent significance level. Thus, the unit root hypothesis cannot be rejected for most cases. This implied that the variables for foreign exchange rates are non-stationary at level.

The KPSS test however postulates a different null hypothesis as compared to the previous two tests. In Table 1, the KPSS result found that the calculated statistics for all variables when tested at level with and without trend exceeds their critical value which implies that all variables are non-stationary at level. However, results are not support for CHF, CZK, DKK, MXN, SEK and TRY as they indicated a stationary at level from ADF and PP tests.

The DF and PP tests were also tested to the first difference on all series in Table 2. The t-statistics are smaller than the critical value at 5% significance level for all variables. Thus the results indicate that all currencies, after differencing, do not contain a unit root and are first difference stationary. This implies that the variables are stationary at first difference. However, the KPSS test showed that not all variables fail to reject null at 95% confidence level.

Overall, the unit root tests found that all variables are integrated at order I(1) except for selective few mentioned earlier which are integrated at I(0). As a result we say that most currencies examined are stationary at first differences and said to be integrated at I(1).

This test is conducted to determine the degree of integration of the time series, and to properly account for the non-stationary. Two asymptotically equivalent procedures are presented, namely the Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP) unit root tests with another reversed null hypothesis test, namely, the KPSS unit root test. This is essential for appropriate policy conclusions to be inferred from the estimated results.

The results show most variables are integrated of order one, I(1). This implied that they are non-stationary in the level, but stationary in the first difference. The level of significance of the statistics for all currencies is five percent. These results are consistent with the weak form of the EMH that says financial time series behave as random walks.

5. Conclusion

The efficiency in the foreign exchange market has long been debated in the economic literature. As set out in the introduction, the primary aim of this paper was to test the weak form efficiency of the foreign exchange market in the OECD countries by using bilateral foreign exchange rates for the past seven years. Weak-form efficiency is examined using unit root tests.

The results for weak-form efficiency using the ADF and PP tests indicate that the exchange rates studied follow random walks. Therefore, the current value of an exchange rate cannot be predicted using its past values. These results are consistent with the weak form of the efficient market hypothesis. This is consistent with findings in the literature of Aron (1997), Wickremasinghe (2004), Kasman and Ayhan (2007) and Kang (2008) but contradicts to findings by Wu and Chen (1998).

We examined the predictability of excess returns in the OECD foreign exchange markets based on the past history of returns. The reason is that the excess returns is a difficult concept in most developing countries where interest differentials would not appear to be important for investors, given exchange and credit controls, and where the returns on alternative assets are not easily assessed. Furthermore, the characteristics of exchange rates itself may be readily predictable in periods of hyper-inflation. We proposed further research such as based on nominal and real exchange rates, other econometric model such as asymmetric and nonlinear models and applying different causality test to investigate and compare with current findings.

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Table 1. Results of Unit Root Tests in Levels (t-statistics (lag/bandwidth))

	ADF				PP				KPSS			
	Ho: Variable is non-stationary				Ho: Variable is non-stationary				Ho: Variable is stationary			
Currency	Constant with trend	lag	Constant without trend	lag	Constant with trend	band width	Constant without trend	band width	Constant with trend	band width	Constant without trend	band width
AUD	- 1.9997	0	- 1.1638	0	- 1.9969	5	- 1.1431	6	0.3199	14*	1.4807	14*
AUD3	- 2.03	0	- 1.1149	0	- 2.0244	5	- 1.0904	6	0.3176	14*	1.5169	14*
AUD6	- 2.0577	0	- 1.075	0	- 2.0479	5	- 1.0531	7	0.3178	14*	1.5494	14*
AUDY	- 2.0945	0	- 1.0073	0	- 2.0793	5	- 0.9784	7	0.3218	14*	1.5993	14*
CAD	- 2.362	0	- 0.5079	0	- 2.4891	6	- 0.5093	5	0.2692	14*	2.0057	14*
CAD3	- 2.6359	0	- 0.2816	0	- 2.841	7	- 0.2958	6	0.2012	14*	2.0333	14*
CAD6	- 2.4704	0	- 0.7419	0	- 2.6691	7	- 0.7516	6	0.2221	14*	1.936	14*
CADY	- 2.3419	0	- 0.6884	0	- 2.5341	7	- 0.7012	6	0.231	14*	1.8342	14*
CHF	- 3.0379	0	- 3.2892	0*	- 3.0166	2	- 3.3035	1*	0.3917	14*	1.3088	14*
CHF3	- 2.8784	0	- 2.9572	0*	- 2.8429	3	- 2.9831	2*	0.3887	14*	1.3639	14*
CHF6	- 2.881	0	- 2.9502	0*	- 2.8454	3	- 2.9782	2*	0.3911	14*	1.4016	14*
CHFY	- 3.2405	0	- 3.1481	0*	- 3.2458	5	- 3.1699	3*	0.3719	14*	1.3887	14*
CZK	- 3.7279	0*	- 1.9822	0	- 3.8176	2*	- 1.9824	2	0.2837	11*	2.0349	12*
CZK3	- 3.6989	0*	- 1.579	0	- 3.9054	4*	- 1.5839	1	0.1896	11*	2.0648	12*
CZK6	- 3.7166	0*	- 1.5652	0	- 3.9358	4*	- 1.5652	0	0.185	11*	2.0775	12*
CZKY	- 3.6931	0	- 1.5363	0	- 3.933	4*	- 1.5363	0	0.1841	11*	2.0951	12*
DKK	- 3.1762	0**	- 3.2599	0*	- 3.1771	6	- 3.2703	6*	0.3608	14*	1.3891	14*
DKK3	- 2.866	0	- 2.7126	0	- 2.8781	6	- 2.7146	6	0.3487	14*	1.4441	14*
DKK6	- 2.8517	0	- 2.6996	0	- 2.8648	6	- 2.7012	6	0.3546	14*	1.4738	14*
DKKY	- 2.7892	0	- 2.677	0**	- 2.8051	6	- 2.6759	6*	0.368	14*	1.5152	14*
EUR	- 2.6736	0	- 2.1247	0	- 2.7786	6	- 2.1504	6	0.2189	11*	1.2434	11*
EUR3	- 2.8602	0	- 2.3369	0	- 2.9607	6	- 2.3503	5	0.232	11*	1.3259	11*
EUR6	- 2.8942	0	- 2.3393	0	- 2.9972	6	- 2.3509	5	0.2379	11*	1.3862	11*
EURY	- 2.9215	0	- 2.3542	0	- 3.028	6	- 2.3625	5	0.2557	11*	1.4678	11*
GBP	- 2.5336	0	- 1.5572	0	- 1.5572	2	- 1.5544	2	0.2513	14*	1.528	14*
GBP3	- 2.7017	0	- 1.7808	0	- 2.7288	2	- 1.7813	2	0.2703	14*	1.5722	14*
GBP6	- 2.7655	0	- 1.7448	0	- 2.794	2	- 1.7448	2	0.2688	14*	1.6175	14*
GBPY	- 2.8568	0	- 1.6731	0	- 2.8994	3	- 1.677	1	0.2694	14*	1.6883	14*
HUF	- 2.6575	0	- 2.3958	0	- 2.6362	4	- 2.3931	3	0.3303	14*	1.2817	14*
HUF3	- 2.5479	0	- 1.9897	0	- 2.5573	4	- 1.9779	3	0.2959	14*	1.3743	14*
HUF6	- 2.6048	0	- 1.9199	0	- 2.6291	4	- 1.9105	3	0.2826	14*	1.4479	14*
HUFY	- 2.5783	0	- 1.7042	0	- 2.6757	5	- 1.7094	3	0.2572	14*	1.5422	14*
ISK	- 2.8604	0	- 2.8198**	0	- 2.9487	6	- 2.7944	7	0.3405	14*	1.2865	14*
ISK3	- 2.5652	0	- 2.4589	0	- 2.6726	8	- 2.4688	7	0.3294	14*	1.2236	14*
ISK6	- 2.6082	0	- 2.6714**	0	- 2.6991	8	- 2.6684	7	0.3407	14*	1.1192	14*
ISKY	- 2.5888	0	- 2.5568	0	- 2.6853	8	- 2.5606	7	0.3356	14*	1.1844	14*

Table 1. (cont'd)

	ADF				PP				KPSS			
	Ho: Variable is non-stationary				Ho: Variable is non-stationary				Ho: Variable is stationary			
Currency	Constant with trend	lag	Constant without trend	lag	Constant with trend	band width	Constant without trend	band width	Constant with trend	band widt h	Constant without trend	band width
JPY	- 2.2777	0	- -2.3415	0	- -2.2027	5	- -2.3097	4	0.4217	14*	0.4227	14*
JPY3	- 2.2229	0	- 2.3622	0	- 2.1462	5	- 2.3338	4	0.4174	14*	0.4314	14*
JPY6	- 2.1841	0	- 2.3957	0	- 2.1058	5	- 2.3675	4	0.4175	14*	0.4608	14*
JPYY	- 2.0534	0	- 2.3576	0	- 1.9249	6	- 2.3149	5	0.4172	14*	0.5379	14*
KRW	- 2.7582	0	- 1.1385	0	- 2.7582	0	- 1.1372	4	0.1594	13*	1.8541	14*
KRW3	- 2.5157	0	- 0.8808	0	- 2.5157	0	- 0.8813	4	0.1722	14*	1.8507	14*
KRW6	- 2.4474	0	- 0.8592	0	- 2.4474	0	- 0.8589	4	0.1714	14*	1.8524	14*
KRWY	- 2.3358	0	- 0.8384	0	- 2.3357	0	- 0.8406	4	0.1654	14*	1.8555	14*
MXN	- 2.8946	0	- 3.1461	0*	- 2.8772	2	- 3.1288	3*	0.3319	14*	0.6138	14*
MXN3	- 3.0162	0	- 3.287	0*	- 2.8773	2	- 3.2734	3*	0.3444	14*	0.5271	14*
MXN6	- 3.0827	0	- 3.3227	0**	- 3.0759	2	- 3.3201	2**	0.3476	14*	0.4299	14*
MXNY	- 3.2629	0**	- 3.3338	0**	- 3.2451	2**	- 3.3333	1*	0.3436	14*	0.3387	14*
PLN	- 3.2034	0**	- 0.6781	0	- 3.3774	6**	- 0.6665	3	0.0961	14*	1.7761	14*
PLN3	- 3.1729	0	- 0.4967	0	- 3.3695	6**	- 0.4973	3	0.0896	14*	1.7964	14*
PLN6	- 3.1858	0	- 0.4844	0	- 3.3858	6	- 0.4863	3	0.0927	14*	1.8109	14*
PLNY	- 3.1329	0	- 0.4794	0	- 3.3321	6	- 0.4831	3**	0.1025	14*	1.824	14*
SKK	- 2.4789	0	- 1.9547	0	- 2.4461	4	- 1.9884	3	0.3286	14*	1.6585	14*
SKK3	- 2.2774	0	- 1.1932	0	- 2.3304	6	- 1.1921	5	0.2754	14*	1.7166	14*
SKK6	- 2.2638	0	- 1.1769	0	- 2.3342	6	- 1.1779	5	0.2798	14*	1.7326	14*
SKKY	- 2.2087	0	- 1.1314	0	- 2.2964	6	- 1.1339	5	0.2913	14*	1.7532	14*
SEK	- 2.9041	0	- 2.8973	0*	- 2.9259	5	- 2.8856	5*	0.3203	14*	1.2346	14*
SEK3	- 2.6789	0	- 2.4707	0	- 2.7296	6	- 2.4665	5	0.3076	14*	1.2975	14*
SEK6	- 2.6792	0	- 2.4543	0	- 2.7296	6	- 2.4486	5*	0.3148	14*	1.3479	14*
SEKY	- 2.6385	0	- 2.4197	0	- 2.6882	5	- 2.4109	5**	0.3308	14*	1.4209	14*
TRY	- 3.0812	0*	- 2.1015	0	- 3.4133	9**	- 2.4781	9	0.171	13*	0.7025	14*
TRY3	- 2.7931	0	- 1.4714	0	- 3.1013	8	- 1.7594	8**	0.2163	14*	1.0593	14*
TRY6	- 2.3918	0	- 1.0673	0	- 2.7723	9	- 1.3967	9	0.2675	14*	1.2291	14*
TRYY	- 1.9159	0	- 0.8585	0	- 2.2955	9*	- 1.1356	8	0.3218	14*	1.37	14*

Notes: The critical value at 5% level is -2.8841 for no trend regression and -3.4453 for trend regression. These critical values are given in MacKinnon (1991). The 5% critical value of the KPSS test is 0.4630 for constant without trend and 0.1460 for constant with trend. The numbers in the parenthesis represent the number of lag differences, selected on the basis of Akaike Information criteria (AIC) and Schwarz Information Criteria (SIC). *, ** denotes rejection of null hypothesis at 5%, 10% significant level

Table 2. Results of Unit Root Tests in First Differences (t-statistics (lag/bandwidth))

Currency	ADF				PP				KPSS			
	Ho: Variable is non-stationary				Ho: Variable is non-stationary				Ho: Variable is stationary			
	Constant with trend	lag	Constant without trend	lag	Constant with trend	band width	Constant without trend	band width	Constant with trend	band width	Constant without trend	band width
AUD	- 15.2133	0*	- 15.2411	0*	- 15.1658	8*	- 15.1958	8*	0.0959	7	0.1049	7*
AUD3	- 12.6746	1*	- 12.6992	1*	- 15.1829	9*	- 15.2138	9*	0.0926	7	0.0997	7*
AUD6	- 12.6939	1*	- 12.7187	1*	- 15.2213	9*	- 15.2525	9*	0.0896	7	0.0957	7*
AUDY	- 12.7154	1*	- 12.7402	1*	- 15.2491	9*	- 15.2806	9*	0.0849	7	0.0894	7*
CAD	- 17.1014	0*	- 17.1286	0*	- 17.0998	4*	- 17.1276	4*	0.0569	4	0.0532	4
CAD3	- 17.145	0*	- 17.1678	0*	- 17.1454	6*	- 17.1681	6*	0.05126	6	0.0531	6
CAD6	- 16.6415	0*	- 16.6703	0*	- 16.642	6*	- 16.6711	6*	0.0404	6	0.0429	6*
CADY	- 16.1985	0*	- 16.2286	0*	- 16.1965	5*	- 16.2268	5*	0.044	6	0.0449	6*
CHF	- 17.3461	0*	- 17.2251	0*	- 17.3694	2*	- 17.2297	4*	0.0737	2*	0.3659	4
CHF3	- 17.2881	0*	- 17.2056	0*	- 17.3091	2*	- 17.2207	3*	0.057	2	0.2787	4
CHF6	- 17.2877	0*	- 17.2012	0*	- 17.3085	2*	- 17.2157	3*	0.0544	2*	0.2824	4
CHFY	- 16.9315	0*	- 16.844	0*	- 16.9503	3*	- 16.8483	4*	0.2614	4*	0.0529	2*
CZK	- 15.8527	0*	- 15.8458	0*	- 15.8529	3*	- 15.8468	3*	0.0938	2*	0.03	3
CZK3	- 15.9316	0*	- 15.9458	0*	- 15.9255	2*	- 15.9401	2*	0.027	1	0.0538	1*
CZK6	- 15.8994	0*	- 15.9126	0*	- 15.8931	2*	- 15.9065	2*	0.0258	1	0.0542	1*
CZKY	- 15.7956	0*	- 15.8071	0*	- 15.7879	2*	- 15.7997	2*	0.0236	1	0.0546	1*
DKK	- 17.2241	0*	- 17.0626	0*	- 17.2118	6*	- 17.0679	7*	0.1146	6*	0.37	7*
DKK3	- 17.1483	0*	- 17.0604	0*	- 17.1385	6*	- 17.0563	7*	0.0937	6*	0.2666	6*
DKK6	- 17.1421	0*	- 17.0492	0*	- 17.1325	6*	- 17.046	7*	0.0889	6*	0.269	6*
DKKY	- 17.1282	0*	- 17.0238	0*	- 17.1193	6*	- 17.0234	7*	0.0801	6*	0.2755	6*
EUR	- 15.7005	0*	- 15.72	0*	- 15.6989	5*	- 15.7181	5*	0.0829	5	0.1037	5
EUR3	- 15.6721	0*	- 15.6769	0*	- 15.6718	5*	- 15.6769	5*	0.0816	5	0.1219	5
EUR6	- 15.6513	0*	- 15.6524	0*	- 15.6518	5*	- 15.6535	5*	0.0781	5	0.1237	5
EURY	- 15.6446	0*	- 15.6371	0*	- 15.6469	5*	- 15.6408	5*	0.072	5	0.1298	5**
GBP	- 16.234	0*	- 16.2588	0*	- 16.2311	4*	- 16.2552	3*	0.06819	3	0.0826	3**
GBP3	- 16.1709	0*	- 16.1854	0*	- 16.165	3*	- 16.1798	3*	0.0634	3	0.0984	3**
GBP6	- 16.1953	0*	- 16.2096	0*	- 16.1899	3*	- 16.2046	3*	0.0589	3	0.0929	3**
GBPY	- 16.231	0*	- 16.245	0*	- 16.227	2*	- 16.2413	2*	0.0493	2	0.0827	2*
HUF	- 17.0776	0*	- 17.0423	0*	- 17.0914	3*	- 17.0482	4*	0.0943	3	0.1846	3**
HUF3	- 16.7362	0*	- 16.7386	0*	- 16.742	3*	- 16.7438	3*	0.0819	3	0.1222	3**
HUF6	- 16.7328	0*	- 16.7386	0*	- 16.7375	2*	- 16.7416	3*	0.0752	2	0.1104	2**
HUFY	- 16.3472	0*	- 16.3606	0*	- 16.3441	3*	- 16.3578	3*	0.0651	3	0.0871	3**

Table 2. (cont'd)

Currency	ADF				PP				KPSS			
	Ho: Variable is non-stationary				Ho: Variable is non-stationary				Ho: Variable is stationary			
	Constant with trend	lag	Constant without trend	lag	Constant with trend	band width	Constant without trend	band width	Constant with trend	band width	Constant without trend	band width
ISK	- 17.6075	0*	- 17.5554	0*	- 17.5987	7*	- 17.5632	8*	0.08127	7*	0.2144	7**
ISK3	- 18.1364	0*	- 18.1147	0*	- 18.0791	8*	- 18.0658	8*	0.0783	7**	0.1683	7**
ISK6	- 18.1255	0*	- 18.0813	0*	- 18.082	8*	- 18.054	8*	0.0843	7**	0.2003	7**
ISKY	- 18.1342	0*	- 18.1027	0*	- 18.0766	7*	- 18.0577	8*	0.0805	7**	0.1829	7**
KRW	- 16.3142	0*	- 16.3382	0*	- 16.3145	5*	- 16.3382	5*	0.0379	5	0.0433	5*
KRW3	- 16.2599	0*	- 16.2889	0*	- 16.2613	5*	- 16.29	5*	0.043	4	0.0425	4*
KRW6	- 16.3024	0*	- 16.3313	0*	- 16.3016	4*	- 16.3307	4*	0.0455	4	0.0451	4*
KRWY	- 16.2855	0*	- 16.3137	0*	- 16.2849	4*	- 16.3132	4*	0.0493	4	0.0497	4**
MXN	- 17.2187	0*	- 17.156	0*	- 17.2855	6*	- 17.1729	4*	0.0563	6	0.2175	5
MXN3	- 16.9637	0*	- 16.894	0*	- 17.0278	6*	- 16.911	4*	0.0581	6	0.2295	4
MXN6	- 16.8018	0*	- 16.7324	0*	- 16.8631	6*	- 16.7498	4*	0.06	6	0.2327	4
MXNY	- 16.7899	0*	- 16.7216	0*	- 16.8571	5*	- 16.7408	3*	0.0666	5	0.2371	3
PLN	- 17.1101	0*	- 17.1275	0*	- 17.1064	2*	- 17.1335	2*	0.0326	3	0.0467	3
PLN3	- 16.9198	0*	- 16.9297	0*	- 16.9169	2*	- 16.9169	2*	0.0304	3	0.0549	3
PLN6	- 16.9007	0*	- 16.9134	0*	- 16.898	2*	- 16.898	2*	0.0297	3	0.0518	3
PLNY	- 16.9701	0*	- 16.9867	0*	- 16.9699	1*	- 16.9699	1*	0.0302	3	0.0484	3
SKK	- 17.8582	0*	- 17.8058	0*	- 17.844	4*	- 17.844	4*	0.1007	3*	0.2242	4*
SKK3	- 17.5992	0*	- 17.6166	0*	- 17.5718	5*	- 17.5718	6*	0.0872	5*	0.1103	5*
SKK6	- 17.4767	0*	- 17.4938	0*	- 17.455	5*	- 17.455	6*	0.0823	5	0.1066	5*
SKKY	- 17.5841	0*	- 17.6006	0*	- 17.5585	6*	- 17.5585	6*	0.0752	5**	0.1005	5*
SEK	- 16.336	0*	- 16.2736	0*	- 16.3396	5*	- 16.3396	5*	0.0996	5**	0.2599	5**
SEK3	- 16.2375	0*	- 16.2106	0*	- 16.2417	5*	- 16.2417	5*	0.0841	5**	0.1892	5**
SEK6	- 16.244	0*	- 16.213	0*	- 16.2482	5*	- 16.2482	5*	0.0796	5**	0.1916	5**
SEKY	- 16.95	0*	- 16.1559	0*	- 16.1998	5*	- 16.1998	5*	0.0727	4*	0.1971	5*
TRY	- 16.6838	0*	- 16.6414	0*	- 16.7694	8*	- 16.7694	8*	0.0718	8	0.1178	8
TRY3	- 16.8413	0*	- 16.8183	0*	- 16.9292	8*	- 16.9292	8*	0.0753	7	0.0998	7
TRY6	- 15.7886	0*	- 15.7823	0*	- 16.0402	8*	- 16.0402	8*	0.079	8	0.0852	8**
TRYY	- 15.0813	0*	- 15.0993	0*	- 15.362	8*	- 15.362	8*	0.0834	8	0.0768	8**

Notes: Refer to the notation in Table 4.1 The asterisks (*, **) indicate the 5%, 10% level of significancy