Purchasing Power Parity and Real Exchange Rate in Japan

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Abstract

This paper examines the validity of both the short-run and long-run purchasing power parity (PPP) hypotheses in Japan using two estimation methods, namely, a unit root test and an Autoregressive Distributed Lag (ARDL) cointegration test. Some important findings are obtained from our analysis. The first test reveals the mean reversion of real exchange rate (RER) in the long-run. On the other hand, from the second test, we found that there is a strongly robust long-run PPP relationship but no significant short-run PPP relationship. Furthermore, unlike the previous literature, this paper confirms the stability of the estimated results by CUSUM and CUSUMQ tests. Overall, the results suggest that PPP hypothesis in Japan strongly holds for the long-run while not for the short-run.

JEL classification: C22, F31, F41

Keywords: PPP, Real Exchange Rate, Unit Root, ARDL to cointegration

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1. Introduction

Purchasing Power Parity (PPP) hypothesis is a fundamental assumption for many open macroeconomic models. PPP hypothesis postulates a proportional relationship between a nominal exchange rate and relative price levels; this also implies the constancy of real exchange rate (RER) over time. The intuition is straightforward. If the long-run PPP relationship exists, any short-run deviations, such as depreciation of a currency, will transmit to the change of inflation or capital movement. This adjusts and equilibrates the trade flows; as a result, it tends to return the exchange rate level. Beyond being the fundamental element for many exchange rate models, PPP theory also provides some implications such as serve as a prediction model for exchange rates as well as a benchmark for judging the movements of exchange rates since it relates to undervaluation or overvaluation of a country's currency and enables international comparison of various national income levels.

As shown above, with a lot of implications of PPP hypothesis, its validity has been a subject of interest for many researchers.[1] Besides simple regression, two major methodologies have been used to examine the validity of PPP hypothesis, namely, the augmented Dickey Fuller (ADF) unit root test and the Johansen-Juselius cointegration technique. The ADF unit root test enables us to examine the stationarity of RER, or alternatively, a mean reverting process of RER.[2] On the other hand, the Johansen-Juselius cointegration allows us to test the long-run relationships among variables in absolute PPP model. Among the previous studies of the mean reverting process, Adler and Lehmann (1983) tested the null hypothesis that RER follows a random walk, or the archetypal non-mean reverting time series process; they could not reject the random walk model. Fraser et al. (1991) tested the unit roots in several sectoral RERs using disaggregated data. Besides these, Papell (1997), O`Connell (1998), Papell and Theodoridis (1998), and Coakley et al. (2005) are empirical studies using panel unit root test. However, from these researches, it is shown that only a few studies could be able to reject the null hypothesis of unit root in RER.

As for the cointegration technique as a more generalized approach for testing the long-run validity of PPP hypothesis, earlier studies include Taylor (1988), Enders (1988), Mark (1990), Layton and Stark (1990), Baharumshah and Ariff (1997), and Taylor and Sarno (1998). These studies might suffer from a number of deficiencies. Based on the conventional Johansen-Juselius cointegration technique, the power of the test might not be strong enough to meet the assumption that all variables be I(1). To solve this problem, this paper employs the Autoregressive Distributed Lag (ARDL) approach to cointegration, a relatively recent econometric technique developed by Pesaran et al. (1996, 2001) to estimate the short-run and long-run stable relationship among variables. This approach tests the cointegration relationship without requiring the same order of integration of all variables. Hence, it can be viewed as more discerning in its ability to reject a false null hypothesis.

Regarding cointegration and stability issues, we refer to Bahmani-Oskooee and Chomsisengphet (2002) which examined the money demand function in industrial countries. Though they found that there is evidence of cointegration relationships in those selected countries, when incorporating the CUSUM (Cumulative Sum of Recursive Residuals) and CUSUMQ (Cumulative Sum of Square of Recursive Residuals) stability tests into cointegration procedure, some signs of instability are found in the cases of Switzerland and the UK.[3] This means that cointegration relationship does not imply the stability of the estimated model; appropriate stability tests need to be conducted additionally after cointegration is established. Considering this, unlike the previous studies, in this paper the stability tests, namely CUSUM and CUSUMQ are also implemented in order to investigate the stability of the estimated regression.

This paper aims to contribute to the literature by presenting an empirical investigation of whether or not the short-run and long-run PPP hypothesis holds for the case of Japan. Two estimation methods, namely, the ADF unit root test and the ARDL cointegration test are employed. Existing empirical researches of cointegration of PPP are mainly based on traditional econometric techniques (Johansen cointegration) without examining the stability situation of the estimated regression. In this paper, we adopt a state-of-the-art econometric method namely ARDL to cointegration and to confirm the stability of the estimation results, the stability tests namely CUSUM and CUSUMQ are conducted. Moreover, taking structural breaks into consideration, we use the quarterly data starting from 1970, the starting point at which most of the leading economies moved from fixed exchange rate to the floating exchange rate system, so-called the starting point of falling of the Bretton woods system. To deal with the structural breaks mentioned in some literature, in addition to the full sample (1970Q1-2006Q4) estimation, by using the same techniques we analyze the subperiod spanning for 15 years from 1970Q1-1984Q4 to 1992Q1-2006Q4 by rolling them yearly, all sum up to be 23 subperiods. These subperiod estimations help examine the robustness of PPP hypothesis.

The outline of the remainder of this paper is as follows. In section 2, the theoretical frameworks and the methodology processes of the models are mentioned, while the explanations of data and empirical results are provided in section 3. Section 4 provides the robustness of estimation results as well as the results of subsample analysis. Finally, some conclusions are drawn in section 5.

2. Theoretical Framework

2.1. Absolute PPP Theory

Absolute PPP states that given the same currency, a basket of goods will cost the same in any country.[4] This can be thought as a generalization of the law of one price (LOP), which suggests that once converted to a common currency, the same good should cost the same price in different countries. The LOP and absolute PPP can be expressed respectively as below:

$$P_i = P_i^* S_i , \tag{1}$$

$$P_t = P_t^* S_t , \tag{2}$$

where P_i and P_i* are the domestic and foreign prices for good *i* respectively and S_i is the nominal exchange rate, or the domestic price of a unit of foreign currency. Similarly, P_t and P_t* are the prices of the identical basket of goods in the domestic and foreign countries respectively and S_t again is the nominal exchange rate at time *t*. Absolute PPP implies that the nominal exchange rate equals to the ratio of the two relevant prices, as shown below.

$$S_t = \frac{P_t}{P_t^*} \tag{3}$$

Expressing equation (3) in term of the logarithm as lower-case letters, it takes the following form.

$$s_t = p_t - p_t^* \tag{4}$$

Thus, by conducting the regression on equation (4), we are able to examine the short-run and long-run relationships of PPP hypothesis.

2.2. Mean Reverting Process Theory

According to its definition, real exchange rate (RER) can be written as:

$$Z_t \equiv \frac{S_t \times P_t^*}{P_t}, \tag{5}$$

where *Z* is the real exchange rate; *S* is the nominal exchange rate (*S* yen per US dollar), *P* and *P** are consumer price index (CPI) of Japan and the United States respectively. Expressing equation (5) in term of the logarithm, we obtain:

$$z_t \equiv s_t - p_t + p_t^*, \tag{6}$$

where the lower-case letters denote the logarithm of each variable in equation (5) respectively.

Based on PPP hypothesis, the logarithm of RER should be identically equal to zero. It is worth noting that the movements in RER are tantamount to the deviations in PPP condition. Hence, a necessary condition for the long-run PPP to hold is that RER be mean reverting. Generally, such investigation has tested the null hypothesis of non-mean reversion against the alternative of mean reversion. The existence of the unit root of RER implies that RER is non-stationary; as a result, there is no evidence that RER will return back to its mean value suggesting that PPP hypothesis does not hold.

3. Empirical Analysis

3.1. Data

The data used for the analysis in this paper are obtained from International Financial Statistics (IFS) CD-ROM (2007) released by International Monetary Fund (IMF). We use quarterly data that span from 1970Q1 to 2006Q3 as 1970 is the starting point of shifting to the flexible exchange rate regime for most countries in the world. Exchange rates are period-average and period-end value of Japanese currency (Yen) per unit of the US dollar as shown respectively in line RF.ZF and AE.ZF of the IFS database. For domestic and foreign (the United States) price variables, Consumer Price Index (CPI) as shown in line 64ZF are used for estimation. Regarding RER variable, it is calculated according to the definition in equation (6). It is confirmed from the augmented Dickey Fuller (ADF) unit root tests that the domestic (Japan) CPI data is I(0) while the foreign (the US) CPI data is I(1).[5] These results, the inconsistent integration order of the variables in the system, suggest the inappropriateness of using Johansen-Jesulius cointegration method to conduct the analysis.

3.2. Estimation Model and Methodology

3.2.1. Mean Reverting Process Estimation

A popular estimation method used to test the mean reverting process of RER is the augmented Dickey Fuller (ADF) unit root test. Since this approach is widely known for economists we present its basic idea in the Appendix.

3.2.2. Absolute PPP Cointegration Estimation

The estimation form of the equation (4) may be written as below:

$$s_t = c + \beta(p_t - p_t^*) + \varepsilon_t \quad (7)$$

where c is constant term and ε_t is a disturbance term. Theoretically, it is expected that $\beta = 1$.

Absolute PPP model can be represented in the form of the unrestricted error correction model as below:

$$\Delta s_t = \alpha + \sum_{i=1}^{n} \gamma_i \Delta s_{t-i} + \sum_{i=1}^{n} \delta_i \Delta(p_{t-i} - p_{t-i}^*) + \lambda_1 s_{t-1} + \lambda_2 (p_{t-1} - p_{t-1}^*) + \varepsilon_t \quad (8)$$

Before testing the model, we present a brief explanation of the ARDL approach to cointegration. As mentioned in Pesaran and Pesaran (1997), there are two steps for implementing the ARDL approach to cointegration procedure. First, we test the existence of the long-run relationship between the variables in the system. In particular, the null hypothesis $H_0 : \lambda_1 = \lambda_2 = 0$ of having no cointegration or no long-run relationship among variables in the system is tested against the alternative hypothesis

$H_1 : \lambda_1 \neq \lambda_2 \neq 0$ by judging from the F-statistics. Since the distribution of this F-statistics is non-standard irrespective of whether the variables in the system are I(0) or I(1), we use the critical values of the F-statistics provided in Pesaran and Pesaran (1997) and Pesaran et al. (2001). In there, there are two sets of critical values, when all variables are I(0) or I(1). For each application, the two sets provide the bands covering all the possible classifications of the variables into I(0) or I(1), or even fractionally integrated ones. If the computed F-statistics is higher than the appropriate upper bound of the critical value, the null hypothesis of no cointegration relationship is rejected; if it is below the appropriate lower bound, the null hypothesis cannot be rejected, and if it lies within the lower and upper bounds, the result is inconclusive.

Secondly, after the existence of the cointegration relationship between variables is confirmed, the lag lengths of variables are chosen; in this paper, we choose by using Akaike Information Criterion (AIC). After the lag length is selected, the short-run, the error correction, and the long-run model are estimated. Then, the stability tests, namely, CUSUM and CUSUMQ tests are conducted.

3.3. Estimation Results

3.3.1. Results of Unit Root Test for RER

In implementing the ADF unit root test, three steps are required. First step is to judge whether the sample has a trend or not, while the second step is to select an optimal lag length. The final step is to conduct a unit root test of RER. Following the estimation procedure of the mean reverting of RER, test results of the null hypothesis $H_0 : \rho = 0$ (having unit root in the process of RER) are shown in Table 2.

Table 2 provides the results of the ADF unit root tests of both period-average and period-end values of RER when including an intercept but not a trend. For judging whether RER have a trend or not, Figure 1 tells us that, in the whole sample, there are two trends for RER, down from 1970 to 1995 and up from 1995 to 2006. From this, we judge that there is no single trend over the whole sample. Within the maximum lag length of 4, four lag selection criteria, namely, Maximized Log-Likelihood (LL), Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC), and Hannan-Quinn Criterion (HQC), are used. From Table 1 a lag length of 4 is selected to be optimal for both period-end and period-average values with the test statistics value of −2.9582 and −2.8877, respectively. These results are summarized in Table 2. It is clear that both cases of the period-average and period-end exchange rates are significant at 5% implying that the long-run PPP hypothesis holds for the case of Japan.

3.3.2. Results of ARDL cointegration test for PPP

Following the process explained in section 3.2.2, in the first step, we test whether there is a long-run relationship among variables in the system.[6] Table 3 provides the results of F-statistics when the maximum lag lengths are set from 2 (6 months) to 24 (4 years). It is clear from the results that even though all of the cases could not be rejected, lag length up to 4 has the best power among all of rejecting the null hypothesis of no cointegration relationship among variables. As also mentioned in Bahmani-Oskooee and Nasir (2004), the results of F-statistics are just the preliminary ones while those of the second step are more efficient and considerable in ARDL approach to cointegration, the insignificance of F-statistics at this step should not be a major concern.

In the second step, we estimate the equation (7) and select the lag lengths of the variables in the system based on Akaike Information Criterion (AIC). Based on the F-statistics results, the maximum lag length is set up to 4. Table 4 provides the results of the lag length selection of the variables, which is ARDL(4,0) and of the diagnostic tests of the short-run model.[7] They show that, only the lagged exchange rate variables are statistically significant at 1% and the relative price coefficient is not statistically significant, suggesting that, in the short-run, PPP hypothesis does not hold. From the result of the adjusted coefficient of determination ($\bar{R}^2 = 0.9865$), it is clear that the overall goodness of fits of the estimated equations is very high. Moreover, the diagnostic test results indicate that the short-run model passes all of the tests for serial correlation, functional form, and heteroscedasticity. Therefore, we argue that the estimated short-run model performs well.

Table 5 provides the ARDL test results of an error correction model. The results indicate that a coefficient of the error correction term, EC_{t-1} has an appropriate sign (negative) and is statistically significant at 10% level. In particular, the estimated coefficient of EC_{t-1} is −0.0356, implying that the speed of adjustment to the long-run equilibrium is 3.56%. Specifically, the estimation result of the error correction term takes the following form.

$$EC_t = e_t - 1.1079(p_t - p_t^*) - 4.7285c$$

To test the stability of the model, we employ the tests of CUSUM and CUSUMQ. Figure 4 and 5 provide the outcomes of CUSUM and CUSUMQ tests respectively. Since the plots of both CUSUM and CUSUMQ are within 5% of critical bands, this suggests the stability of the estimated model.

Table 6 demonstrates the result of the long-run relationship of the variables in the model. It shows that given maximum lag lengths of higher than 4, the coefficients $(p_t - p_t*)$ are strongly statistically significant at 1% and have an expected sign (positive value close to 1). These indicate that PPP hypothesis holds in the long-run in Japan. Specifically, the estimated result of the long-run model is shown as below:

$$\underset{(t-value)}{e} = \underset{(29.24)}{4.7285} + \underset{(1.95)}{1.1079}(p - p^*)$$

In order to check the robustness of the results, we also estimate the long-run relationship of PPP hypothesis by setting the maximum lag length from 2 to 24 (Table 6). It is evident that for all the maximum lag lengths, the coefficients of the relative price and error correction term are statistically significant with the expected signs. In particular, the relative prices are significantly positive with the estimation value close to 1 and the error correction terms are significantly negative with the speed of adjustment within 3.5% and 4.5%. Furthermore, it is worth noting that when allowing the maximum lag length to be long enough (at least 1 year) the degree of significance could be improved for both the relative prices and the error correction terms.

4. Robustness and Subsample

As mentioned in most of the literature, a structural break is a concern for estimating and testing the validity of PPP hypothesis. Hence, to confirm the robustness of the estimation and take a structural break into consideration we divide the full sample into subsamples by using rolling estimates over the 15-year subsample periods; all sum up to be 23 subsamples.

4.1. Subsamples of Unit Root Test for RER

As mentioned in estimation results of the ADF unit root for the full sample, the first step of this test is to judge whether the estimation samples have a trend or not. Figure 2 shows the plot of RER of each of the subsamples with the judgment of having a trend or no trend in the parenthesis next to their sample periods. Subsequently, the optimal lag length could be chosen by exactly the same way as in the whole sample period described in subsection 3.3.1. After these two processes are done, we are ready for implementing the ADF unit root test. Following the same procedure for all the 23 subperiods, we summarized the ADF unit root test results by plotting its p-value of rejecting the null hypothesis (RER is non-mean reversion) into the Figure 3. The results of the p-value of rejecting the null hypothesis suggest that though some subperiods are strongly significant in rejecting null hypothesis, specifically subperiod 11, 15, 16, 22, and 23, when allowing only 15 years as the estimation sample, the power of rejecting the null hypothesis seems to be weak in most of the subperiods. From the changing tendency, we should note that the likelihood of rejection seems to be stronger for the recent subsamples.

4.2. Subsamples of ARDL cointegration test for PPP

For subsample periods, since the most important results for judging the long-run PPP relationship are those of the second step, in particular, the long-run parameters and the error correction term coefficient, we provide only these results of each subperiod and listed them in Table 7. It is obvious that only very few subsamples have both statistically significant coefficients of error correction terms and relative prices. For instance, in subperiod 9, 10, 12, and 16, the coefficients of relative prices are positively significant and of the error correction terms are negatively significant; these imply the long-run relationship of PPP hypothesis in Japan. However, this evidence seem to be weak since it is shown that though the relative prices are statistically significant, they are much bigger than the expected value (positive close to 1), for instance, in subperiod 10, the relative price become 2.9697. Furthermore, for other cases, both the coefficients of relative prices and error correction terms are not statistically significant simultaneously. It is found that the coefficients of error correction terms tend to be more significant in the recent sample, while of the relative prices are not significant, on the other hand. These results are congruent with the results of mean reverting process, implying that short span (15 years) of sample has weak test power to reject the null hypothesis. This evidence is consistent with the results of Monte Carlo experiments of Lathian and Taylor (1997) and Sarno and Taylor (2002) which showed that short span data has a very low power to reject the null hypothesis.

5. Conclusions

This paper investigates the validity of both the short-run and long-run purchasing power parity (PPP) hypotheses in Japan using two estimation methods, namely, the augmented Dickey-Fuller (ADF) unit root test for real exchange rate (RER) and the Autoregressive Distributed Lag (ARDL) cointegration test for PPP. This latter state-of-the-art method has the advantage over the conventional Johansen-Jesulius cointegration method because it does not require that all the variables in the system have the same order of integration, specifically I(1).

Some important findings are obtained from our analysis. By using the ADF unit root test, we are able to find the evidence supporting the mean reversion of RER for the long-run. Moreover, from the result of the ARDL cointegration test, we found that there is a strongly robust long-run PPP relationship while the short-run relationship is not found to be statistically significant. The significance of the estimated coefficients for the long-run PPP hypothesis and the error correction term (ECT) with the right expected sign, positive close to 1 and negative less than 1 respectively suggest that there is a cointegration relationship among variables in the system. These results are also supported by robustness check via setting various maximum lags (2 to 24) for estimation. Furthermore, from the results of the stability test confirmed by CUSUM and CUSUMQ that have not been conducted in most of the previous studies, it is found that they are stable within 5% significant level. Therefore, overall, the results seem to suggest that there exists a significant both statistically as well as economically, stable long-run relationship of PPP hypothesis for the case in Japan while the evidence for the short-run could not be found.

Besides, when dividing the full sample into subsamples only very weak evidence is found in both methodologies. From the ADF unit root test, only few results suggest the rejection of the null hypothesis of the mean reversion of RER and similarly from ARDL to cointegration results we could not find strong evidences of the long-run relationship among variables of PPP hypothesis. Therefore these results indicate that the test power of short span (15 years) of sample is not strong enough to reject the null hypothesis or, alternatively saying, it has weak evidence that PPP hypothesis holds. This evidence supports the results of Monte Carlo experiments of Lathian and Taylor (1997) and Sarno and Taylor (2002) which showed that short span data has a very low test power to reject the null hypothesis. These results seem to suggest that for testing PPP hypothesis ample long span data should be used.

Footnote

[1] Taylor (2003), Taylor (2006), and Taylor and Taylor (2004) are the best literature surveys of the PPP hypothesis and the exchange rate.

[2] In particular, this allows us whether or not RER is constant around its mean value in the long-run.

[3] CUSUM and CUSUMQ stability tests are originally developed by Brown et al. (1975).

[4] Another version of the PPP theory is the relative PPP saying that the rate of growth in the exchange rate offsets the differential between the rate of growth in home and foreign price indices.

[5] The results of the unit root test could be provided upon request.

[6] The estimation results are computed by using the Microfit 4.1 (Oxford University Press).

[7] With the selected maximum lag length the estimation sample is adjusted to be 1971Q2 to 2006Q4.

Appendix: Mean Reverting Process

Suppose that the RER does revert to a constant long run mean. Then under weak additional assumptions and according to Wold's theorem, the RER should have the following *p*-th order autoregressive form:

$$z_t = \beta_0 + \sum_{i=1}^{p} \beta_i z_{t-i} + \varepsilon_t \qquad (1)$$

where ε_t is a white-noise disturbance. Suppose that RER can be isolated from all shocks, specifically $\varepsilon_t = 0$ for all *t*. If the RER is mean reverting, then it must in the absence of shocks and given enough time settle down to its long run equilibrium level, *z**. Setting the $\varepsilon_t = 0$ and putting all the values of the RER equal to the long run equilibrium level *z** in equation (1), we can solve the for *z** as:

$$z^* = \frac{\beta_0}{1 - \sum_{i=1}^{p} \beta_i}. \qquad (2)$$

If $\sum_{i=1}^{p} \beta_i = 1$, then *z** is undefined; the process of z_t is thought to have unit root implying that any shocks imparted to the RER will be permanent. In other word, it will not behave in a mean reverting fashion and its long run equilibrium does not exist. $\sum_{i=1}^{p} \beta_i < 1$, therefore, is a necessary condition for the existence of long run equilibrium. It is worthy noted that $\sum_{i=1}^{p} \beta_i > 1$ is not an alternative because this would imply explosive behavior of the RER.

Equation (1) can be expressed as:

$$\Delta z_t = \beta_0 + \rho z_{t-1} + \sum_{i=1}^{p-1} \theta_i \Delta z_{t-i} + \varepsilon_t \qquad (3)$$

where ε_t is again a white-noise disturbance and $\Delta z_t = z_t - z_{t-1}$. Testing the null hypothesis $H_0 : \rho = 0$ of equation (3) is equivalent to testing the null hypothesis of the existence of unit root in the process of z_t (not mean reverting). Therefore, rejection of the null hypothesis $H_0 : \rho = 0$ implies that the RER is mean reverting.

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Tables and Figures

Table 1: The Augmented Dickey Fuller Unit Root Test of RER (no trend)

End Value	**Test Statistics**	**LL**	**AIC**	**SBC**	**HQC**
DF	−2.7369	320.0155	318.0155	315.0526[a]	316.8115[a]
ADF(1)	−2.7865	321.1084	318.1084	313.6641	316.3025
ADF(2)	−2.7315	321.7922	317.7922	311.8665	315.3843
ADF(3)	−2.8336	324.3948	319.3948	311.9877	316.3850
ADF(4)	−2.9582[b]	325.7509[a]	319.7509[a]	310.8623	316.1390
Average Value	**Test Statistics**	**LL**	**AIC**	**SBC**	**HQC**
DF	−2.7258	342.2438	340.2438	337.2809	339.0398
ADF(1)	−2.7932	347.8547	344.8547	340.4105[a]	343.0488
ADF(2)	−2.7358	348.6529	344.6529	338.7272	342.2449
ADF(3)	−2.8502	351.5794	346.5794[a]	339.1723	343.5695[a]
ADF(4)	−2.8877[b]	351.8297[a]	345.8297	336.9412	342.2179

Note: 1. [a] and [b] denote respectively the maximum value among various lags of a criterion (therefore the number of lag order suggested for selection by that criterion) and the final test statistics selected after all.

2. LL, AIC, SBC, and HQC denote respectively maximized Log-Likelihood, Akaike Information Criterion, Schwarz Bayesian Criterion, and Hannan-Quinn Criterion.

Table 2: ADF Unit Root Result of RER include an intercept but not a trend
143 observations from 1971Q2 to 2006Q4

RER	**Average Period Value**	**End Period Value**
T-statistics	−2.8877***	−2.9582***

Note: 1. *, **, ***, and **** are respectively significant of 15%, 10%, 5%, and 1%.

2. Critical Value for the ADF statistic are −2.5775, −2.8816, and −3.4764 for 10%, 5%, and 1% respectively.

Table 3: F-statistics of Bound Tests, 10%CV[3.182, 4.126], 5%CV[3.793, 4.855]

Lag Order	2	4	6	8	12	16	20	24
F-statistics	1.4875	1.8687	1.3504	0.7356	0.5600	.05253	0.7502	0.9877

Note: 1. *, **, ***, and **** are respectively significant of 15%, 10%, 5%, and 1%.

2. The numbers in brackets are critical values.

Table 4: Autoregressive Distributed Lag Estimation Result
(Dependent Variable: Exchange Rate, e_t)

Variables	**ARDL(4,0) selected based on AIC**
e_{t-1}	1.3032 (0.0831)****
e_{t-2}	－0. 5113 (0.1346)****
e_{t-3}	0.3887 (0.1348)****
e_{t-4}	－0.2163 (0.0835) ***
$(p_t - p_t*)$	0.0395 (0.0357)
c	0.1668 (0.0926)**
$\overline{R}^2$	0.9865
DW-statistics	2.0004
SE of Regression	0.0472
Diagnostic tests	Serial Correlation F(4, 126)= 0.1110 [0.978] Functional Form F(1, 129)= 2.1183[0.148] Heteroscedasticity F(1, 134)= 0.4394[0.508]

Note: 1. *, **, ***, and **** are respectively significant of 15%, 10%, 5%, and 1%.
2. The numbers in parentheses are standard errors.
3. The numbers in bracket are p-value of the tests.
4. AIC denotes Akaike Information Criteria.

Table 5: The Error Correction Representation for the selected ARDL model
(Dependent Variable: Difference of Exchange Rate, Δe_t)

Regressor	**ARDL(4,0) selected based on AIC**
Δe_{t-1}	0.3389 (0.0830)****
Δe_{t-2}	−0.1724 (0.0859)***
Δe_{t-3}	0.2163 (0.0835)***
$\Delta(p_t - p_t^*)$	0.0395 (0.0357)
Δc	0.1688 (0.926)**
EC_{t-1}	−0.0356 (0.0194)**
$\overline{R}^2$	0.15005
$EC_t = e_t - 1.1079\,(p_t - p_t^*) - 4.7285c$	

Note: 1. *, **, ***, and **** are respectively significant of 15%, 10%, 5%, and 1%.
2. The numbers in parentheses are standard errors.
3. AIC denotes Akaike Information Criteria.

Table 6: Long Run Estimation Result of Full Sample (1970Q1-2006Q4)
(Dependent Variable: Exchange Rate, e_t)

Maximum Lag Order	**Expected Value of coefficient**	**Relative Price** $(p_t - p_t^*)$	**ARDL based on AIC**	**Error Correction Term**
2	1	0.9257 (0.7854)	ARDL(2,0)	−0.02777 (0.0182)*
3	1	0.9610 (0.7216)	ARDL(2,0)	−0.0299 (0.0188)*
4	1	1.1079 (0.5673)**	ARDL(4,0)	−0.0356 (0.0194)**
5	1	1.1277 (0.5248)***	ARDL(4,0)	−0.0384 (0.0199)**
6	1	1.1457 (0.4845)***	ARDL(4,0)	−0.0414 (0.0206)***
7	1	1.1490 (0.4795)***	ARDL(4,0)	−0.0414 (0.0206)***
8	1	1.1374 (0.5097)***	ARDL(4,0)	−0.0399 (0.0220)**
12	1	1.1627 (0.4457)****	ARDL(4,0)	−0.0457 (0.0246)**
16	1	1.1427 (0.4550)***	ARDL(4,0)	−0.0455 (0.0260)**
20	1	1.1143 (0.4923)***	ARDL(4,1)	−0.0428 (0.0257)**
24	1	0.9912 (0.4972)***	ARDL(4,1)	−0.0466 (0.0262)**

Note: 1. *, **, ***, and **** are respectively significant of 15%, 10%, 5%, and 1%.
2. The numbers in parentheses are standard errors.
3. AIC denotes Akaike Information Criteria.

Table 7: Long Run Estimation Result of Rolling Sample of 15 years
(Dependent Variable: Exchange Rate, e_t; Lag order: 4)

Sub-Period	**Expected Value of coefficient**	**Relative Price** $(p_t - p_t{*})$	**ARDL based on AIC**	**Error Correction Term**
(1) 1970Q1-1984Q4	1	−0.5417 (0.4809)	ARDL(2,3)	−0.1294 (0.0479)****
(2) 1971Q1-1985Q4	1	0.1293 (0.8223)	ARDL(2,0)	−0.0726 (0.0375)***
(3) 1972Q1-1986Q4	1	0.6450 (0.7738)	ARDL(2,0)	−0.0767 (0.0428)**
(4) 1973Q1-1987Q4	1	1.7582 (1.5612)	ARDL(2,0)	−0.0426 (0.0452)
(5) 1974Q1-1988Q4	1	2.2226 (2.2226)	ARDL(2,0)	−0.0294 (0.0426)
(6) 1975Q1-1989Q4	1	1.2514 (0.9931)	ARDL(2,0)	−0.0521 (0.0389)
(7) 1976Q1-1990Q4	1	1.3995 (0.8879)*	ARDL(2,0)	−0.0579 (0.0407)
(8) 1977Q1-1991Q4	1	0.6238 (1.6797)	ARDL(2,1)	−0.0416 (0.0427)
(9) 1978Q1-1992Q4	1	1.7711 (0.9727)*	ARDL(2,0)	−0.0604 (0.0406)*
(10) 1979Q1-1993Q4	1	2.9697 (0.7749)****	ARDL(2,0)	−0.0925 (0.0403)***
(11) 1980Q1-1994Q4	1	2.9634 (0.9491)****	ARDL(2,0)	−0.0711 (0.0495)
(12) 1981Q1-1995Q4	1	3.3679 (0.4237)****	ARDL(4,0)	−0.1772 (0.0663)**
(13) 1982Q1-1996Q4	1	2.8858 (0.6578)****	ARDL(4,5)	−0.1369 (0.0969)
(14) 1983Q1-1997Q4	1	1.5451 (1.9618)	ARDL(4,0)	−0.0764 (0.0704)
(15) 1984Q1-1998Q4	1	1.1182 (1.7762)	ARDL(2,0)	−0.0693 (0.0520)
(16) 1985Q1-1999Q4	1	1.3451 (0.7994)**	ARDL(4,0)	−0.1252 (0.0506)***
(17) 1986Q1-2000Q4	1	0.8077 (0.6687)	ARDL(4,1)	−0.1358 (0.0555)
(18) 1987Q1-2001Q4	1	0.3382 (0.7265)	ARDL(4,1)	−0.1227 (0.0613)**
(19) 1988Q1-2002Q4	1	0.4180 (0.6955)	ARDL(4,1)	−0.1084 (0.0597)**
(20) 1989Q1-2003Q4	1	0.6113 (0.5883)	ARDL(4,1)	−0.1186 (0.5811)***
(21) 1990Q1-2004Q4	1	0.0693 (0.4669)	ARDL(4,0)	−0.1367 (0.0565)***
(22) 1991Q1-2005Q4	1	−0.1563 (0.4403)	ARDL(4,0)	−0.1391 (0.0601)***
(23) 1992Q1-2006Q4	1	−0.1759 (0.2881)	ARDL(4,0)	−0.1892 (0.0644)****

Note: 1. *, **, ***, and **** are respectively significant of 15%, 10%, 5%, and 1%.
2. The numbers in parentheses are standard errors.
3. AIC denotes Akaike Information Criteria.

Figure 1: The Real Exchange Rate Movement for Whole Period (No Trend)

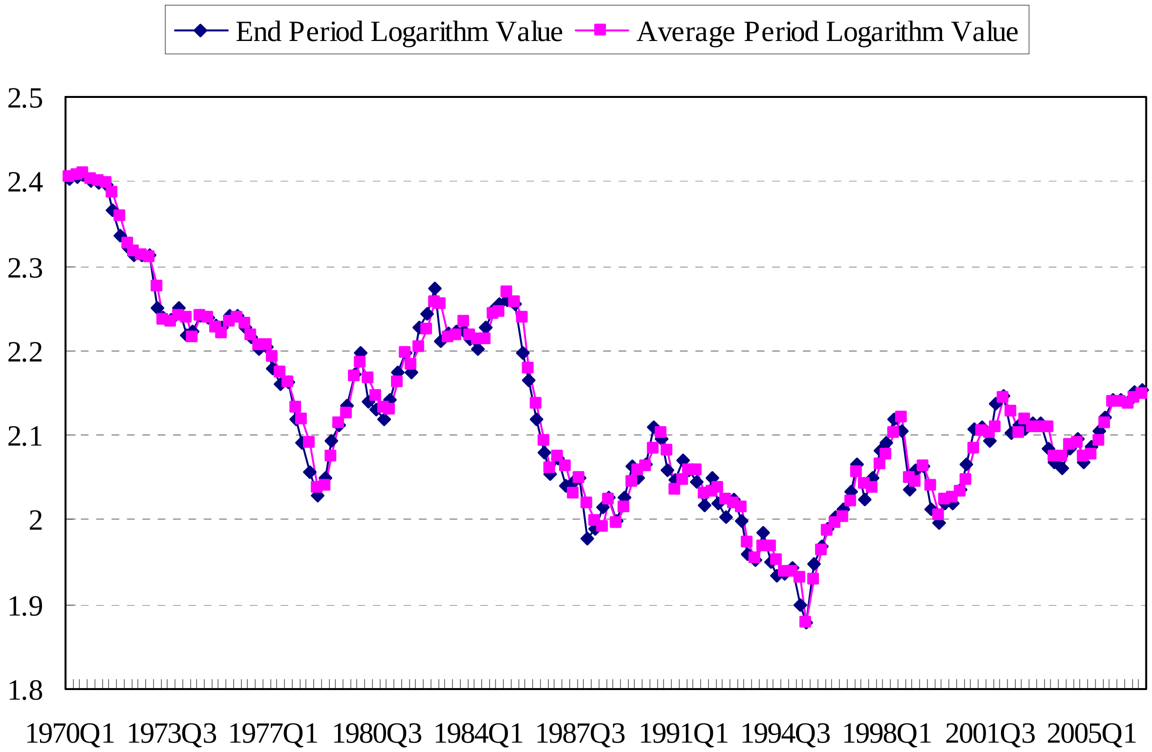
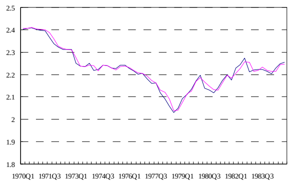
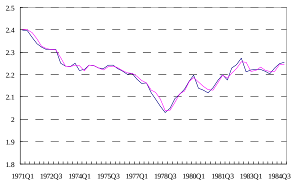


Figure 2: Rolling of the Real Exchange Rate Movement Moving by 15 years (In parenthesis, T and NT denote Trend and No Trend respectively.)

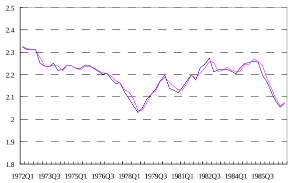
RER1: 1970Q1-1984Q4 (NT)



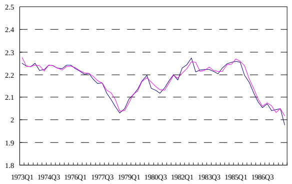
RER2: 1971Q1-1985Q4 (NT)



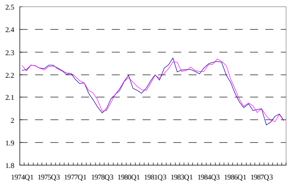
RER3: 1972Q1-1986Q4 (NT)



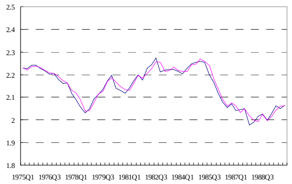
RER4: 1973Q1-1987Q4 (NT)



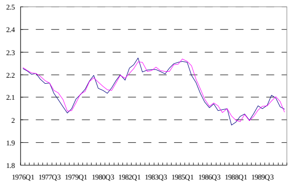
RER5: 1974Q1-1988Q4 (NT)



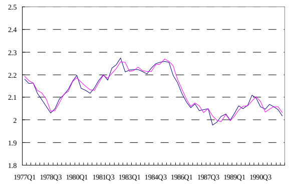
RER6: 1975Q1-1989Q4 (NT)



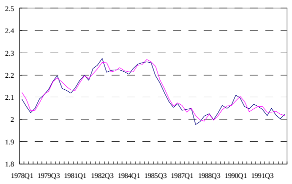
RER7: 1976Q1-1990Q4 (NT)



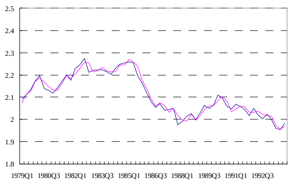
RER8: 1977Q1-1991Q4 (NT)



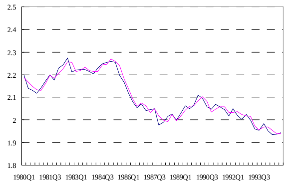
RER9: 1978Q1-1992Q4 (T)



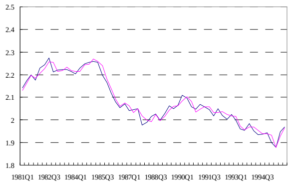
RER10: 1979Q1-1993Q4 (T)



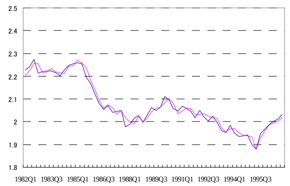
RER11: 1980Q1-1994Q4 (T)



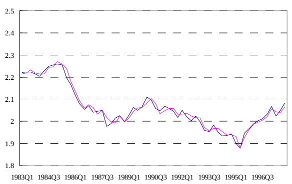
RER12: 1981Q1-1995Q4 (T)



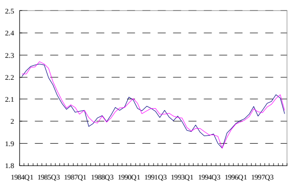
RER13: 1982Q1-1996Q4 (T)



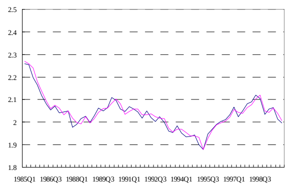
RER14: 1983Q1-1997Q4 (NT)



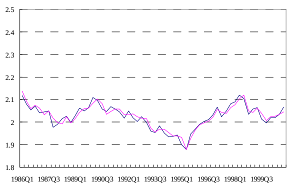
RER15: 1984Q1-1998Q4 (NT)



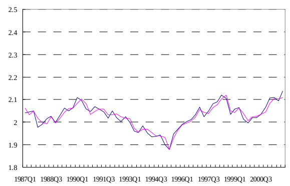
RER16: 1985Q1-1999Q4 (NT)



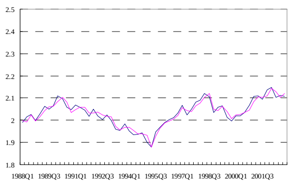
RER17: 1986Q1-2000Q4 (NT)



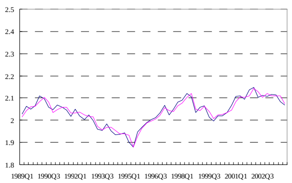
RER18: 1987Q1-2001Q4 (NT)



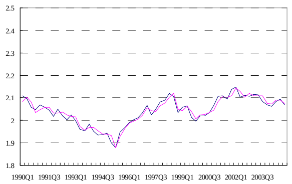
RER19: 1988Q1-2002Q4 (NT)



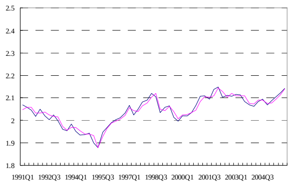
RER20: 1989Q1-2003Q4 (NT)



RER21: 1990Q1-2004Q4 (T)



RER22: 1991Q1-2005Q4 (T)



RER23: 1992Q1-2006Q4 (T)

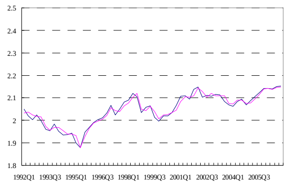


Figure 3: The P-Value of Rejecting the Unit Root of Real Exchange Rate of Each Period

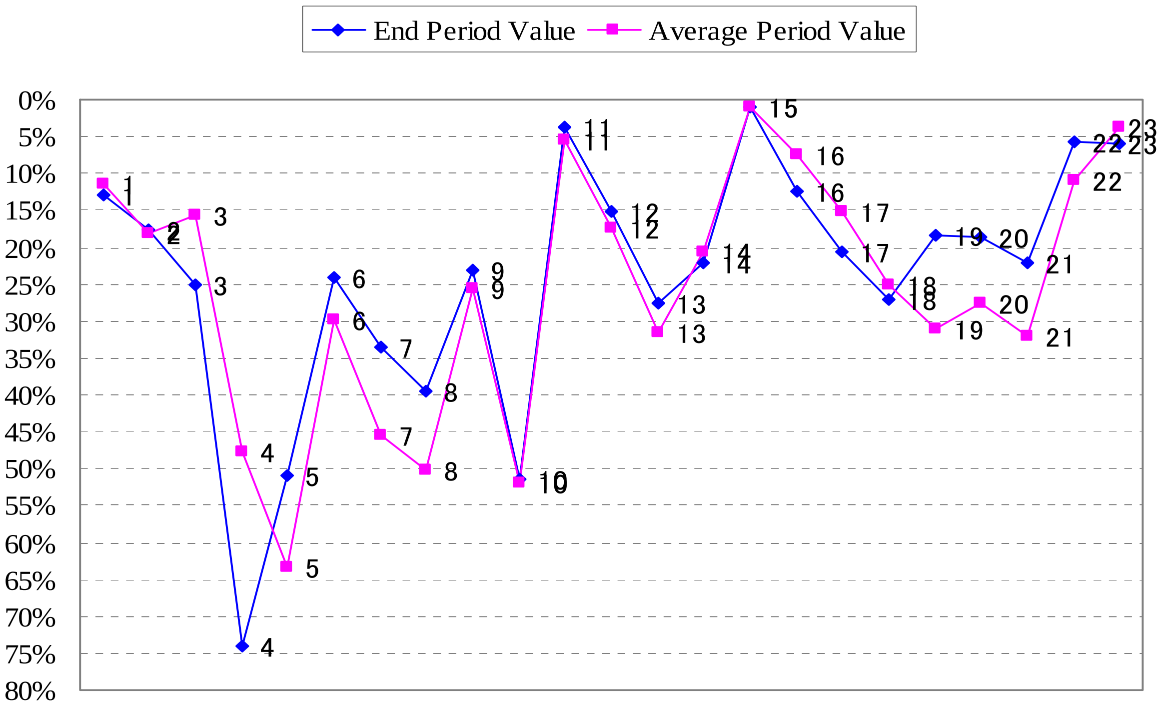


Figure 4: Plot of Cumulative Sum of Recursive Residuals (CUSUM)

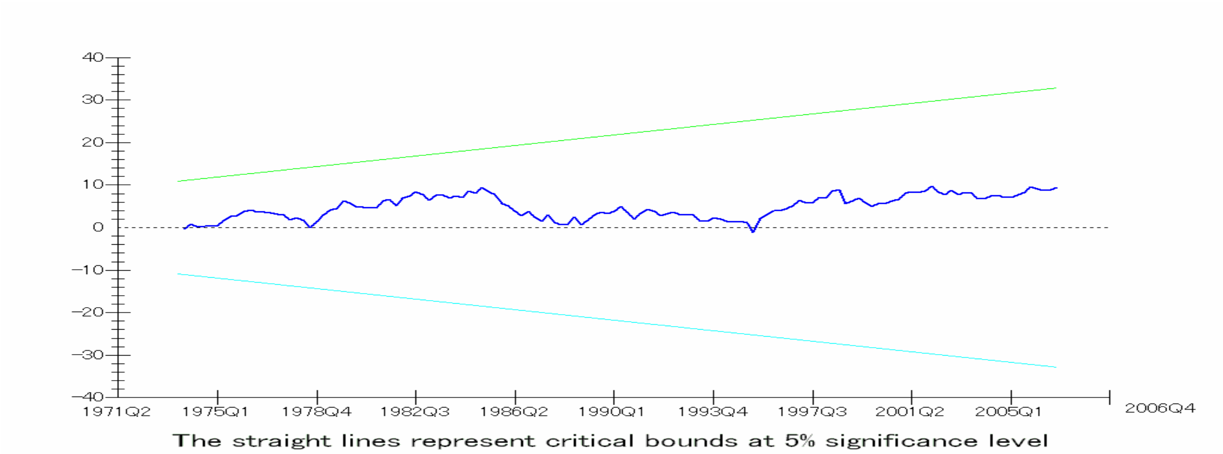


Figure 5: Plot of Cumulative Sum of Square of Recursive Residuals (CUSUMQ)