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The Long-Run of Purchasing Power Parity: The Case of 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 the case of the Yen-Dollar exchange rate 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. From the second test, we found that there is a strongly robust long-run PPP relationship but only weakly significant short-run PPP relationship. Furthermore, unlike the previous literature, we use CUSUM and CUSUMSQ stability tests and rolling estimations to deal with the problems of structural breaks and power of the test respectively. Overall, the results suggest that PPP hypothesis in the case of Yen-Dollar exchange rate strongly holds in the long-run but weakly in the short-run. Finally, our results suggest that a minimum of 30 years of sample be a benchmark required for long-run PPP to hold for the case of Japan.

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1 Introduction

With a lot of implications of Purchasing Power Parity (PPP) hypothesis, its validity has been a subject of interest for many researchers.[1] Empirical literatures on PPP seem to be divided into three generations. In the first generation, PPP was tested by using simple regression. However, since these tests do not take into account the prospective of nonstationarity of exchange rates and price levels, they are considered to be flawed.

In the second generation, PPP is regarded as a long-run relationship, so they test whether the deviation from PPP follows a stationary process. In other words, they investigate whether the Real Exchange Rate (RER) is a mean reverting process by using unit root tests.[2] 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) examined the unit roots in several sectoral RERs using disaggregated data. However, it is known that only a few studies were able to reject the null hypothesis of unit root in RER. The reason is that time series data used had not been long enough for the unit root tests to have power. Lathian and Taylor (1997) and Sarno and Taylor (2002) showed that short span data has a very low power to reject the null hypothesis. To take this problem into account, for short span sample studies such as Papell (1997), O‘Connell (1998), Papell and Theodoridis (1998), and Coakley et al. (2005) panel unit root tests are used to investigate PPP relationship. In our study, which have a long span sample, with the purpose to reveal the sufficient period of estimation, we divide the full sample (1970Q1-2008Q4), into 15 years, 20 years, 25 years, 30 years, and 35 years' subperiods and conduct the rolling estimations. Specifically, for the case of 15 years sample span, 25 subperiods in total from 1970Q1-1984Q4 to 1994Q1-2008Q4 by rolling them yearly, are obtained. Similarly, for the cases of 20, 25, 30 and 35 years span, we have 20, 15, 10, and 5 subperiods respectively. The estimation results of these subperiods help us to examine the sufficient length of data for analysis.

The third generation of PPP studies refers to those conducted by using cointegration analyses. Earlier studies such as Taylor (1988), Mark (1990), Layton and Stark (1990), Baharumshah and Ariff (1997), and Taylor and Sarno (1998) test the long-run validity of PPP hypothesis using a Johansen-Juselius cointegration technique. However, it is considered that these studies might suffer from a couple of deficiencies due to the strong consumption that all variables are required to 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. (2001) to estimate the short-run and long-run stable relationship among variables. This approach tests the cointegration relationship without requiring the condition that all variables have the same order of integration.[3] Hence, it can be viewed as more discerning in its ability to reject a false null hypothesis. Regarding structural breaks or stability issues, we refer to Bahmani-Oskooee and Chomsisengphet (2002) which examined the money demand function in industrial countries. Though they found an evidence of cointegration relationships in those selected countries, when incorporating the CUSUM (Cumulative Sum of Recursive Residuals) and CUSUMSQ (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.[4] This means that cointegration re-

[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] Bahmani-Oskooee and Nasir (2004) and Long and Samreth (2008), to mention a few, are studies of ARDL application.

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

lationship 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 CUSUMSQ are also implemented in order to investigate the stability of the estimated regression.

In summary, this paper aims to contribute to the literature in three ways. First, to present an empirical investigation of whether or not the short-run and long-run PPP hypotheses hold for the case of Yen-Dollar exchange rate by employing two estimation methods, namely, a ADF unit root test and an ARDL cointegration test. While existing empirical researches of cointegration of PPP are mainly based on traditional econometric techniques (Johansen cointegration) without examining the stability of the estimated regression, this paper adopt a state-of-the-art econometric method, namely an ARDL cointegration test. Second, to provide a cointegration study that take into account the problems of structural break by conducting the CUSUM and CUSUMSQ stability tests. Finally, with the aim to deal with the power of test we suggest a benchmark on when is the suffient lenght for long run PPP for the case of Japan by conducting rolling estimations on subsamples.

The outline of the remainder of this paper is as follows. In Section 2, the theoretical framework and the methodologies of the model estimations are described, while the explanations of data and empirical results are provided in Section 3. Section 4 explains the results of subsamples for confirming the power of the test. Finally, some conclusions are drawn in Section 5.

2 Theoretical Framework

2.1 The absolute PPP Theory

Absolute PPP states that given the same currency, a basket of goods will cost the same in any country.[5] The absolute PPP can be expressed as below:

$$P_t = P_t^* S_t, \tag{1}$$

where P_t and P_t^* are the prices of the identical basket of goods in the domestic and foreign countries respectively and S_t 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.

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

Expressing equation (2) in term of the logarithm as lower-case letters, it takes the following form.

$$s_t = p_t - p_t^* \tag{3}$$

Thus, by conducting the regression on equation (3), we are able to examine the short-run and long-run relationships of PPP hypothesis.

2.2 Mean Reverting Process Theory

The real exchange rate (RER) can be defined as:

$$Z_t \equiv \frac{S_t \times P_t^*}{P_t}, \tag{4}$$

[5]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.

where Z is the real exchange rate; P and $P*$ are consumer price index (CPI) of Japan and the United States respectively. Expressing equation (4) in term of the logarithm, we obtain:

$$z_t = s_t - p_t + p_t^*, \tag{5}$$

where the lower-case letters denote the logarithm of each variable in equation (4) 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 (2009) released by International Monetary Fund (IMF). We use quarterly data that span from 1970Q1 to 2008Q4 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 end of period 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 is used for estimation. Regarding RER variable, it is calculated according to the definition in equation (5). 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 and exchange rate data are I(1).[6] These results, the inconsistent integration orders among variables, 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 only present its basic idea in the Appendix.

3.2.2 Absolute PPP Cointegration Estimation

The estimation form of the equation (3) may be written as below:

$$s_t = c + \beta(p_t - p_t^*) + \varepsilon_t, \tag{6}$$

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

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

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

$$\Delta s = \alpha + \sum_{i=1}^{n} \gamma_i \Delta s_{t-i} + \sum_{i=1}^{n} \delta_i \Delta (p_{t-i} - p^*_{t-i}) + \lambda_1 s_{t-1} + \lambda_2 (p_{t-1} - p^*_{t-1}) + \varepsilon_t. \tag{7}$$

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 $H_1 : \lambda_1 \neq 0, \lambda_2 \neq 0$ 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). They provide two sets of critical values, one is under assumption that all variables are I(0) case while another is I(1) case. 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 CUSUMSQ 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. Figure 1 shows that, in the whole sample, there seem to be two trends for RER, down from 1970 to 1995 and up from 1997 to 2008. From this, we judge that there is no single trend over the whole sample. The second step is to select an optimal lag length. 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 end of period and period average values with the test statistics value of -3.0023 and -2.8929, respectively. 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 (having unit root in the process of RER) are shown in Table 2. The results are those of the ADF unit root tests of both period average and end of period values of RER when including an intercept but not a trend. It is clear that both cases of the period average and end of period 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.[7] Table 3A and 3B provide the results of F-statistics when the maximum lag lengths are set from 2 (6 months) to 12 (3 years). While F_e and $F_{relative}$ represent the F-statistics of the model in which exchange rate and relative price are dependent variable respectively, it is clear from the results that the null hypothesis of no cointegration relationship among variables are strongly rejected. Therefore, we proceed to the second step.

In the second step, we estimate the equation (6) and select the lag lengths of the variables in the system based on Akaike Information Criterion (AIC). According to 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.[8] They show that, only the lagged exchange rate variables are statistically significant at 1% and the relative price coefficient is only statistically significant at 15%, suggesting that there is only weak relation for short-run PPP hypothesis. The result of the adjusted coefficient of determination ($\bar{R}^2 = 0.9866$) reveals 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 of serial correlation, functional form, and heteroscedasticity. Therefore, we argue that the estimated short-run model is well-performed.

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 5% level. In particular, the estimated coefficient of EC_{t-1} is -0.0393, implying that the speed of adjustment after one period, three months, to the long-run equilibrium is 3.93%. Specifically, the estimation result of the error correction term takes the following form.

$$EC_t = e_t - 1.2675(p_t - p_t^*) - 4.6927c$$

To examine the stability of the model, we employ the tests of CUSUM and CUSUMSQ. Figure 4 and 5 provide the outcomes of CUSUM and CUSUMSQ tests respectively. Since the plots of both CUSUM and CUSUMSQ 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 with the cointegrating vector (1, 1.2675). Specifically, the estimated result of the long-run model is shown as below:

$$\begin{array}{cccc} e & = & 4.6927 & + \; 1.2675\,(p - p^*). \\ (t - value) & & (33.30) & (3.0106) \end{array}$$

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 values close to 1 and the error correction terms are significantly negative with the speed of adjustment within 3% and 5%. Interestingly, these results, the coefficients of EC_{t-1}, in

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

[8] With the selected maximum lag length the estimation sample is adjusted to be 1971Q2 to 2008Q4.

Table 6 reveal that when we allows enough time (long lag length) for the disequilibrium to adjust, then the speed of adjustment go faster.

4 Power of the Test

As mentioned in most of the literatures, power of the test is a major concern for estimating and testing the validity of PPP hypothesis. Hence, to overcome this we divide the full sample into subsamples by using rolling estimations over the 15-year, 20-year, 25-year, 30-year, and 35-year span of samples; all sum up to be 25, 20, 15, 10, and 5 subperiods respectively. Since it is found that in the full sample estimation, there exists the long-run PPP relationship, it is expected that by conducting the estimations of its subsamples of 15-year, 20-year, 25-year, 30-year, and 35-year, we could draw the conclusion on the sufficient length of estimation that has close results to the whole sample.

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 subsample 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 estimation procedure for all subperiods of subsamples, 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 3A, 3B, 3C, 3D, and 3E respectively.[9] For subperiods of 15-year-span sample, the results of the p-value of rejecting the null hypothesis suggest that although it is strongly rejected for some subperiods, specifically Subperiod 11, 15, 16, 22, 23, 24 and 25, 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. However, it is seen that the longer the estimation length we take the stronger power of rejecting the null hypothesis seems to be. For example, for 30-year-span subperiods, all most all of the null hypotheses are rejected within 20% level of significant, which show the strong power of the test. Similarly, when allowing 35 years to be estimation period, all null hypotheses are rejected within 15%. As a result, we argue that 30 years span of estimation data should be the stable length for conducting the analysis.

4.2 Subsamples of ARDL cointegration test for PPP

Regarding estimation results of ARDL cointegration test, since the most important ones 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, for subsample periods, we provide only these results of each subperiod and list them in Table 7A, 7B, 7C, 7D, and 7E respectively.

For the case of 15-year-span subperiods, it is obvious that only very few subperiods 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

[9]Note that for robustness check, the author also calculate the results of these subperiod using only AIC for lag selection. Those result appear similar to those in this paper and available upon request.

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 becomes 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.

However, when taking longer length of estimation, the coefficients of the relative prices and error correction terms are both statistically significant with the sign as expected. For instance, when allow 30 years span of data, it is seen that almost all of the subperiods are significant at at least 10% level, which suggests the strong power of the test. These results are congruent with the results of mean reverting process implying that while short span (15 years) of sample has weak test power to reject the null hypothesis the estimation period of 30 years is sufficient for conducting the analysis.

5 Conclusions

This paper investigates the validity of both the short-run and long-run purchasing power parity (PPP) hypotheses in the case of Yen-Dollar exchange rate 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. First, by using the ADF unit root test, we are able to find the evidence supporting the mean reversion of RER for the long-run. Second, from the result of the ARDL cointegration test, we found a strongly robust long-run PPP relationship while the short-run relationship is found to be only weakly 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 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 CUSUMSQ that have not been conducted in most of the previous studies, it is found that our estimated results are stable within 5% significant level. Therefore, overall, the results suggest that there exists a significant both statistically as well as economically, stable long-run relationship of PPP hypothesis for the case in the case of Yen-Dollar exchange rate while only weak evidence for the short-run be found.

Moreover, when dividing the full sample into subsamples, short estimation length, say 15 or 20 years, has very weak test power while a 30-year-span should be considered as a sufficient estimation period. When taking 30 years length as a sample, we obtained strong power of tests from both methodologies, the ADF unit root test for testing the mean reversion of RER and ARDL cointegration test for investigating PPP hypothesis in which consistent with the results of the full sample. Our results are consistent with Lathian and Taylor (1997) and Sarno and Taylor (2002) regarding sample span, and imply that 30 years span without structural break should be considered as the estimation sample that has sufficient power of the test.

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:

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

where ε_t is a white-noise disturbance. Suppose that RER can be isolated from all shocks, specifically 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 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:

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

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:

$$\triangle z_t = \beta_0 + \rho z_{t-1} + \sum_{i=1}^{p-1} \theta_i \triangle z_{t-i} + \varepsilon_t \tag{3}$$

where ε_t is again a white-noise disturbance and $\triangle z_t = z_t - z_{t-1}$. 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 of Period	Test Statistics	LL	AIC	SBC	HQC
DF	−2.7694	208.9458	206.9458	203.9285[a]	205.7200[a]
ADF(1)	−2.8094	209.6504	206.6504	202.1245	204.8118
ADF(2)	−2.7555	210.2778	206.2778	200.2432	203.8262
ADF(3)	−2.8663	212.8341	207.8341	200.2909	204.7697
ADF(4)	−3.0023[b]	214.4491[a]	208.4491[a]	199.3973	204.7718
Average Period	**Test Statistics**	**LL**	**AIC**	**SBC**	**HQC**
DF	−2.7627	234.7793	232.7793	229.7620	231.5535
ADF(1)	−2.8304	240.0778	237.0778	232.5518[a]	235.2391
ADF(2)	−2.7658	240.9663	236.9663	230.9317	234.5147
ADF(3)	−2.8929[b]	244.2282	239.2282[a]	231.6850	236.1638[a]
ADF(4)	−2.9339	244.5029[a]	238.5029	229.4511	234.8256

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
151 observations from 1971Q2 to 2008Q4

RER	Average Period Variable	End of Period Variable
T-statistics	−2.8929***	−3.0023***

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 3A: F-statistics of Bound Tests for the case of Period Average Exchange Rate

Lag Order	2	3	4	5	6	8	12
$\mathbf{F_e}$	1.60	2.45**	2.32*	2.19*	1.80	1.01	0.77
$\mathbf{F_{relative}}$	5.2114****	3.5861***	3.5358***	2.7582**	3.0881***	4.6025***	2.6264**

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

Table 3B: F-statistics of Bound Tests for the case of End of Period Exchange Rate

Lag Order	2	3	4	5	6	8	12
$\mathbf{F_e}$	2. 0522*	2.7961**	3.1513***	2.8080**	2.0148*	1.4741	1.0974
$\mathbf{F_{relative}}$	5.3304****	3.4600***	3.5004***	2.9620**	2.9971***	3.6123***	2.5876**

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

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

Variables	**ARDL(4,0) selected based on AIC**
e_{t-1}	1.2989 (0.0822)****
e_{t-2}	−0. 5154 (0.1336)****
e_{t-3}	0.4072 (0.1337)****
e_{t-4}	−0.2300 (0.0823) ****
$(p_t - p_t*)$	0.0498 (0.0312)*
c	0.1864 (0.0884)***
$\overline{R}^2$	0.9866
DW-statistics	1.975
SE of Regression	0.0471
Diagnostic tests	Serial Correlation F(4, 142)= 0.0677 [0.992]
	Functional Form F(1, 145)= 2.0847 [0.151]
	Heteroscedasticity F(1, 150)= 0.4147 [0.521]

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}	0.3382 (0.0818)****
Δe_{t-2}	−0.1772 (0.0850)***
Δe_{t-3}	0.2300 (0.0823)****
$\Delta(p_t - p_t*)$	0.0498 (0.0312) *
Δc	0.1846 (0.0884)***
EC_{t-1}	−0.0393 (0.0183)***
$\overline{R}^2$	0.1481
$EC_t = e_t - 1.2675(p_t - p_t^*) - 4.6927c$	

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 (1970Q1-2008Q4)
(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	1.1969 (0.5392)***	ARDL(2,0)	−0.0316 (0.0175)**
3	1	1.2018 (0.5051)***	ARDL(2,0)	−0.0338 (0.0179)**
4	1	1.2675 (0.4210)****	ARDL(4,0)	−0.0393 (0.0183)***
5	1	1.2659 (0.3956)****	ARDL(4,0)	−0.0419 (0.0188)***
6	1	1.2637 (0.3711)****	ARDL(4,0)	−0.0448 (0.0193)***
7	1	1.2632 (0.3666)****	ARDL(4,0)	−0.0455 (0.0199)***
8	1	1.2646 (0.3816)****	ARDL(4,0)	−0.0438 (0.0205)***
12	1	1.2544 (0.3410)****	ARDL(4,0)	−0.0495 (0.0227)***
16	1	1.2369 (0.3452)****	ARDL(4,0)	−0.0496 (0.0238)***
20	1	1.2204 (0.3785)****	ARDL(4,1)	−0.0456 (0.0235)**
24	1	1.0998 (0.3699)****	ARDL(4,1)	−0.0499 (0.0239)***

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 7A: 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)****
(24) 1993Q1-2007Q4	1	−0.1415 (0.2442)	ARDL(4,1)	−0.2083 (0.0716)****
(25) 1994Q1-2008Q4	1	0.0675 (0.2910)	ARDL(4,1)	−0.1810 (0.0760)***

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 7B: Long Run Estimation Result of Rolling Sample of 20 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) 1970Q1-1989Q4	1	1.3878 (1.3087)	ARDL(2,0)	−0.0354 (0.0250)
(2) 1971Q1-1990Q4	1	1.8470 (1.2741)	ARDL(2,0)	−0.0347 (0.0252)
(3) 1972Q1-1991Q4	1	1.7364 (0.9441)**	ARDL(2,0)	−0.0439 (0.0302)
(4) 1973Q1-1992Q4	1	1.7662 (0.7284)***	ARDL(2,0)	−0.0532 (0.0347)*
(5) 1974Q1-1993Q4	1	1.8950 (0.7768)***	ARDL(2,0)	−0.0480 (0.0365)
(6) 1975Q1-1994Q4	1	1.8981 (0.7988)	ARDL(2,0)	−0.0443 (0.0342)
(7) 1976Q1-1995Q4	1	1.6734 (0.7763)***	ARDL(2,0)	−0.0519 (0.0358)
(8) 1977Q1-1996Q4	1	0.9164 (1.5330)	ARDL(2,1)	−0.0384 (0.0368)
(9) 1978Q1-1997Q4	1	1.1548 (1.2674)	ARDL(4,1)	−0.0509 (0.0409)
(10) 1979Q1-1998Q4	1	2.3625 (0.5343)****	ARDL(2,0)	−0.0899 (0.0379)***
(11) 1980Q1-1999Q4	1	1.7273 (0.8817)**	ARDL(4,1)	−0.0653 (0.0433)*
(12) 1981Q1-2000Q4	1	2.1297 (0.6652)****	ARDL(4,1)	−0.0754 (0.0417)**
(13) 1982Q1-2001Q4	1	1.4659 (1.0575)	ARDL(4,1)	−0.0547 (0.0385)
(14) 1983Q1-2002Q4	1	0.8002 (1.0759)	ARDL(4,1)	−0.0592 (0.0343)**
(15) 1984Q1-2003Q4	1	1.0181 (0.7221)	ARDL(4,1)	−0.0706 (0.0331)***
(16) 1985Q1-2004Q4	1	0.6109 (0.4901)	ARDL(4,1)	−0.0995 (0.0339)****
(17) 1986Q1-2005Q4	1	0.3352 (0.3809)	ARDL(4,1)	−0.1203 (0.0417)****
(18) 1987Q1-2006Q4	1	0.2713 (0.3210)	ARDL(4,1)	−0.1280 (0.0482)**
(19) 1988Q1-2007Q4	1	0.3413 (0.3228)	ARDL(4,1)	−0.1167 (0.0506)***
(20) 1989Q1-2008Q4	1	0.4954 (0.3147)*	ARDL(4,1)	−0.1187 (0.0514)***

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

The numbers in parentheses are standard errors.

AIC denotes Akaike Information Criteria.

Table 7C: Long Run Estimation Result of Rolling Sample of 25 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) 1970Q1-1994Q4	1	2.2382 (1.0908)***	ARDL(2,0)	−0.0308 (0.0224)
(2) 1971Q1-1995Q4	1	2.0568 (0.9345)***	ARDL(2,0)	−0.0356 (0.0232)*
(3) 1972Q1-1996Q4	1	1.8628 (0.7188)*	ARDL(2,0)	−0.0445 (0.0274)*
(4) 1973Q1-1997Q4	1	1.7428 (0.5228)****	ARDL(4,0)	−0.0609 (0.0337)**
(5) 1974Q1-1998Q4	1	1.7270 (0.5647)****	ARDL(2,0)	−0.0557 (0.0342)*
(6) 1975Q1-1999Q4	1	1.7443 (0.4674)****	ARDL(4,1)	−0.0637 (0.0353)**
(7) 1976Q1-2000Q4	1	1.4603 (0.5323)****	ARDL(4,1)	−0.0603 (0.0348)**
(8) 1977Q1-2001Q4	1	0.8883 (0.8651)	ARDL(4,1)	−0.0501 (0.0339)*
(9) 1978Q1-2002Q4	1	0.9671 (0.7786)	ARDL(4,1)	−0.0521 (0.0323)*
(10) 1979Q1-2003Q4	1	1.5504 (0.5017)****	ARDL(4,1)	−0.0641 (0.0301)***
(11) 1980Q1-2004Q4	1	1.0643 (0.6825)*	ARDL(4,1)	−0.0516 (0.0289)**
(12) 1981Q1-2005Q4	1	1.1817 (0.7202)*	ARDL(4,1)	−0.0457 (0.0281)*
(13) 1982Q1-2006Q4	1	0.9037 (0.7460)	ARDL(4,1)	−0.0447 (0.0267)**
(14) 1983Q1-2007Q4	1	0.6189 (0.5112)	ARDL(4,1)	−0.0575 (0.0256)***
(15) 1984Q1-2008Q4	1	0.7598 (0.4466)**	ARDL(4,1)	−0.0655 (0.0271)***

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

The numbers in parentheses are standard errors.

AIC denotes Akaike Information Criteria.

Table 7D: Long Run Estimation Result of Rolling Sample of 30 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) 1970Q1-1999Q4	1	1.8342 (0.6214)****	ARDL(4,0)	−0.0445 (0.0234)**
(2) 1971Q1-2000Q4	1	1.6441 (0.6233)****	ARDL(4,0)	−0.0429 (0.0230)**
(3) 1972Q1-2001Q4	1	1.4504 (0.5818)***	ARDL(4,0)	−0.0468 (0.0267)**
(4) 1973Q1-2002Q4	1	1.4326 (0.4632)****	ARDL(4,0)	−0.0553 (0.0295)**
(5) 1974Q1-2003Q4	1	1.4823 (0.3847)****	ARDL(4,0)	−0.0601 (0.0294)***
(6) 1975Q1-2004Q4	1	1.3661 (0.4301)****	ARDL(4,1)	−0.0519 (0.0279)**
(7) 1976Q1-2005Q4	1	1.0354 (0.5179)***	ARDL(4,1)	−0.0479 (0.0274)**
(8) 1977Q1-2006Q4	1	0.7915 (0.5485)	ARDL(4,1)	−0.0491 (0.0263)**
(9) 1978Q1-2007Q4	1	0.8709 (0.4860)**	ARDL(4,1)	−0.0504 (0.0252)***
(10) 1979Q1-2008Q4	1	1.1912 (0.4159)****	ARDL(4,1)	−0.0523 (0.0243)***

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

Table 7E: Long Run Estimation Result of Rolling Sample of 35 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) 1970Q1-2004Q4	1	1.4039 (0.5135)****	ARDL(4,0)	−0.0411 (0.0205)***
(2) 1971Q1-2005Q4	1	1.1324 (0.6007)**	ARDL(4,0)	−0.0362 (0.0201)**
(3) 1972Q1-2006Q4	1	1.1374 (0.5097)***	ARDL(4,0)	−0.0399 (0.0220)**
(4) 1973Q1-2007Q4	1	1.1476 (0.4140)****	ARDL(4,0)	−0.0452 (0.0232)**
(5) 1974Q1-2008Q4	1	1.2369 (0.3452)****	ARDL(4,0)	−0.0496 (0.0238)***

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

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

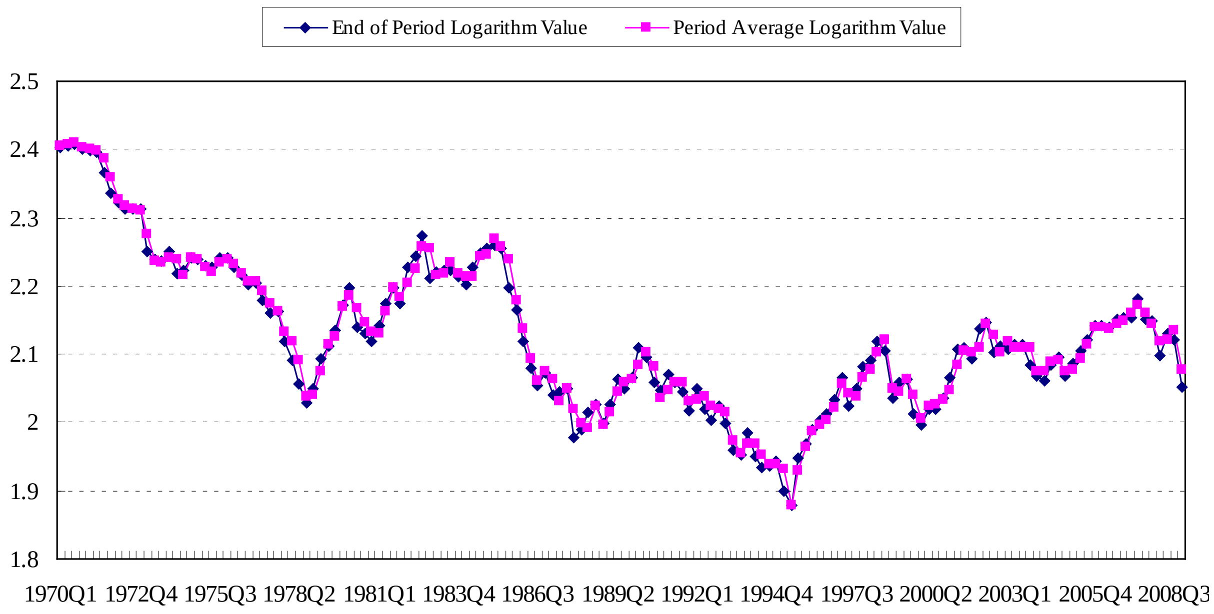


Figure 2: Rolling of the Real Exchange Rate Movement Moving by 15 years (In parenthesis, T and NT denote Trend and No Trend respectively.)

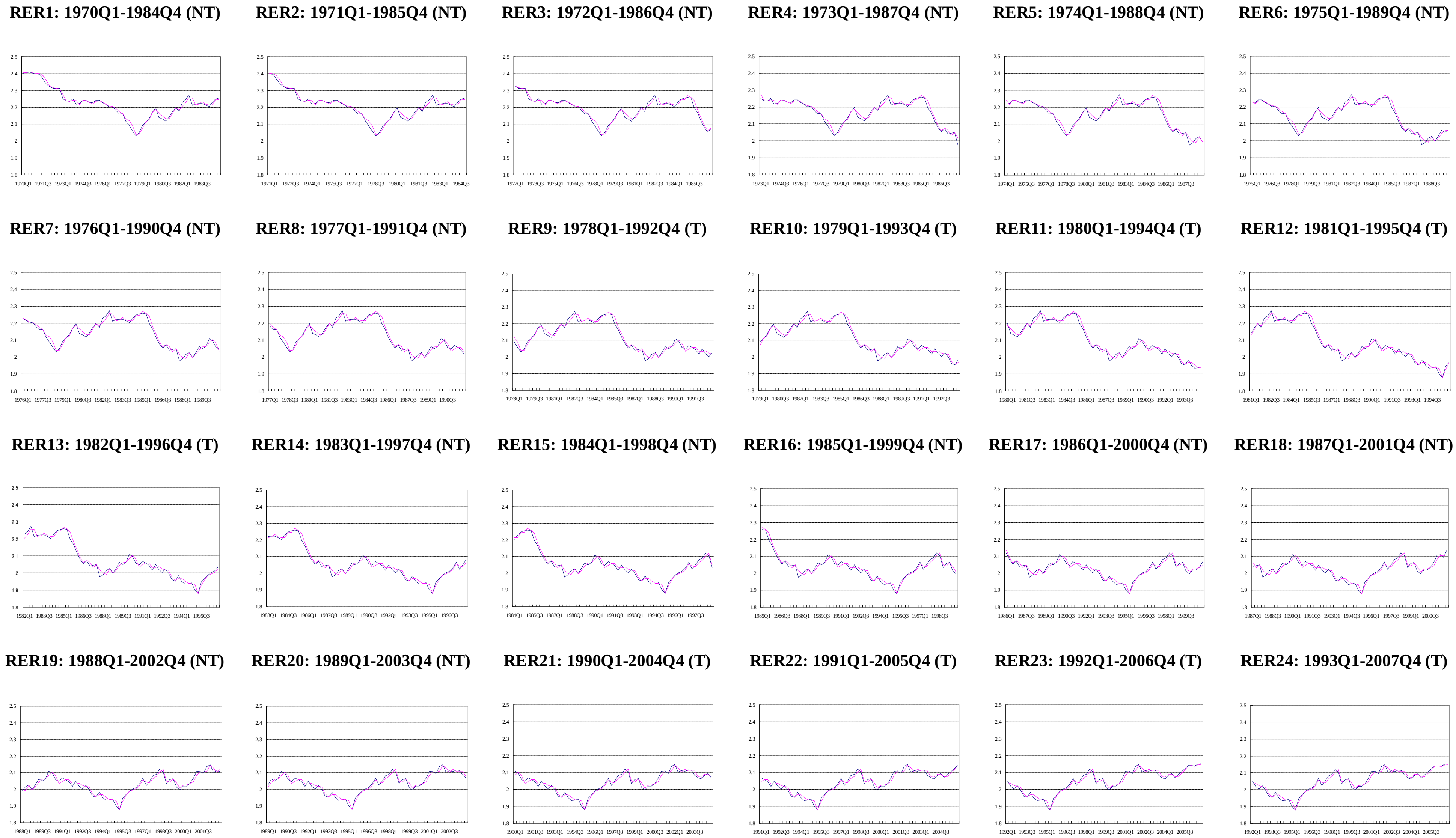
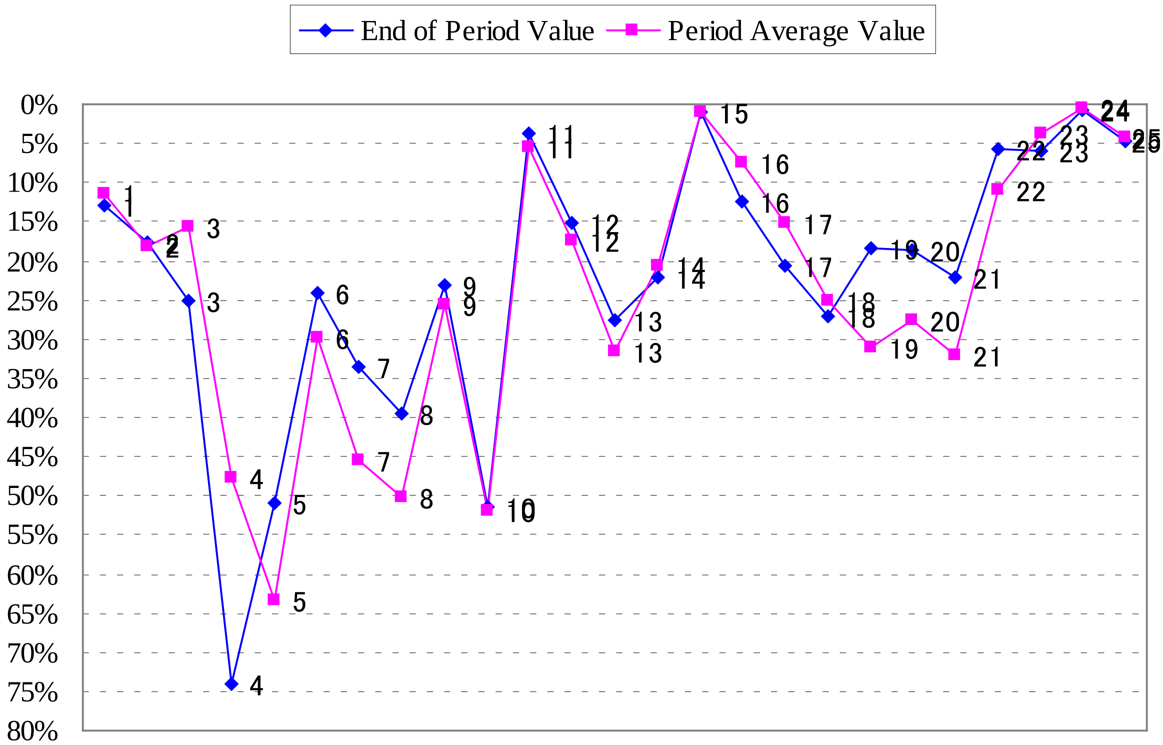
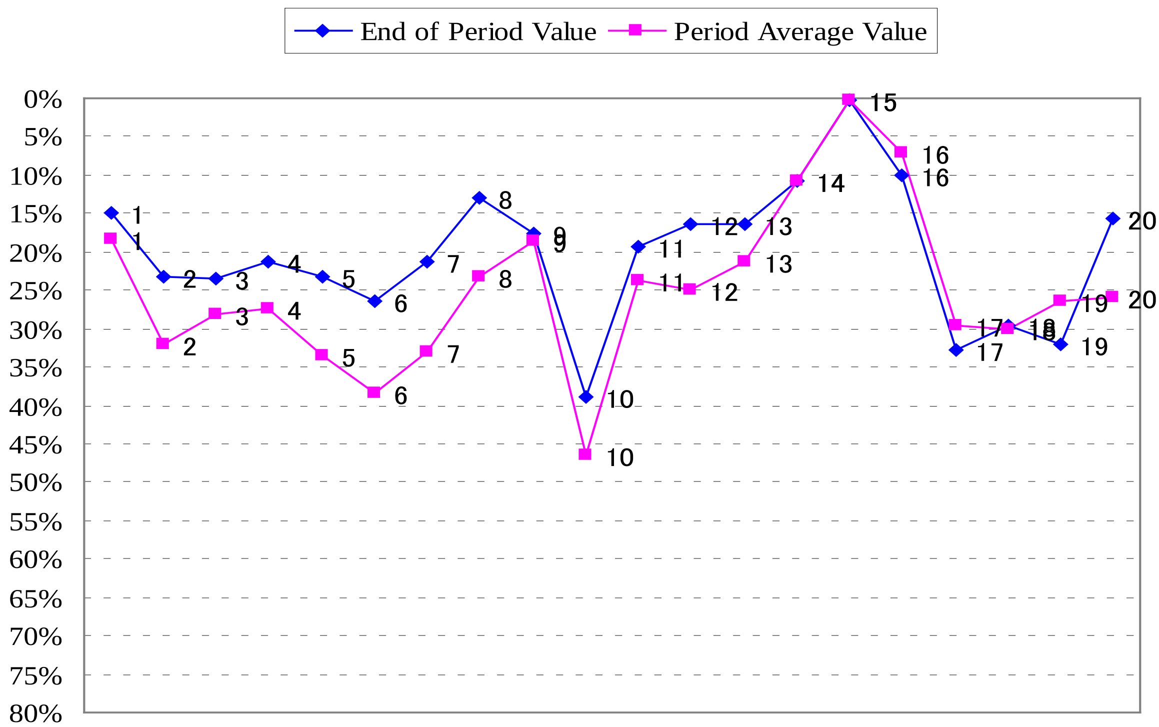


Figure 3A: The P-Value of Rejecting the Unit Root of RER of 15-year subperiods



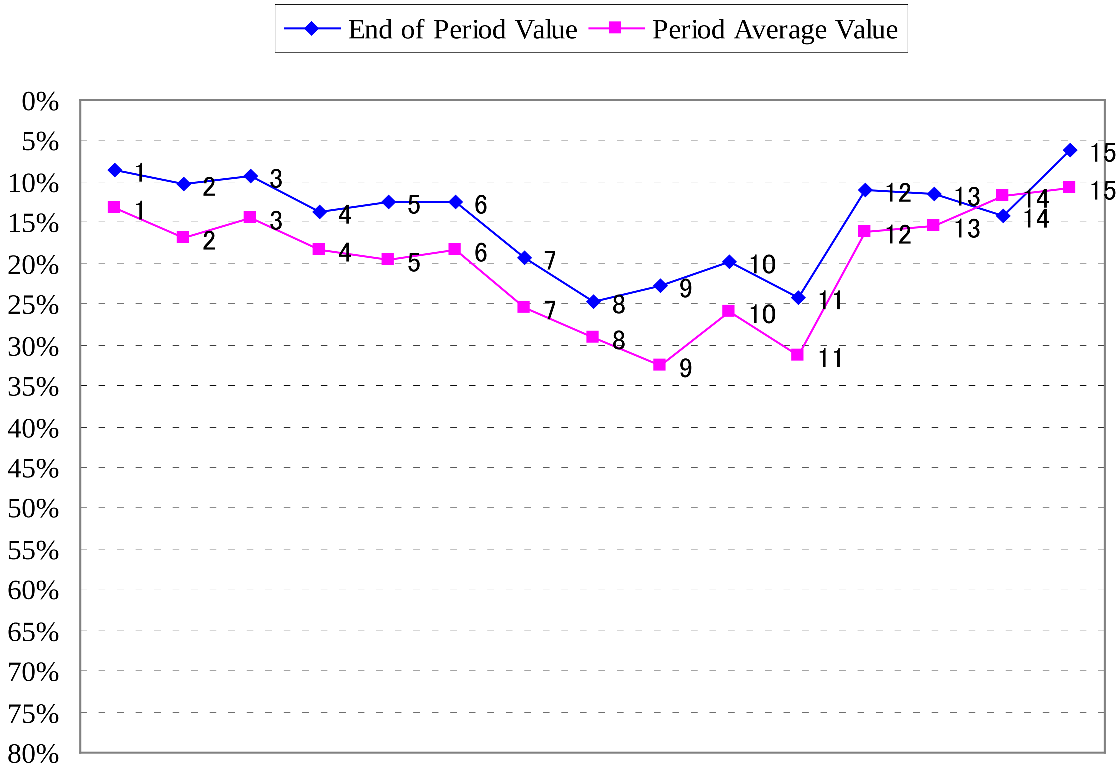
Note: 1, 2, …, 25 denotes span of 1970Q1-1984Q4, 1971Q1-1985Q4, …, 1994Q1-2008Q4 respectively.

Figure 3B: The P-Value of Rejecting the Unit Root of RER of 20-year subperiods



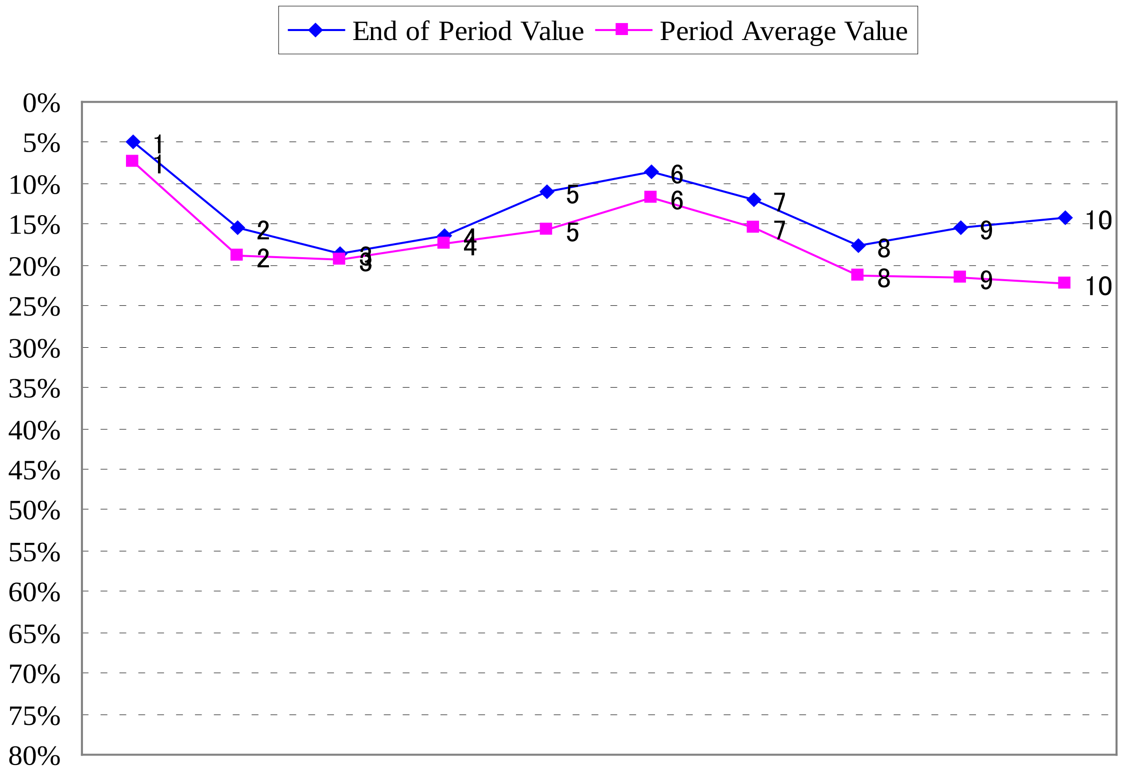
Note: 1, 2, …, 18 denotes span of 1970Q1-1989Q4, 1971Q1-1990Q4, …, 1989Q1-2008Q4 respectively.

Figure 3C: The P-Value of Rejecting the Unit Root of RER of 25-year subperiods



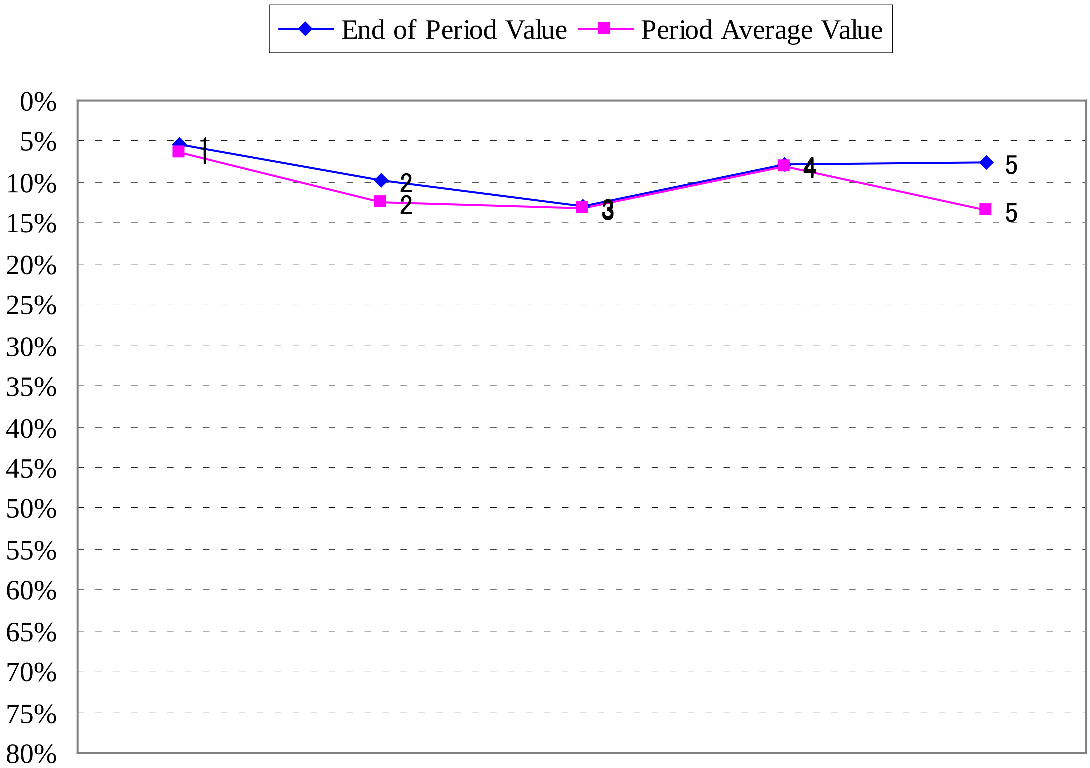
Note: 1, 2, …, 13 denotes span of 1970Q1-1994Q4, 1971Q1-1995Q4, …, 1984Q1-2008Q4 respectively.

Figure 3D: The P-Value of Rejecting the Unit Root of RER of 30-year subperiods



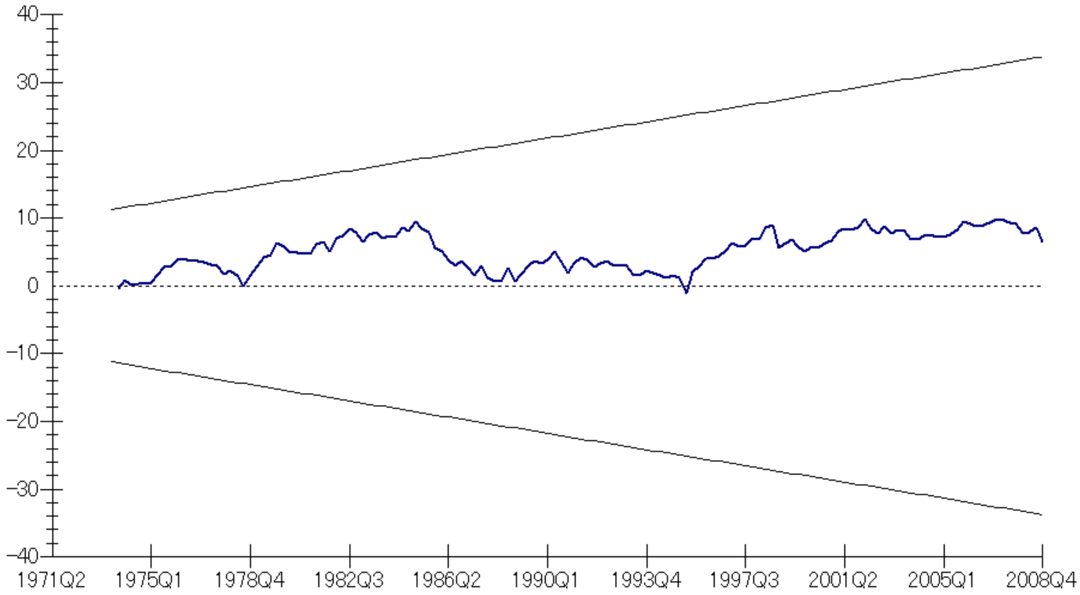
Note: 1, 2, …, 8 denotes span of 1970Q1-1999Q4, 1971Q1-2000Q4, …, 1979Q1-2008Q4 respectively.

Figure 3E: The P-Value of Rejecting the Unit Root of RER of 35-year subperiods



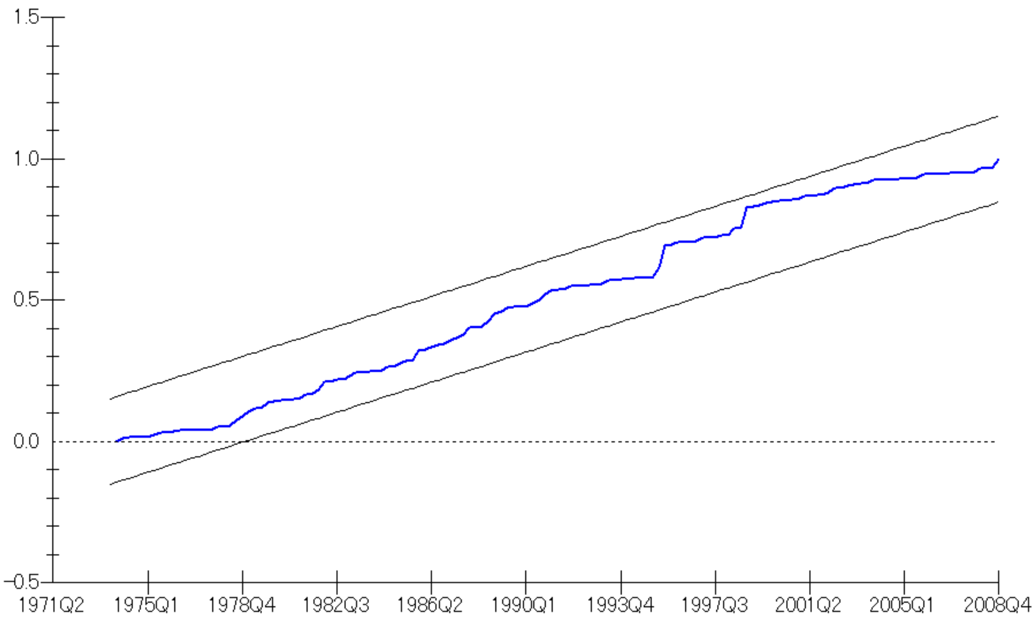
Note: 1, 2, and 3 denotes span of 1970Q1-2004Q4, 1971Q1-2005Q4, and 1974Q1-2008Q4 respectively.

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



The straight lines represent critical bounds at 5% significance level

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



The straight lines represent critical bounds at 5% significance level