Accounting for Korea-Japan Real Exchange Rate Persistence

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ABSTRACT

The purpose of this paper is to understand the behavior of the disaggregate Korea-Japan real exchange rates (RERs). Four different disaggregate price levels, from sectoral price index level to product level, are obtained from the decomposition of the aggregate consumer price index. The Lagrange multiplier (LM) unit-root test with level shifts (0-2 breaks) are used to detect the possible structural changes. Our empirical results show that most series accept the unit roots hypotheses by univariate unit root tests or by univariate LM unit root tests with breaks. It implies that the Korean RERs should be persistent if they are examined by conventional unit root tests. However, we found all of the disaggregate RERs are stationary processes and decrease half-life estimate successfully by panel unit root tests without structural breaks. Comparison with the panel LM unit root test with structural breaks under correction aggregation bias, only part of the disaggregation RERs can be rejected unit root at least at the 10% significant level, and the convergence rate is similar. As our panel LM unit root test with structural breaks is calculated by individual LM test of t-test statistics and AR(1) coefficient and then total average. Thereby, the measurement is the individual persistence rather than persistence of sectoral. Consequently, the influence on aggregation bias becomes unobviously. The half-lives for all Korean disaggregate RERs are less than the consensus views of 3-5 years (Rogoff, 1996). In conclusion, the disaggregate prices provide the strong evidence to support PPP between Korea and Japan.

JEL Classifications: C33, F31

Keywords: disaggregate price index, real exchange rate persistence, structural break

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1 Introduction

Korea is one of the most active economies over the past decade in the world. It makes long run GDP (per capita) from 643 million $(1,660)$ U.S. dollars to $8,329$ million $(17,175)$ U.S. dollars from 1980 to 2009.[1] However, the active Korean economy is not coming from the long term increases in domestic consumption, but is coming from the trade sector. The important factor which affects trade balance is the real relative prices, i.e., the real exchange rates.

After 1980, when the Korean government began to expand trade liberalization, the appropriate management of real exchange rate is regarded as the crucial matter, phasing out the varieties of export subsidies and import protection. In the early 1980s, Korea changed the fixed exchange rate system to peg Korean won to a basket of major trading partner currencies. The new exchange rate system is designed to maintain a more stable real effective exchange rate of Korean won to the major trading partners. In March 1990, a new exchange rate system is known as the *market average rate* system replaced the previous multi-currency peg exchange rate regime. The essential feature of this new system was to allow market forces to determine exchange rate, and thus lay the foundation for the market to become more efficient, and go into free-floating exchange rate system in the future. The trade structure of Korea is similar to its neighbor, Japan. The main export products are electronics, automotive, and petrochemical products. The imports mainly are machinery and equipment, and fossil fuels. As long as Korea and Japan are competition in the international market, the exchange rate of two currencies are usually moving together.

The economic between Japan and Korea have stronger relationship than to other countries. The movement of real exchange rate in Korea and Japan is opposite direction before 1990s. During this period, the Japanese yen continued to appreciate, while the Korean won was in depreciation. However, there was an obvious co-movement between these two countries from the mid-1990s. Particularly after the economic crisis in Korea, the fluctuation of two currencies was tightly together. The exports of Korea is sensitive to won-yen exchange rate volatility, because the products of Japan and Korea are close competition in international markets. This is the main reason that Korean won exchange rate move along with Japanese yen exchange rate. In 1997, the Korean government abolished the previous system of managed floating exchange rate, so that the exchange rate system was more liberalized in Korea. However, the Asian financial crisis occurred at 1997, so that the won-dollar exchange rate depreciated to 1008:1. The Korean government had to ask for help to the International Monetary Fund (IMF) which temporarily control

[1] The data are obtained from economic statistics system, the Bank of Korea.

the crisis. While the won-dollar exchange rate still depreciated to 1737.60:1 soon after. The currency crisis of Korean won had also assault on a substantial investment with Japan finance in Korea. Japanese yen depreciate from 115 yen against 1 U.S. dollar in the end of June 1997 to 133 yen against 1 U.S. dollar in early April 1998. In May and June, the Japanese yen continued to depreciate, once close to 150 yen against 1 dollar. Due to exchange rate fluctuations in 1998, Korean gross national income and per capita gross national income decline sharply to $3,521$ million U.S. dollars and $7,607$ U.S. dollars, respectively. Nevertheless, these digital returned to the level that before the economic crisis in 2002.

Up to 2009, Korea is the eighth largest exporter in the world. Trade accounts for more than half in the economy. Korea has been trading with the United States, Japan, the European Union, and other developed countries or regional. Japan is second largest trading partner of Korea after the United States.[2] Most Korean foreign investment is consist of United States and Japan. The theoretical basis for the theory of purchasing power parity (PPP) comes from the law of one price (LOP) that without consider tariffs, transport costs and other trade restrictions, the same goods in different countries should have the same price. But in the real economy, either trade costs such as tariffs and transportation costs or the tradability of products and services, and market is imperfect competition. Japan and Korea are geographically proximity, and same as the East Asian Free Trade Agreement (FTA) of the member. Hence, the transaction costs is lower than the U.S. Therefore, the observed interaction between the two countries (Korea and Japan) is important. Although the U.S. and China are major trading partners with Korea, and U.S. dollars is main import currency of them. Because of the price index report by the U.S. and China is inadequate in the classification, we give up to observe the interaction between the U.S. and Korea.

[Insert Figure 1]

Figure 1 reports the relative consumer price index (CPI) as well as the won-yen exchange rate of the monthly movement in Korea and Japan. As the figure illustrates, the variance of nominal exchange rate fluctuations is greater than that in the variance of relative price index. Less fluctuations in the relative price index are attributable to price

[2] Japan is a very important source of imports instead of just a destination for Korean exports. Until 2009, Japan accounted for 9.46% of total exports of Korea, China becomes the largest share, accounting for 16.27% of Korean total exports. At the same time, the United States to become second largest export destination of Korea, about 16.16%. With import market in Korea, Japan enjoys the largest share, accounting for 18.73% of Korean total imports, while the United States and China accounted for 14.7% and 12.05%.The relevant data is calculated by the economic statistics system of the Bank of Korea which is accumulated during the period 1990 to 2009.

rigidity. When the nominal exchange rate fluctuated by a large margin due to shocks, the real exchange rate also shows significant fluctuations. At first glance, Figure 1 demonstrates the entire series exhibit a mixed movement. In addition, the curve also implies that there may be one or two structural changes.

The most existing literatures use aggregation price data to examine PPP. However, there is estimation bias if data includes aggregation bias. Imbs, Mumtaz, Ravn, and Rey (2005) emphasize that because aggregation bias fails to take into account the heterogeneity of the estimated coefficient, leading to exaggerated estimates of half-lives. Chen and Engel (2005) advocate failed to explain the small sample properties, resulting in an estimated half-lives downward bias. Recently, Robertson, Kumar, and Dutkowsky (2009) discuss the different types of biases of the relative importance of the role in estimating PPP convergence and applied to the Mexican case. The study shows that regardless of estimating aggregation bias or data aggregation bias, the PPP of the United States and Mexico hold. The paper also emphasized that aggregation bias is importance for testing PPP.

Our data include Korea and Japan at the four different levels of aggregate price, in monthly, and cover at most the period 1985:1 to 2009:7. According to the Bank of Korea which publish price data based on the different aggregation levels, we match the price level data with Korea and Japan as close as possible at each level. The most disaggregation level consist of specific goods in Level 4. The differences across goods give different recovery rate to rise under shock. Breakdown of the different price level is able to prevent the heterogeneity across commodity and reduce the half-life exaggerated estimates caused by data component. Our dataset allows us to use several panel estimation techniques to examine half-lives. This endue us to investigate the real exchange rate persistence between Korea and Japan carefully. We use either conventional univariate unit root test such as, Augmented Dickey-Fuller (ADF) test, Phillips-Perron (PP) test, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, and Dickey-Fuller Generalize Least Squares (DF-GLS) test, or comparison with recent developed panel unit root test which is comprised of the Levin, Lin, and Chu (LLC) test; the Im, Pesaran, and Shin (IPS) test; Augmented Dickey-Fuller-Fisher χ^2 (ADF-Fisher) test; and the Phillips-Perron Fisher χ^2 (PP-Fisher) test. We attempt to estimate half-lives with Pool Fixed Effect (PFE) test, Radom Effect (RE) test, Mean Group (MG) test and Generalized Method of Moments (GMM) test. If the data component exist the heterogeneity but not join in the estimates, using of homogeneity coefficient estimates result in lower convergence rate. Heterogeneity is added in the heterogeneous coefficient estimation.

Im, Lee, and Tieslau (2005) propose a new panel Lagrangian multiplier (LM) unit root test with structure breaks. They argued that shift does not exist, there is no size distortion and significant power loss. However, when ignoring the presence of structural shifts will cause a serious size distortion and power loss. According to the data of real exchange rate, it is obvious that there are one or two fluctuations. If this volatility is regarded as common, the power of test is reduced and tended to improper conclusions. In order to study the possible structural change in the data series, we consider panel LM unit root with structural change to increase the accuracy of the estimation results. Panel LM unit root test with structural breaks come by individual series with different number of breaks in the LM unit root test. The location of structural breaks for individual series reflect the locations for sectoral. By understanding the convergence rate of individual commodities extend to sectoral.

Univariate unit root test at the 10% significant level have lower rejection rate. Even taking into account univariate LM unit root with structural breaks are still inclined to accept unit root null hypothesis. It implies that Korean disaggregation real exchange rate may be persistent if they are examined by traditional unit root test. However, we find that all of the disaggregation real exchange rate are stationary by traditional panel unit root tests. Comparison with the panel LM unit root test with structural breaks. Although the Level 1 and Level 2 are unable effectively to reject unit root, but the Level 3 and Level 4 which consist of specific commodities are capable of rejecting unit root at least at the significant level of 10%. The sectoral first point of structural change occurred in 1997 or 1998, which coincides with the Asian financial crisis spread to Korea. From 2000 to 2002 is the second point of structural change, at this time, the Korean economy began to recover to pre-crisis level. Weigh the structural breaks in the half-live estimates take on about 28 months. In the disaggregated real exchange rate is a slight decrease in 27 months.

After correct the aggregation bias, the traditional panel unit root test without structural breaks can be given to the characteristics of stationarity process and decline the half-life successfully. Compared with panel LM unit root test with structural breaks under correction aggregation bias which disagree with the previous results. It indicate that unable to reject a unit root null hypothesis effectively and the half-life is about the same. As our panel LM unit root test with structural breaks is calculated by individual LM test of t-test statistics and AR(1) coefficient and then total average. Thereby, the measurement is the individual persistence rather than persistence of sectoral. Consequently, the influence on aggregation bias becomes unobvious. Because it take account of structural breaks, the half-life estimate with structural breaks is still less than Rogoff's (1996) consensus views of 3 to 5 years.

The rest is structured as follows. Section 2 constructs the real exchange rate to examine half-life persistence. A brief description of the structural breaks in the model specification. Data description and collection and empirical results appear in Section 3. Section 4 summarizes the conclusions.

2 The model

2.1 Real exchange rate

The basic structure of any PPP variation is the LOP. Without taking into trade costs account, such as tariffs and transportation costs, the same goods in different countries should have the same price:

$$P_{\mathrm{it}} = S_{\mathrm{t}} \times P^{*}_{\mathrm{it}}, \quad \mathrm{i} = 1, 2, ..., N,$$

where P_{it} is the domestic currency price of goods i at time t, and P^{*}_{it} is the foreign currency price of goods i at time t. S_{t} denotes the nominal exchange rate expressed as the domestic currency per foreign currency. When the equation is set up that arbitrage opportunities do not exist, that is LOP. The LOP deviations change significantly across a wide range of goods. In general, volatility of the relative nominal prices is much less than the exchange rate. Earlier studies found that the deviations from LOP is highly correlated with the exchange rate movements.

Commodity i expressed by the real exchange rate (Q_{it}) between the two countries as follows:

$$Q_{\mathrm{it}} = \frac{S_{\mathrm{t}} \times P^{*}_{\mathrm{it}}}{P_{\mathrm{it}}}, \tag{1}$$

When the real exchange rate (Q_{it}) equals to 1, it imply that PPP hold. Go through the monotony of the natural logarithm of conversion:

$$\ln Q_{\mathrm{it}} = \ln(\frac{S_{\mathrm{t}} \times P^{*}_{\mathrm{it}}}{P_{\mathrm{it}}}) = \ln S_{\mathrm{t}} - \ln P_{\mathrm{it}} + \ln P^{*}_{\mathrm{it}},$$

it can get the commodity i expressed by the real exchange rate as follows:

$$q_{\mathrm{it}} = s_{\mathrm{t}} - p_{\mathrm{it}} + p^{*}_{\mathrm{it}}, \tag{2}$$

where q_{it}, s_{t}, p_{it}, and p^{*}_{it} are the corresponding natural logarithm values.

2.2 Half-life estimation

This paper estimates univariate unit root test which the lag selection criteria is most of one. Accordingly, the paper also uses the AR(1) as a standard specification. In fact, many studies use the AR(1) as a standard specification, such as Choi, Mark, and Sul (2003), Taylor (2001), and Murray and Papell (2005).

Suppose that there are N kinds of products in the economies of Korea and Japan. The ith product at time t, the logarithm of real exchange rate (q) behavior based on:

$$q_{\mathrm{it}} = \alpha_{\mathrm{i}} + \rho_{\mathrm{i}} q_{\mathrm{i,t-1}} + \epsilon_{\mathrm{it}}, \tag{3}$$

where ϵ_{it} are non-serially correlation residuals, for $i = 1, 2, ..., N$, and $t = 1, 2, ..., T$. We assign the N commodities in the economy to different sectors. Each sector contains different product categories as well as the number of goods. The more disaggregate sector is composed by a specific commodity. Therefore, we are able to investigate the behavior and the convergence rate of the sectoral real exchange rate. We estimate half-life persistence according to:

$$\tau_{\mathrm{HL}} = \frac{\ln(0.5)}{\ln\rho}. \tag{4}$$

Different goods should have different characteristics. Substantial differences in goods is their tradability, the degree of competition, or transaction costs. Therefore, the recovery rate under impact is different. If we treated it as homogeneous, the standard panel data estimator suffer from inconsistent. Aggregation bias comes from the heterogeneity of goods. The bias arise from failure to account for the heterogeneity of goods in the component of real exchange. The degree of heterogeneity increase the magnitude of bias rise. The vast majority of studies dealing with PPP puzzle which relative price persistence estimate base not on different commodity price data but on time series of aggregation real exchange. The relationship between commodity prices may affect magnitude of bias. Thereby, controlling for the relevance of commodity is important in our application.

A large bias can find a long half-life, besides the deviation grows with the degree of aggregation bias. Aggregation bias will promote the half-life deviation and weaken the power of unit-root test. In addition, if the data generating process present structural breaks but not combine in the model, the analysis is biased that tends to accept the null hypothesis of a unit root and overvalue from half-life estimate. Most of failure to find the evidence of PPP, not only unable to consider the heterogeneity of goods, but also attribute to not allow the structural breaks in data series.

2.3 Panel LM test with structural breaks

The conventional univariate unit root tests, such as ADF test, PP test, KPSS test, DF-GLS test, have been widely used in the literature. In order to save space, we are not discuss these methodologies here. However, we provide a brief description of panel LM unit root test with structural breaks.

As Im, Lee, and Tieslau (2005) expanded panel LM unit root test with structural breaks. Suppose a structural change occurred at the time $T_{\mathrm{B,i}}$ for ith series, the data generating process is given by:

$$Y_{\mathrm{it}} = \gamma_{\mathrm{i}}' Z_{\mathrm{it}} + x_{\mathrm{it}}, \\ x_{\mathrm{it}} = \delta_{\mathrm{i}} x_{\mathrm{i,t-1}} + \mu_{\mathrm{it}}, \tag{5}$$

where the Z_{it} is a vector of exogenous variables. Testing the unit root null hypothesis is based on the parameter δ_{i}, while μ_{it} is mean error term that allowing heterogeneous variance structure across the cross-section units but assuming no serial correlation. Structural breaks can be incorporated in the model by including the vector of exogenous variables Z_{it} such as $[1, t, D_{\mathrm{it}}]'$, where the D_{it} is a dummy variable which denotes the time for structural breaks. It follows that if a structural break occurs in the $T_{\mathrm{B,i}}$, then the dummy variables take the following form:

$$D_{\mathrm{it}} = \begin{cases} 0 & t \leq T_{\mathrm{B,i}}, \\ 1 & t \geq T_{\mathrm{B,i+1}}. \end{cases} \tag{6}$$

In a similar way, it can be combined with two structural breaks in the model with Z_{it} as $[1, t, D1_{\mathrm{it}}, D2_{\mathrm{it}}]'$, where the $D1_{\mathrm{it}}$, and $D2_{\mathrm{it}}$ are dummy variables that denoted first structural break and the second structural break, respectively.

The panel LM unit root test statistic is calculated for individual commodities by univariate LM unit root test statistic. The univariate LM test developed by Lee and Strazicich (2003), which is based on:

$$\triangle Y_{\mathrm{it}} = \gamma_{\mathrm{i}}' \triangle Z_{\mathrm{it}} + \delta_{\mathrm{i}} \widetilde{S}_{\mathrm{i,t-1}} + e_{\mathrm{it}}, \tag{7}$$

where the $\triangle Y_{\mathrm{it}}$ and $\triangle Z_{\mathrm{it}}$ are the first difference value for Y_{it} and Z_{it}, respectively. The $\widetilde{S}_{\mathrm{i,t-1}}$ is detrended value of $Y_{\mathrm{i,t-1}}$ and the e_{it} is stochastic disturbance term. If real exchange rate is presence of unit root which implied $\delta_{\mathrm{i}} = 0$. It follow that the univariate LM test statistic can be calculated by using t-statistic to test the null hypothesis $H_0 : \delta_{\mathrm{i}} = 0$ against the alternative hypothesis $H_1 : \delta_{\mathrm{i}} < 0$. The panel LM test statistic is calculated by average optimal univariate LM unit root test of t-statistic estimate for each commodities. The individual is denoted as $\mathrm{LM}_{\mathrm{it}}$:

$$\overline{LM}_{\mathrm{NT}} = \frac{1}{N} \sum_{\mathrm{i}=1}^{N} LM_{\mathrm{it}}. \tag{8}$$

A standardized panel LM unit root test statistic by letting $E(L_{\mathrm{T}})$ and $V(L_{\mathrm{T}})$ denote the expected value and variance of $\mathrm{LM}_{\mathrm{it}}$, respectively, under H_0. Where the values of

$E(L_{\mathrm{T}})$ and $V(L_{\mathrm{T}})$ are associated with the optimal lag lengths for individual series. Then calculated the following:

$$\Gamma_{\mathrm{LM}} = \frac{\sqrt{N}[\overline{LM}_{\mathrm{NT}} - E(L_{\mathrm{T}})]}{\sqrt{V(L_{\mathrm{T}})}}, \tag{9}$$

Im et al. (2005) provide numerical values for $E(L_{\mathrm{T}})$ and $V(L_{\mathrm{T}})$ in each lag length. The existence of structural breaks unaffect the panel LM test of asymptotic distribution which is a standard t-distribution and is a standard normal one.

3 Empirical results

In this section, we present our empirical results of the unit root test and half-life estimations. We try to understand the different panel estimation techniques and different disaggregated data on variety of estimated half-lives. Looking into the aggregation bias and structural breaks are influence on the convergence rate of PPP.

3.1 Korea and Japan price level data

The Bank of Korea publish product-level price index which composed of Korean consumer price index. The information available from the Bank of Korea website http://ecos.bok.or.kr/EIndex_{}en.jsp. The Japan data come from the website http://www.stat.go.jp/. The bank of Korea posts about 286 items of CPI and combination of these items. The nominal exchange rate which won to yen comes from the database of *DataStream*. All the series compose of monthly CPI index start from 1985:1 to 2009:7, a time series of 295 observations.

The Bank of Korea based on a variety of aggregation levels reported price level data, according to index code. In our price level data, they use four different levels of aggregation, as 1, 2, 3, and 4. The lower numbers indicate greater aggregation. The aggregation level is similar to the general observation that the industry and product classification system. For example, in case of glutinous rice, progressive disaggregation occurs when the category moves from Level 1 - Food & non-alcoholic beverages; to Level 2 - Food; to Level 3 - Cereals; to Level 4 - glutinous rice. If Japan's data can not be obtained in the same category, we match Korean price data to Japan price data with the closest category. Using of these products and category descriptions, we match the Korean price indices with the Japanese price indices as closely as possible. For instance, we match Razor blade with Electric shavers at the low of the classification. Unfortunately, we abandon some items which unable to be paired successfully as well as the data length is too short, such as Korean hot pepper sauce.

The product includes tradable and non-tradable goods, as well as goods suffer restriction from a variety of tariffs and taxation. The most disaggregation occurs at Level 4, which contains 171 items. Level 3 has 42 sectors, Level 2 has 28 sectors, and Level 1 has 11 sectors. Japan price level data converted into won by using the nominal Korea-Japan exchange rate.

3.2 Unit root test

Unit root test includes univariate unit root test and recent development of panel unit root test. First of all, we exercise the four univariate unit root test, ADF, PP, KPSS, and DF-GLS test, which have been widely used to investigate real exchange rates for unit root. The null hypotheses of ADF, PP, and DF-GLS test is that series is non-stationary and contains unit root. The null hypotheses of KPSS which different from the other test is that variable is stationary or without unit root. The lag selection criteria is AIC, and the maximum lags is 20. Testing is divided into four levels. Each level contains the same time series dimension but different from cross-sectional dimension. We use the intercept in the model for unit root test. The significance level of univariate unit root test is 10%.

[Insert Table 1]

Table 1 is the results of univariate unit root tests. The report illustrates that the ADF test and the PP test have higher rejection rate at each level. The rejection rate of KPSS test is always lower. So far, we have found strong evidence that the real exchange rate between Korea and Japan is unit root characteristic. The DF-GLS test is regarded as more powerful method up to now. From this test, we find overwhelming evidences that a unit root of the null hypothesis cannot be rejected at the conventional significance level, which implied real exchange rate is non-stationary.

Failure to find the stationarity of real exchange rate may be due to structural breaks are ignored (Perron, 1989). If the data generating process is present of structural breaks but not combine in the model specification, the analysis is incorrect and tend to accept the unit root null hypothesis. For this reason, think of the univariate LM unit root test with structural breaks, which shows a rejection rate of 0 to 2 breaks. We start from the univariate LM without structural breaks in order to establish a basis for comparisons. Univariate LM unit root test without any breaks reveal that most series of test statistic is larger than the conventional significant level, so that the rejection rate is low. Now we consider the present of one structural break in the stationarity. As the results of univariate LM unit root test without any breaks, most series of test statistics are greater than the critical value at the conventional significance level. Therefore, we can not reject the unit root null hypothesis that present of one structural break. However, we know the fact that there is no ability to reject a unit root null hypothesis may due to failure to allow more than one structural break in the data series. Accordingly, we examine the stationarity of real exchange rate by allowing for two structural breaks. Even allowing two structural breaks in the model, we are unable to reject a unit root null hypothesis in most of the data series.

Most series accept the unit root by traditional univariate unit root or by the univariate LM unit root test with structural breaks. This imply that Korean disaggregated real exchange rate may be persistence in the conventional univariate unit root test. The PPP does not hold between Korea and Japan. Whereas, this conclusion most likely is defective. Univariate unit root test only considers the time series and does not consider cross-sectional individual specific effects and different patterns of residual serial correlations. Furthermore, in a limited sample, univariate unit root test procedures have been aware of the high degree of equilibrium deviation. In order to overcome the misleading conclusions for univariate unit root test, we compared with recent developed panel unit root tests to coordinate weakness of univariate unit root and improve the power of test.

We practice traditional panel unit root test without structural breaks such as LLC, Breitung, IPS, ADF-Fisher, and PP-Fisher test. The first two tests assume a common cross-sectoral unit root process, but the other tests assume unit root process by individual.

[Insert Table 2]

LLC test assumes a homogeneous autoregressive unit root, and IPS test is a group of panel unit root test which allow heterogeneous autoregressive. Breitung test allows bias correction terms and detrend bias. Fisher test is non-parameter test, we can calculate a unit root test of any arbitrary choice in a cross-sectional. The null hypothesis of panel unit root test is series contains a unit root and non-stationary process. The results are presented in Table 2. The different methods of panel estimate receive the same result that Korean real exchange rate is a stationarity process which by way of rejecting the null hypothesis at the 5% significant level from Level 1 to Level 4. The Korean disaggregation real exchange rate is not persistence which supports to PPP.

In order to clearly quantify the speed of PPP reversion, we estimate the half-life based on the results of panel unit root tests. This paper employs four difference panel technique estimates: PFE, RE, MG, and GMM estimator. Which MG is divided into pool and individual estimates. The PFE estimator assumes parameter homogeneity, while the MG is heterogeneous coefficient estimation.

[Insert Table 3]

The half-lives estimates are presented in Table 3. Reading the horizontal estimates to examine the different panel technology influence on the magnitude of aggregation bias. For a given level, except for RE, the half-life estimator ought to successfully decrease from left to right. Reviewing the estimates of individual columns to investigate how different level affect the degree of aggregation bias. For a given estimator, when the level estimate is going down, the half-life estimated is lower.

Moving from the PFE to the RE and pool MG estimators find a slight reduction in the half-life estimates. These findings are particularly relevant in estimating the more products of Level 3 and 4. When the cross-sectional exists heterogeneity, using the homogeneity coefficient estimates will overestimate the half-lives. We obtain smaller half-lives estimated with the GMM estimator than the pool MG estimator. GMM estimation demonstrates a faster reversion rate in most levels. If the individual effects and explanatory variables are related, then the RE estimator should be affected. Even RE estimation, estimated half-life is approximately 30 months in Level 1 but 15 months in Level 4. The PFE, MG, and GMM estimates successful decrease at the same pattern. By individual MG estimations, we conclude the similar results.

[Insert Figure 2]

Different levels represent different product components and the degree of heterogeneity is dissimilar. The higher levels have more disaggregate product classifications, and the degree of heterogeneity is lower relatively. Even the homogeneity coefficient estimates, the lower heterogeneity obtain the faster convergence rate. The findings support that the parameter heterogeneity of estimates will obtain shortest half-lives in most disaggregated data. In Robertson et al. (2009), it falls into Level 5 to estimate the Mexico-US exchange rate of half-lives. In their study, the convergence rate of half-life declines rapidly at each level. This may due to each level contains a far cry from the number of goods. Because of our data increase the little number of goods at each level. Therefore, the decline of half-life is more slowly.

When the cross-sectional data contains heterogeneity, using the homogeneity coefficient estimates will overestimate the half-lives. With the lowest level of aggregation and homogeneity coefficient estimation at the same time, we obtain estimated half-life for 25 months. Using this estimated technique to reduce the half-life to 13 months successfully in the most disaggregated price level data, which significantly less than the consensus views of 3 to 5 years for PPP (Rogoff, 1996). Allowing for parameter heterogeneity estimates results in further reduction in 8 months for GMM estimator at most disaggregated price level data.

If it is simple to consider the aggregation bias without structural breaks, the fast convergence rates of half-life support the result for panel unit root tests. The findings demonstrate that there is no persistence in real exchange rate and support to PPP between Korea and Japan. Nonetheless, the traditional panel unit root tests ignore the potential structural changes which will lead to possible misinterpretation. In order to clarify this issue, we conduct panel LM unit root test with structural breaks and allow up to two breaks.

3.3 Panel LM with structural breaks.

Imbs et al. (2005) using disaggregate data and found that aggregation bias lead to exaggerated estimates of half-lives. Further research from Robertson et al. (2009) emphasized that estimator aggregation bias and data aggregation bias have substantive effect. Previous experience works are constructed in the panel data framework but with no structural breaks. Because they suggest that aggregation bias is important for testing PPP. We observe aggregation bias and structural breaks for PPP deviation at the same time.

As univariate LM unit root test, we allow maximum two structural breaks at each time series. We consistent use the AIC selection criteria to decide the lag length at each breaks. Then, the locations of structural shift are determined. Following, we decided the optimal number of breaks for each good which use the significance of dummy coefficient based on the usual t-statistic. The test results for panel LM unit root test which allows structural breaks in the real exchange rates are presented in Table 4.

[Insert Table 4 and Figure 3]

The testing result differs from the traditional panel unit root test without structural breaks. The traditional panel unit root test significantly reject the unit root null hypotheses. However, the results of panel unit root test with structural breaks interpret that the test statistics for higher heterogeneity of Level 1 and Level 2 are larger than the critical value at the 5% or 10% significant level. The lower extent of aggregation bias take place at Level 3 and Level 4. Their test statistics of panel LM unit root test with structural breaks are -1.49 and -6.46, respectively, which are less than the critical value at least

10% significant level. The finding implies that the most disaggregation real exchange rates between Korea and Japan support for PPP.

Figure 3 presents the location of structural breaks for individuals. In each level, most of data series contain at least one structural break and only a few series exist two structural breaks. Interestingly, the first location of the average structural break occurred in 1996 to 1998, which corresponds exactly to the Asian financial crisis hit Korea before and after. In 2000 to 2002 is the second location of the average structural break. In this period, the Korean economy began to return to pre-crisis level. The half-life estimate with structural breaks produce about 27 months. In the most disaggregation real exchange rate is slightly reduced to 26 months.[3] This results is longer than the half-live estimate without structural breaks.

The worthy of discussion is when the structural breaks are taken into model specification, whether aggregation bias present the same effect or not. After correcting the aggregation bias, the conventional panel unit root test without structural breaks give to the characteristics of stationarity and to decline the half-life successfully. Our results are similar to Imbs et al. (2005) and Robertson et al. (2009). Comparison with panel LM unit root test with structural breaks under correction aggregation bias, the results is inconsistent with the previous studies that it is unable to reject the null hypothesis of unit root effectively and have similar half-lives. The reason for inconsistency is that tests ignore the influence on potential structural breaks. Previous studies concern about the aggregation bias which caused by the differences between goods but not think about the impact of structural breaks. The finding which comes from panel LM test with structural breaks under correction aggregation bias emphasize that the influence on aggregation bias is not significant.

The source of bias is the definition for "average" response function which is employed by the authors. The study of Imbs et al. (2005) use the "sectoral" real exchange rate to calculate the "sectoral" impulse response function. They estimate the average of heterogeneous model coefficients at the first, and use this average value to estimate their "average impulse response function." It is likely that model is a homogeneous coefficient which is given average of heterogeneous AR coefficients, rather than calculated the impulse response function for individuals and then average them to generate an estimated average of sectoral impulse response. When it averages the individual of response, a high

[3]We do not use the average coefficient ($\overline{\rho}$) to convert into half-life, but the average half-life which is obtained from the sum of the individual half-life. Because of using the average coefficient ($\overline{\rho}$) to estimated half-life would result in distortion and underestimate. For example, $\rho_1 = 0.93$ and $\rho_2 = 0.98$ correspond to the half-life is 9.55 and 34.31, respectively. The average $\overline{\rho}$ is 0.955 and the half-life is 15.05 unit, though the average half-life is 21.93.

degree of persistence commodity increase the average greatly.[4] In other words, the aggregation process is persistent which is not that sectoral present heterogeneity, but sectoral, on average, is persistent. The difference persistence of the real exchange rate between aggregate and sectoral is not aggregation data estimates upward bias which is heterogeneous from the sector but the negative bias affect their sectoral persistence estimates.

As our panel LM unit root test with structural breaks is calculated by individual LM test of t-statistics and AR(1) coefficient and then total average. Thereby, the measurement is the individual persistence rather than persistence of sectoral. Consequently, the influence on aggregation bias becomes unobvious. Because it take account of structural breaks, the half-life estimate with structural breaks is still less than Rogoff's (1996) consensus views of 3 to 5 years.

3.4 Bai and Perron estimate

Details of the estimation results are presented in Table 5. First to be considered is determining the number(s) of breaks (Bai and Perron, 2003). In the Level 1 and 2, the $\sup F_{\mathrm{T}}(k)$ tests are all significant for k between 1 and 2. So there is one break at least. The $\sup F_{\mathrm{T}}(2|1)$ test takes the value 30.68 and 31.76 respectively, which are also highly significant. The sequential procedure which using a 5% significance level chooses 2 breaks, the BIC and the LWZ have the same choice. However, Level 3 and 4 have shown that the $\sup F_{\mathrm{T}}(1)$ test is not significant at the 5% significant level, but the $\sup F_{\mathrm{T}}(2)$ test and the $\sup F_{\mathrm{T}}(2|1)$ test can be rejected in the same significant level. Because the $\sup F_{\mathrm{T}}(1)$ test is not significant, this is not surprising that the sequential procedure chosen zero break; while the BIC and LWZ maintain the same choice of 2 breaks. The $\sup F_{\mathrm{T}}(2)$ test and the $\sup F_{\mathrm{T}}(2|1)$ test are significant, therefore, we decided to approve of the presence of two breaks.

[Insert Table 5]

4 Conclusion

The purpose of this paper is trying to understand the behavior of the disaggregate Korean real exchange rates. We use monthly data from 1985:1 to 2009:7. The four different

[4] As the estimate difference between Table 3 and Table 4. The estimates of Table 3 is based on the heterogeneity between sectoral and use pool data. Table 4 considers that the individual have different impulse response, so that it get the average for sum of individual.

disaggregate price levels in Korea and Japan are the decompositions of CPI from sectoral price level to product level. We match the Korea price indices with the Japan price indices as closely as possible.

Conventional univariate unit root tests only consider the time series and do not consider cross-sectional individual specific effects. Even allowing for univariate LM unit root with structural breaks still gives misleading results. In addition, recent developed panel approaches, such as panel unit root test and panel data estimation, are adopted to investigate the panel stationary property as well as half-life for the four levels of disaggregate real exchange rates. We use panel date which provides different levels of aggregation price data and long time span to find the evidence of PPP.

The heterogeneity of goods is the main source of aggregation bias. The differences between the homogeneity coefficient estimates and heterogeneity coefficient estimates suggest that ignored the aggregation bias will lead to half-life overvalued. Previous studies found that reducing the heterogeneity of the data series is able to effectively decrease the rate of convergence. Whereas, their findings were based on the specification without allowing for structural breaks. Ignored the existence of structural breaks in data generating process result in possible distortion. While the results of the panel LM unit root test with structural breaks after correction aggregation bias indicate that the test statistics for higher heterogeneity of Level 1 and Level 2 are larger than the critical value, and imply that Korean real exchange rate is persistence. A lower extent of aggregation bias can demonstrate that Korean real exchange rate is stationary process, providing an evidence to support the PPP. The half-life estimate with structural breaks is almost unchanged.

The source of bias is the definition for "average" response function which is employed by the authors. As our panel LM unit root test with structural breaks is calculated by individual LM test of t-statistics and AR(1) coefficient and then total average. Thereby, the measurement is the individual persistence rather than persistence of sectoral. Consequently, the influence on aggregation bias becomes unobvious. Because it take account of structural breaks, the half-life estimate with structural breaks is still less than Rogoff's (1996) consensus views of 3 to 5 years.

Integrated to our results, panel LM unit root test with structural breaks after correction aggregation bias accentuates that aggregation bias is unobvious on the convergence rate. The same finding is that the most disaggregation price level data provide the strongest evidence in support for PPP between Korea and Japan. In addition, the finding of panel unit root test with structural breaks reveals that aggregation bias can not help solving the PPP puzzle as examined by Chen and Engel (2005) and Gadea and Mayoral (2009).

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Table 1: Univariate unit root tests

						LM with breaks		
Level	Deterministic	ADF	PP	KPSS	DF-GLS	0	1	2
1	Intercept	72.73	63.64	0	9.09	0	0	0
2	Intercept	67.86	60.71	0	7.14	0	0	0
3	Intercept	66.67	69.05	2.38	9.52	0	0	0
4	Intercept	52.63	54.39	5.26	12.28	8.19	8.77	9.36

Notes:

1. All of the data is monthly from 1985:1 to 2009:7. The order selection deterministic criterion is chosen by AIC. The significance level is at the 10%.

2. ADF denotes Augmented Dickey-Fuller unit root test. PP represents Phillips-Perron unit root test. KPSS is developed by Kwiatkowski et al. (1992). DF-GLS is Elliott, Rothemberg and Stock (1996) test.

3. For no breaks, Schmidt and Phillips, "LM tests for a unit root in the presence of deterministic trends." For 1 break, Lee and Strazicich, "Minimum LM unit root test with one structural break." For 2 breaks, Lee and Strazicich, "Minimum LM unit root test with two structural breaks."

4. All of the observations are 295. In Level 1, $N = 11$; in Level 2, $N = 28$; in Level 3, $N = 42$; in Level 4, N = 171.

Table 2: Panel unit root test

Level	Deterministic	Method LLC	IPS	ADF-Fisher	PP-Fisher
1	Intercept	-2.81302	-4.57978	60.2280	56.0427
		[0.0025]	[0.0000]	[0.0000]	[0.0001]
2	Intercept	-5.60787	-7.65595	161.016	149.189
		[0.0000]	[0.0000]	[0.0000]	[0.0000]
3	Intercept	-5.86673	-9.27728	244.096	241.561
		[0.0000]	[0.0000]	[0.0000]	[0.0000]
4	Intercept	-10.3931	-16.4715	938.396	1020.36
		[0.0000]	[0.0000]	[0.0000]	[0.0000]

Notes: All of the data is monthly from 1985:1 to 2009:7. The order selection deterministic criterion is chosen by AIC. Without square brackets are the value of statistics. Numbers in square brackets are probability. All of the observations are 295. In Level 1, $N = 11$; in Level 2, $N = 28$; in Level 3, $N = 42$; in Level 4, N = 171.

Table 3: Half-Life estimates

Level	PFE ρ	PFE τ_{HL}	RE ρ	RE τ_{HL}	PMG ρ	PMG τ_{HL}	GMM ρ	GMM τ_{HL}
1	0.9727	25.04	0.9775	30.46	0.9662	20.16	0.9562	15.48
	[0.000]	-	[0.000]	-	[0.000]	-	[0.000]	-
2	0.9673	20.85	0.9719	24.31	0.9651	19.51	0.9526	14.27
	[0.000]	-	[0.000]	-	[0.000]	-	[0.000]	-
3	0.9645	17.24	0.9698	20.04	0.9581	16.19	0.9373	10.70
	[0.000]	-	[0.000]	-	[0.000]	-	[0.000]	-
4	0.9481	13.01	0.9542	14.78	0.9562	15.48	0.9125	7.57
	[0.000]	-	[0.000]	-	[0.000]	-	[0.000]	-

Notes: All of the data are monthly from 1985:1 to 2009:7. PFE, RE, PMG, and GMM denote estimation of pool fixed effect, random effect, pool mean group, and generalized method of moments, respectively. ρ is AR(1) coefficient. τ_{HL} represents half-life estimates which measure in monthly. Numbers in square brackets are significant level. All of the observations are 295. In Level 1, $N = 11$; in Level 2, $N = 28$; in Level 3, $N = 42$; in Level 4, N = 171.

Table 4: Panel LM unit root test with structural breaks

		Breaks								
Level	N	0	1	2	$\overline{\lambda}_1$	$\overline{\lambda}_2$	$\overline{\rho}$	$\overline{\tau}_{\text{HL}}$	$\overline{t}$	LM test
1	11	2	9	2	0.5318	0.6508	0.9740	27.18	-2.1269	-0.9273
2	28	5	23	8	0.5382	0.7233	0.9742	27.62	-2.0714	-0.9642
3	42	10	32	14	0.4983	0.6908	0.9713	27.25	-2.0981	-1.4888^{*}
4	171	29	142	78	0.5285	0.6787	0.9586	25.89	-2.2487	-6.4615^{***}

Notes:

1. The N is the total number of goods. 0 break, 1 break, and 2 breaks display the numbers of goods in each level. Where the 0 break and 1 break will be added to the total numbers of goods. And the goods for 2 breaks will be counted in the 1 break firstly.

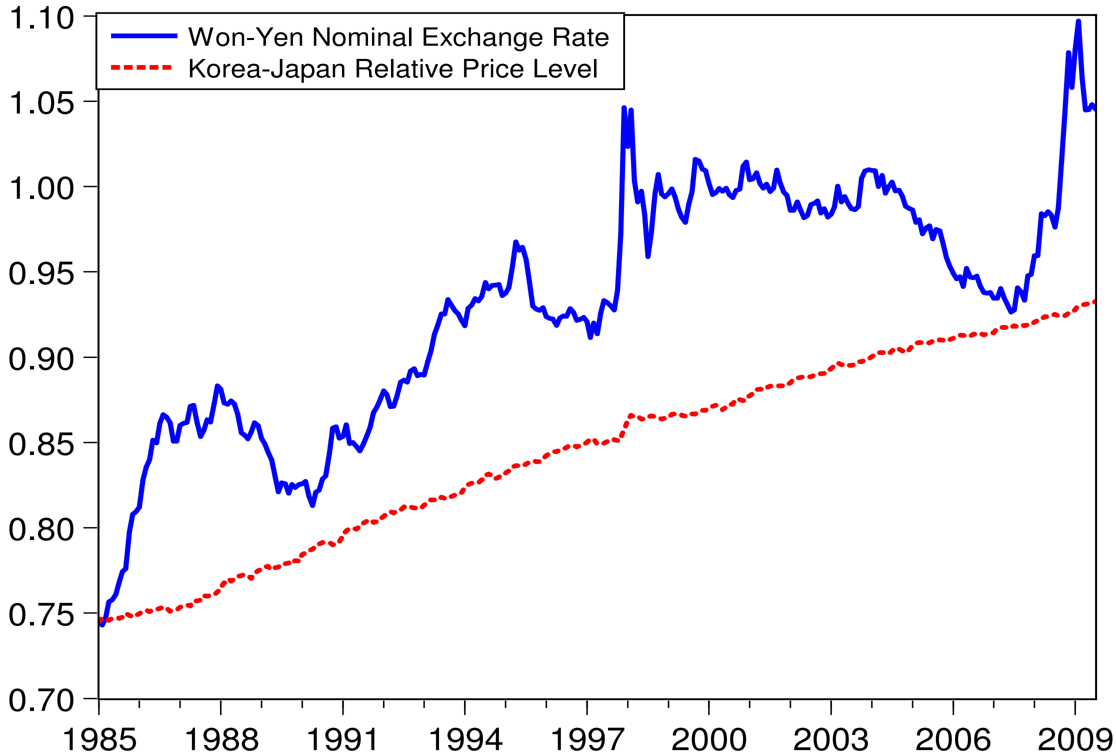
2. The average locations of breaks denote as $\overline{\lambda}_1$ and $\overline{\lambda}_2$. The average coefficient is $\overline{\rho}$. $\overline{\tau}_{\text{HL}}$ represents average half-life estimates which measure in monthly.

3. LM test represents panel LM unit root test which estimate from the average t-test statistics of $\overline{t}$. *, **, and *** significant at the 10%, 5%, and 1% level, respectively.

Table 5: Bai and Perron estimates

	Test			Number of breaks selected			Parameter Estimates with Breaks							
Level	Sup$F_T(1)$	Sup$F_T(2)$	Sup$F_T(2\|1)$	Sequential	LWZ	BIC	$\hat{\rho}_{1.1}$	$\hat{\rho}_{1.2}$	$\hat{\rho}_{1.3}$	$\hat{\rho}_{2.1}$	$\hat{\rho}_{2.2}$	$\hat{\rho}_{2.3}$	$\hat{T}_1$	$\hat{T}_2$
1	12.98	23.12	30.68	0.91	1.91	2.00	0.10	4.21	0.08	0.96	-0.57	0.97	1997:11	1998:03
2	12.91	23.70	31.76	0.86	1.93	2.00	0.08	3.57	0.13	0.97	-0.30	0.95	1997:11	1998:03
3	11.56	20.79	27.86	0.52	1.83	1.95	0.11	3.30	0.17	0.95	-0.22	0.93	1997:11	1998:03
4	11.12	20.54	27.86	0.50	1.69	1.92	0.13	3.57	0.18	0.95	-0.25	0.92	1997:11	1998:03

Notes:The significance at the 5% level of the sup$F_{\mathrm{T}}(1)$ test, sup$F_{\mathrm{T}}(2)$ test, and sup$F_{\mathrm{T}}(2|1)$ test are 12.89, 11.60, and 14.50 respectively. T_1 and T_2 are medium.



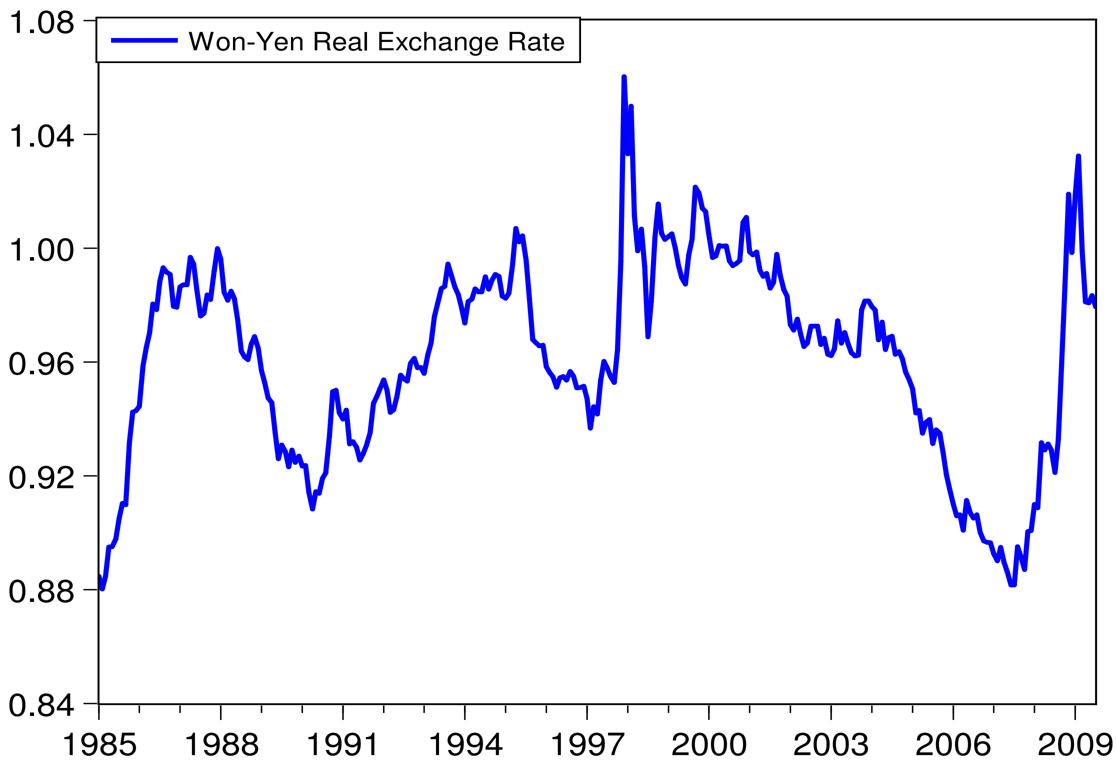


Figure 1: Nominal exchange rate, relative price level ratio, and real exchange rate.

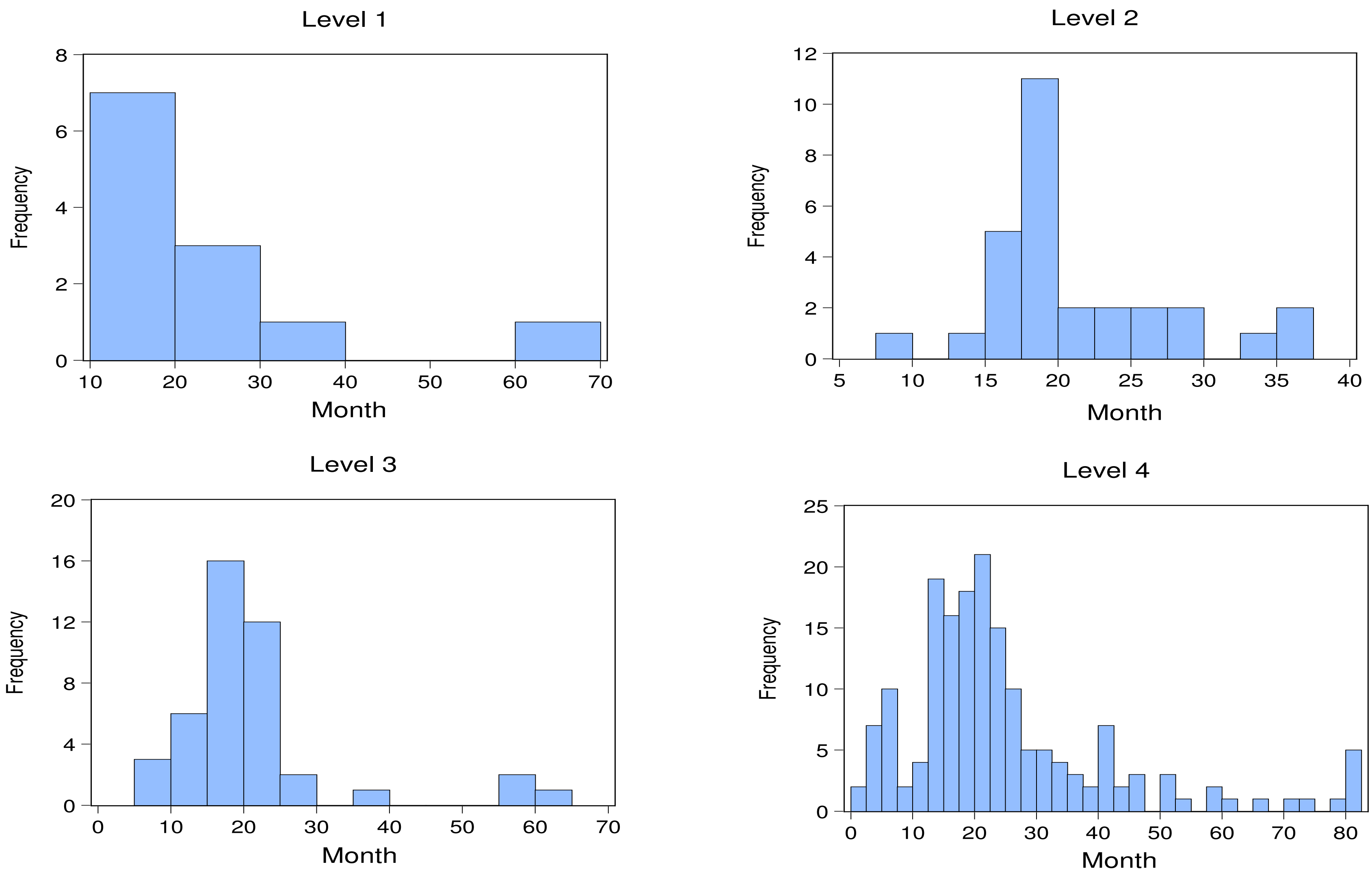


Figure 2: Half-life estimations by individual MG

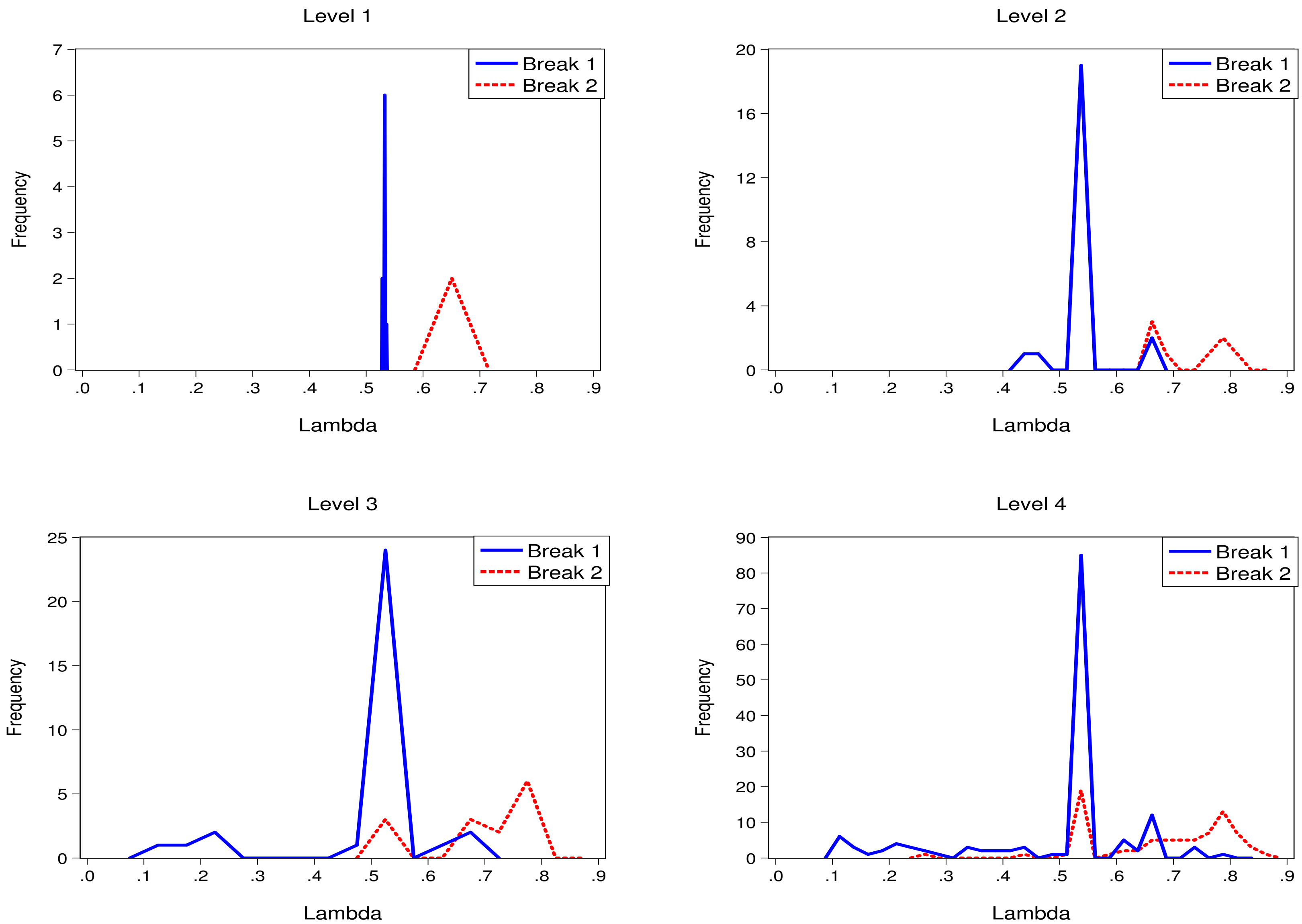


Figure 3: Locations of structural break(s) by panel the LM unit root test