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JAPAN-U.S. REAL EXCHANGE RATE BEHAVIOUR: EVIDENCE FROM LINEAR AND NON-LINEAR ENDOGENOUS BREAK TESTS

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ABSTRACT

This paper explores the mean reversion behaviour of three Japanese real exchange rates during January 1980–January 2010. The CPI- and PPI-based real yen/USD rates and real effective yen rates are examined using newly improved unit root tests allowing for endogenous break(s) in the linear and non-linear manner. We identify structural breaks in 1985 and 1997/98, respectively, via the linear tests from Zivot and Andrews (1992) and Lumsdaine and Papell (1997), but the results were mostly against the PPP hypothesis. The test from Saikkonen and Lütkepohl (2002), however, provides sufficient support for the non-linear adjustment of real exchange rates towards long-run PPP (purchasing power parity), which suggests the goods market integration between the two nations. The exchange rate misalignment is somewhat less evident after the Plaza Accord 1985, and stronger evidence for PPP is found in the post-1999 period. This is supported by a smaller persistency of real exchange (half-life < a year) found in sub-sample analysis. In brief, our findings reveal that the Japanese authorities have implemented a PPP-oriented rule as a basis for their exchange rate policies in the presence of structural break(s) and non-linearity.

Keywords: Real exchange rates, endogenous breaks, non-linearity, half-life

INTRODUCTION

Real exchange rate behaviour has been at the centre of policy debates since the breakdown of the Bretton Woods system in the early 1970s. Because exchange rates play a vital role in global trading and portfolio investments, countries with fixed exchange rates need to know what the equilibrium rate is likely to be, and countries with variable exchange rates need to know what levels and variations in

real and nominal exchange rates are expected. Assumptions about the real exchange rate property are also key factors in many theoretical and empirical models of international finance. For instance, purchasing power parity (PPP) requires a constant real exchange rate that exhibits reversion towards the long-run mean rate over time and is not driven by stochastic trends. In broader terms, understanding real exchange rate adjustments towards the equilibrium PPP helps to determine the extent to which the international macroeconomic system is self-equilibrating.

Quite surprising, however, is the consensus that is expressed in recent literature surveys (see *inter alia*, Rogoff, 1996; Taylor, & Taylor, 2004) that despite the presence of excessive short-term exchange rate volatility, deviations from the long-run equilibrium PPP rates are too persistent with the estimated half-life[1] of real exchange shocks at approximately 3–5 years. This consensus would suggest that the PPP may serve no purpose when international competition is too weak to promote long-run price convergence across borders (Elliot & Pesavento, 2004). This reasoning is obviously counter to the conventional wisdom that in an integrated world, relative prices should not become arbitrarily disparate as goods, services, capital and labour are increasingly traded across borders. The so-called PPP puzzle has challenged the common practice of using the PPP concept in exchange rate benchmarking as well as in the measurement of a nation's macroeconomic standing[2]. The puzzle has gained further attention recently because of the problem of exchange rate misalignment throughout the 1990s, a decade of financial turmoil and currency crises.

The present paper aims to investigate the time series properties of real exchange rates between Japan and the United States (U.S.). Japan and the U.S. have been major trading partners with one another since the 1960s, and the U.S. dollar (USD) and Japanese yen (yen) currency exchange account for a large portion of global trading. Unlike the neighbouring nations in East Asia that promote exports through foreign exchange stability, Japan has allowed the yen/USD exchange rate to be very volatile over the past decade. A new assessment of this floating regime will provide us with new insights into how export competitiveness and foreign exchange arrangements could be sustained at a regional level. To better assess the U.S.-Japan goods market, our study scrutinises three real yen rates: the consumer price- and producer price-based real yen/USD rates, and the real effective yen rate adjusted for trade weightings. Our monthly samples consider the post-Bretton Woods era, which spans from January 1980 to January 2010, to remove the potential sticky price effect observed in fixed exchange rate regimes and the global currency adjustments that occurred during the series of oil shocks in the 1970s.

Because the classical univariate unit root tests have suffered from power deficiency in discerning the unit roots and near unit roots for small samples, the newly improved unit root tests that allow for endogenous (unknown) break(s) are applied. This paper further distinguishes itself from previous studies by modelling the type of structural break to a single and two endogenous break point(s) in the linear form (Zivot & Andrews, 1992; Lumsdaine & Papell, 1997) as well as the non-linear manner for smooth transitions (Saikkonen & Lütkepohl, 2002). A different insight or perspective may be gained from the application of a different estimation strategy.

The rest of the paper is structured as follows. Section 2 presents a brief literature review. Section 3 elaborates on the methodology and describes the data. Section 4 discusses the empirical results, and section 5 provides our concluding remarks.

BRIEF LITERATURE REVIEW

Empirical studies of PPP for developed and developing countries have documented evidence both for and against PPP. Research during the recent floating regime using a variant of the Augmented-Dickey-Fuller (ADF) tests on univariate real exchange rate time series for industrial countries has rarely rejected the unit root null to support PPP. Among others, see Roll (1979), Hakkio (1984), Edison (1985) and Mark (1990). It has become clear that such tests possess low power against local alternatives. Hence, the results from earlier studies say more about the low power of the conventional unit root tests than about PPP (Froot & Rogoff, 1995; Papell, 2002). Likewise, empirical evidence from developing Asian economies based on floating regimes are at best, mixed (e.g., Aggarwal & Mougoue, 1996; Chinn, 2000). In addition, a few studies have addressed the PPP in South Africa (Aron, Elbadawi, & Kahn, 1997; Tsikata, 1998; Subramanian, 1998). Aron et al. (1997) observed that the results are sensitive to the choice of price aggregates and the sample period. Additionally, the fluctuations in real exchange rates can be explained by variations in trade liberalisation, terms of trade, government expenditures, capital flows and official reserves. Alternatively, Catherine and Ariff (2009) employed Theil's Divisia index to group trade-intensive countries in Asia Pacific and Latin America. They found a positive relationship between price differentials and foreign exchange rate changes among the grouped nations, in support of relative PPP.

In response to the low power of the standard unit root tests with long half-lives, a number of researchers have begun to focus on three new models. First, univariate techniques have been applied to long-horizon real exchange rates spanning one to two centuries (Lothian & Taylor, 1996; Taylor, 2003). Second,

panel tests have been applied on the post-1973 or the post-Asian financial crisis series. By this method, favourable but not homogenous support for long-run PPP was observed (e.g., Papell, 1997; O'Connell, 1998; Drine & Rault, 2004; Baharumshah, Aggarwal, & Chan, 2007; Baharumshah, Chan, & Fountas, 2008). Third, the use of median-unbiased estimation (e.g., Murray & Papell, 2002) has produced reasonably short half-lives to support PPP, which contradicts the earlier survey findings by Rogoff (1996).

However, numerous authors have also highlighted the importance of structural breaks or regime changes owing to oil shocks, the emergence of the European monetary system, currency and financial crises in influencing the assessment of the PPP relationship. For instance, if real exchange rates are subjected to structural breaks, then large and permanent devaluations of currencies during a currency crisis will bias the test towards acceptance of the unit root hypothesis. Perron (1989) and Rappoport and Reichlin (1989) were among the first to consider the importance of structural breaks for the implementation and interpretation of unit root tests. Nevertheless, the Perron (1989) method of assuming the break date as exogenously determined and known *ex ante* has often been considered inappropriate. Zivot and Andrews (1992) later developed the single endogenous structural break test of the unit root, which was widely applied in the PPP studies. Lumsdaine and Papell (1997) then furthered the work of Zivot and Andrews (1992) to allow for two endogenous breaks under the alternative hypothesis and additionally allow for breaks in the level and the trend. Series are generally interpreted as broken trend stationary if the null hypothesis of the unit root test is rejected in favour of the alternative of two breaks.

Saikkonen and Lütkepohl (2002) and Lanne, Saikkonen and Lütkepohl (2003) developed an endogenous break model that included the deterministic term shift functions of a general non-linear form using GLS detrending. The deterministic component is subtracted from the original series and then ADF tests are applied to the adjusted series. Unlike much of the literature that followed, which dealt with the case in which a break occurs during one period only, nonlinear break tests follow the reasoning that breaks occur over a number of periods and display a smooth transition to a new level. The approach is extended to situations with an unknown break date by Lanne et al. (2003).

METHODOLOGY AND ECONOMETRIC PROCEDURES

If we let S_t be the log spot rate, p_t^* and p_t be the log foreign and domestic price levels[3] respectively, the real exchange rate, q_t (in logarithm) is defined by

$$q_t = s_t + p_t^* - p_t \tag{1}$$

The estimation of q_t is truly appropriate for testing PPP as it allows one to compute the half-life of a random disturbance to measure the degree of mean reversion. A common approach to investigating the speed of convergence to PPP employs the following linear autoregressive model of order one, AR (1),

$$q_t = \rho q_{t-1} + \varepsilon_t \tag{2}$$

where $0 < |\rho| < 1$ and ε_t is a white noise innovation. For annual data, the half-life of deviations from PPP (τ) is the number of years (or months, for monthly data) required for the initial deviation from the long-run level to dissipate by half, with no future shocks. Suppose the long-run PPP level, with ($E[q_t] = 0$) as the starting point q_0 and with an initial shock, $\delta > 0$. Then, from $\delta / 2 = |q_t| = |\rho|^\tau \delta$, the half-live is given by $\tau \equiv \ln(1/2)/ \ln |\rho|$, where the absolute value is introduced to allow oscillation.[4] In practice, the half-lives are estimated by

$$\hat{\tau} = \frac{\ln(1/2)}{\ln|\hat{\rho}|} \tag{3}$$

where $\hat{\rho}$ is an OLS estimator of ρ in (2). By construction, the speed of adjustment, or the half-life, does not depend on the initial level of real exchange rate q_0 or the size of deviations (δ) in the linear AR (1) model.

Despite the adjustment process, evidence of long run PPP can be provided by a test of the unit root in real exchange rates. A common test of the unit root relies on the augmented Dickey-Fuller (ADF) regression, which is given by

$$\Delta q_t = \mu + \beta t + \varphi_1 q_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta q_{t-i} + \varepsilon_t \tag{4}$$

where Δq_t is the first difference of the real exchange rate, k is the number of lagged q_{t-i} and ε_t is the error term. To be consistent with the PPP hypothesis, q_t must exhibit mean reversion behaviour devoid of a unit root. The φ_1 term should thereby be significantly less than 0 or the real exchange follows a random walk, implying that deviations from PPP are permanent.

The ADF test may be distorted, however, if a potential structural break (currency crises, oil shocks, market crash) in the real exchange series is simply ignored. Lumsdaine and Papell (1997) furthered the work of Zivot and Andrews (1992) to allow for two endogenous breaks under the alternative hypothesis and additionally allow for breaks in the level and the trend. LP uses a modified ADF test, which is specified as follows:

$$\Delta q_t = \mu + \beta t + \theta DU1_t + \gamma DT1_t + \varpi DU2_t + \psi DT2_t + \alpha q_{t-1} + \sum_{i=1}^{k} c_i \Delta q_{t-i} + \varepsilon_t \tag{5}$$

where two structural breaks are allowed for in both the time trend and the intercept, which occur at T_{B1} and T_{B2}. The time breaks in the intercept are shown in equation (5) by *DU1t* and *DU2t*, respectively, whereas the slope changes (or shifts in the trend) are represented by *DT1t* and *DT2t*. *DU1t* = 1 if $t > T_{B1}$ and is otherwise zero; *DU2t* = 1 if $t > T_{B2}$ and is otherwise zero; $DT1t = t - T_{B1}$ if $t > T_{B1}$ and is otherwise zero; and finally $DT2t = t - T_{B2}$ if $t > T_{B2}$ and is otherwise zero.

In addition, Saikkonen and Lütkepohl (2002) suggested that structural breaks may occur over a number of periods and display a smooth transition to a new level. If a level shift function, which is denoted here by a general nonlinear form $f_t(\theta)'\gamma$, is added to the deterministic term μ_t of the data generating process, the model of

$$q_t = \mu_0 + \mu_1 t + f_t(\theta)'\gamma + v_t \tag{6}$$

is shown, where θ and γ are unknown parameters, whereas v_t represents residual errors generated by an AR(p) process with a possible unit root. In this study, we consider the shift function based on the exponential distribution function, which allows for a nonlinear gradual shift to a new level starting at time T_B,

$$f_t(\theta) = \begin{cases} 0, & t < T_B \\ 1 - \exp\{-\theta(t - T_B + 1)\}, & t \geq T_B \end{cases}. \tag{7}$$

In the shift term $f_t(\theta)'\gamma$, both θ and γ are scalar parameters. The first parameter is confined to the positive real line ($\theta > 0$), whereas the second parameter may assume any value. The SL test of model (6) is based on the estimation of the deterministic term, first by a generalised least squares (GLS)

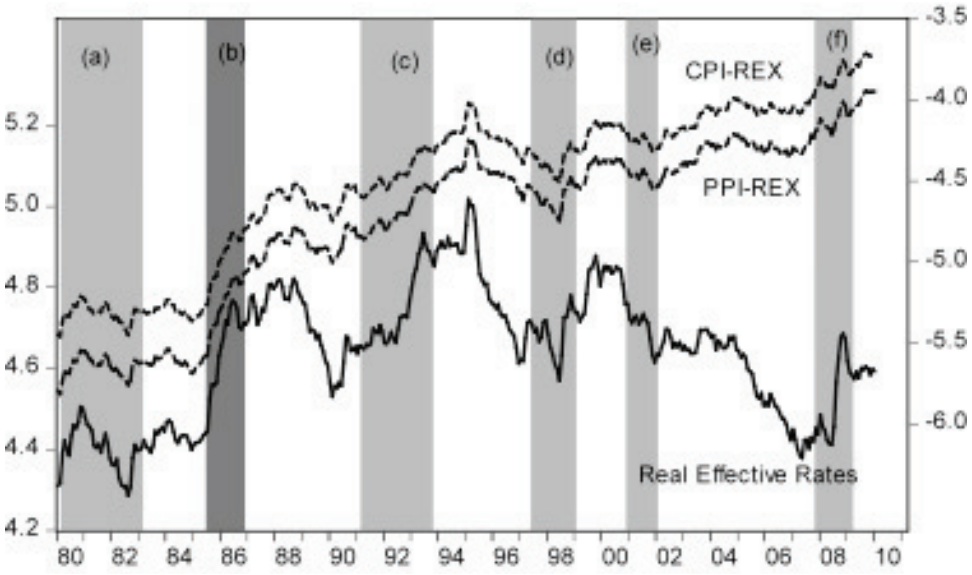
detrending procedure under the unit root null hypothesis and, second, subtracting it from the original series. An ADF-type test is then performed on the adjusted series, which also includes terms to correct for estimation errors in the parameters of the deterministic part. The asymptotic null distribution is nonstandard and critical values are tabulated in Lanne et al. (2002).

Our analysis involves two real yen/USD rates (REX) and real effective yen from January 1980 to January 2010. The construction of CPI- and PPI-based REX are based on equation (1), which consists of nominal yen/USD exchange rates, the Japanese and U.S. consumer prices and producer prices. The real effective yen rates are directly sourced from International Financial Statistics (IFS) of the IMF. To maintain the consistency and reliability in the data, we cross check with various sources such as the IFS, Datastream and the central banks of both economies.

EMPIRICAL DISCUSSION

Since the introduction of the floating regime in February 1973, the Japanese economy has experienced large fluctuations in foreign exchange rates, with the yen on a long rising trend. To mitigate the negative influence of such fluctuations on the Japanese economy, foreign exchange market interventions have been conducted from time to time by the Bank of Japan. In case of U.S. dollar buying/yen selling intervention, for example, the yen funds to be sold are raised by issuing Financing Bills (FBs). In the event of U.S. dollar selling/yen buying intervention, USD funds held in the Foreign Exchange Fund Special Account (FEFSA) are used for buying yen in the financial markets. In Figure 1, we plot the three series of Japanese foreign exchange. The shaded areas show the potential structural breaks experienced by the Japanese economy from 1980 to 2010. These include the global recession in the early 1980s, the 1985 Plaza Accord, the collapse of the Japanese asset bubble in the early 1990s, the Asian financial crisis in 1997/98, the 2001 dot-com crisis and the 2008 subprime crisis.

To examine the time series properties of real exchange rates, we proceeded with the linear unit root tests, as presented in Table 1. The optimal lag length of each case is determined by the general-to-specific method suggested by Ng and Perron (1995), and we assumed that $k_{max} = 8$ as recommended by Lumsdaine and Papell (1997) and Ben-David, Lumsdaine and Papell (2003). In other words, we started with $k = 8$ and reduced the number of lags stepwise and chose the LP model with lag length where the last lag of the first differences is significant at the 10% level or lower.



Notes: All series are logarithmic. The CPI- and PPI-based real yen/USD (REX) are on the right-hand scale, whereas the Japanese real effective rates are on the left-hand scale. Shaded time zones (a), (b), (c), (d), (e) and (f) are potential structural breaks experienced by the Japanese economy from 1980–2010.

Figure 1. The Japanese Yen and structural breaks, January 1980–January 2010

While the Zivot-Andrews test consistently reported a single break in August 1985, the Lumsdain-Papell test reported endogenous breaks in 1985, 1990 and 1997/98, respectively. The 1985 break is due to the Plaza Accord that resulted in the appreciation of Japanese yen against the USD.[5] In this situation, Japanese industries invested abroad to capture business in offshore markets. This, in turn, depressed the domestic industrial growth and employment. In addition, domestic investments dipped and, together with the other factors, promoted deflation in the Japanese economy. At this juncture, the Japanese government intervened in the foreign exchange market to curb yen appreciation to boost the export sector. The second break corresponded to the collapse of the Japanese asset bubble, which resulted in the Japanese 'lost decade.' The asset bubble was caused by speculative investments in real estate and stock market prices. Another structural break occurred with the Asian financial crisis in 1997/98 that caused a general meltdown of Asian currencies and was followed by financial turmoil.

Although they allow for structural breaks, the linear unit root tests do seem to support PPP. In most cases (except for the CPI-based real exchange rates), the reported t-statistics fail to reject the null hypothesis of the unit root. The Zivot-Andrews and Lumsdain-Papell tests indicate that mean reversion does not exist among the yen/USD real exchange series when linear level shifts are

allowed. If this is true, then the deviations from PPP are permanent, and no price convergence takes place to smooth the short-run adjustment towards the long-run PPP equilibrium rate. In other words, the potential misalignment of yen/USD cannot be corrected by market adjustment. Hence, the PPP puzzle remains unsolved until recently.

Table 1
Linear Unit Root Tests with Endogenous Break(s), January 1980 to January 2010

	Zivot-Andrews			**Lumsdaine-Papell**		
	Lag	Break	*t*-statistics	Lag	Breaks	*t*-statistics
			CPI-based REX			
with trend	1	Aug. 1985	–4.942*	2	March 1990, Oct. 1997	–6.164
without trend	1	Aug. 1985	–4.733*	2	Apr. 1990, Nov. 1997	–6.148*
			PPI-based REX			
with trend	5	Aug. 1985	–4.783	2	Nov. 1985 , Sept. 1996	–5.471
without trend	5	Aug. 1985	–4.683*	2	Dec. 1985 , Oct. 1996	–5.469
			Real Effective Rate			
with trend	1	Aug. 1985	–4.171	7	July 1985, Aug. 1998	–5.506
without trend	1	Aug. 1985	–4.190	7	Aug. 1985, Sept. 1998	–5.426
			Critical values			
	1%	5%	10%	1%	5%	10%
with trend	–5.57	–5.08	–4.82	–7.24	–6.65	–6.33
without trend	–5.34	–4.93	–4.58	–6.94	–6.24	–5.96

Note: * denotes the statistical significance at 90% confidence level.

However, it has been well documented recently that unit root tests might be biased by the presence of nonlinearities in the deterministic components. The alternative approach, which captures the structural breaks with a smoother functional form for the transition period, could be more informative. We estimated the Saikkonen-Lütkepohl test with the optimal lag length (k = 1) being determined by the standard Akaike Info Criterion (see Table 2). The estimated coefficients of $dx(-1)$ represents Δq_{t-1}; d(const) represents Z_1 = [1,0,…, 0], the regressor for initial estimation of the constant; d(trend) represents Z_2 = [1,1,…, 1], the regressor for the initial estimation of the trend; and d(shift) represents Z_3 =

$[\, f_1(\theta) : \Delta f_2(\theta) : \ldots : \Delta f_T(\theta) \,]$, the regressor for initial estimation of the exponential shift parameter γ.

Table 2
Unit Root Test with exponential shift, January 1980 to January 2010

	Break	Lag	Coefficients				SL-statistics
			d(const)	*d*(trend)	*d*(shift)	*dx*(–1)	
CPI-based REX	Aug. 1985	1	–5.447*** (38.824)	0.004 (0.130)	–0.467*** (–34.960)	0.255*** (5.008)	–3.211**
PPI-based REX	Aug. 1985	1	–5.788*** (–39.720)	0.0039 (0.141)	0.421*** (30.398)	0.2543*** (4.997)	–2.867*
Real Effective Rate	Aug. 2008	1	4.308*** (34.419)	–0.001 (–0.002)	0.295*** (24.745)	0.291*** (5.784)	–2.837*
Critical Values for SL-statistics			1%		5%		10%
			–3.55		–3.03		–2.76

Notes: *, ** and *** denote the statistical significance at 99%, 95% and 90% confidence levels, respectively. Critical values are sourced from Lanne et al. (2002). The *t*-statistics of each coefficient are in parentheses.

For CPI- and PPI-real exchange rates, the parameters of exponential shift [d(shift)] are highly significant to capture the nonlinear shift at date August 1985, which is consistent with the Zivot-Andrews linear tests reported earlier. Thus, the impact of the Plaza Accord on the Japanese exchange rate regime is confirmed. As for the Japanese real effective exchange rate adjusted for trade weightings, the break occurs at August 2008, which is consistent with the period of the subprime crisis. During the crisis, the USD was depreciating against Asian currencies (including yen), and bilateral trade adjustments due to exchange rate pass-through effect were evident. Moreover, the Saikkonen-Lütkepohl test is able to reject the null hypothesis of the unit root significantly, which provides sufficient support for the non-linear adjustment of real exchange towards long-run PPP. This finding is supported, partly, by Liew, Baharumshah and Chong (2004) who found strong evidence of non-linear behaviour of Japanese yen as well as U.S. dollar based real exchange rates in Asia.

Following the detected break dates, we proceeded to perform the half-life estimations to gauge the degree of real exchange rate adjustment towards long-run PPP (see Table 3). In general, the full sample estimations of half-life are reported at approximately 34.7 months to 40.2 months. When converted, the figure is approximately 3 years. Nevertheless, the sub-sample estimations report a

half-life that is well below the typical estimates of 3–5 years, which were suggested by Rogoff (1996). Indeed, the exchange rate misalignment is less evident after 1985, and stronger support for PPP is found in the post-1999 period. Across the sample periods of 1986–1998 to 1999–2010, the half life figures decrease from 14.4–16.1 months to about 9–11.8 months (less than a year).

Table 3
Half-life estimation

	ρ	S_E	τ	95% CI
		CPI-based REX		
Jan. 1980–Jan. 2010	–0.0187	0.0083	36.7	[4.42, 69.06]
Jan. 1986–Dec. 1998	–0.0421	0.0182	16.1	[2.13, 30.14]
Jan. 1999– Jan. 2010	–0.0738	0.0294	9.0	[1.69, 16.40]
		PPI-based REX		
Jan. 1980– Jan. 2010	–0.0171	0.0079	40.2	[3.35, 77.15]
Jan. 1986–Dec. 1998	–0.0428	0.0182	15.8	[2.34, 29.35]
Jan. 1999– Jan. 2010	–0.0703	0.0296	9.5	[1.37, 17.66]
		Real Effective Rate		
Jan. 1980– Jan. 2010	–0.0198	0.0081	34.7	[6.56, 62.84]
Jan. 1986–Dec. 1998	–0.0469	0.0197	14.4	[2.27, 26.57]
Jan. 1999– Jan. 2010	–0.0571	0.0243	11.8	[1.65, 21.91]

Notes: S_E represents the standard errors of estimated ρ, and τ denotes the estimated monthly half-life with CI abbreviating confidence interval.

The results indicate a smaller persistence of real exchange deviations in the liberalisation era where exchange rate flexibility is allowed to reflect the price changes in both nations. This is consistent with Baharumshah et al. (2008) who found a higher degree of mean reversion among the Japanese and selected Asian real exchange rates after the 1998 crisis. Likewise, Cheung and Lai (2000) who use monthly data from April 1973–December 1996 on four U.S. dollar exchange rates, i.e., the French franc, German mark, Italian lira and British pound, also found the lower bound of the confidence interval for half-lives of real exchange rates to be less than 1.5 years. These half-life estimates, according to Murray and Papell (2002), are low enough to be explained by models with nominal rigidities. This empirical evidence also has implications in exchange rate modelling because exchange rate must be driven by temporary disturbance, which will slowly dissipates over years.

CONCLUSION

Our study shows that a unit root test with a linearity break is not sufficient to gauge the mean reversion behaviour of the three yen/USD real exchange rates. The unit root is rejected, however, when an exponential shift is allowed. In addition, the 1985 Plaza Accord, rather than the 1990 Japanese asset bubble, the 1998 Asian financial crisis or the 2008 subprime crisis, is the most profound exchange rate deviation and appeared to cause a significant shift in the Japanese exchange rate regime during the post-Bretton Woods era. In a nutshell, this finding reveals that the Japanese authorities have used a PPP-oriented rule as the basis for their exchange rate policy. Misalignment of the Japanese yen is short term and can be corrected with appropriate policy responses. Emerging theoretical models, which suggest that exchange rate deviation may be governed by nonlinear factors, support our reasoning (e.g., Dumas, 1992). In addition, PPP holds, which implies that the goods market between Japan and the U.S. is so well integrated that disequilibrium in exchange rates can be corrected by price adjustments.

NOTES

1. Half-life refers to the number of years it takes for at least half of the deviation from PPP to be eliminated, following a monetary or real shock (e.g. productivity, technology) on real exchange rates. It is less useful to know that PPP holds in the long run if the degree of mean reversion in the real exchange rate is infinitely long. Common wisdom dictated that the half-lives for real exchange rates should be less than two years for the PPP-hypothesis to be operationally relevant.
2. In many world organisations, including the IMF, World Bank, EAEA and the Penn World Databank, the cross-country comparison of productivity and living standards (i.e., GDP, per capita income and balance of payment position) are often based on the macroeconomic series that adjusted for PPP.
3. The price level is usually represented by the consumer price index (CPI), the wholesale price index (WPI), or the GDP deflator.
4. When ρ approaches unity, the speed of adjustment $\ln|\rho|$ approaches zero from the left, and the half-life τ approaches infinity, implying the absence of convergence towards PPP.
5. The Plaza Accord was an agreement signed on 22 September 1985 at the Plaza Hotel in New York by five nations, i.e., the U.S., U.K., Japan, France and West Germany. The five agreed to depreciate the U.S. dollar in relation to the Japanese yen and German Deutsche Mark by intervening in the currency markets.

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