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Real Exchange Rate Dynamics: Evidence from India*

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Keywords: India; Bilateral real exchange rate; Panel unit root test; Structural break; Unbiased estimates of half-life

JEL Classifications: C23; F31

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1. Introduction

The dynamics of real exchange rate has been an important and widely researched topic in economics. The purchasing power parity (PPP) hypothesis, based on the law of one price, is at the core of this literature. PPP implies that, "once converted to a common currency, national price levels should be equal" (Rogoff 1996). The test of this hypothesis essentially involves testing for mean-reversion in real exchange rate. This is important for several reasons. *First*, in most models of exchange rate determination, PPP is regarded as a long-run equilibrium or an arbitrage condition in goods and assets markets. *Second*, real exchange rate movement plays an important role in inter-temporal smoothing of traded goods consumption (Rogoff 1992) and in cross-country redistribution and transfer of wealth (Obstfeld and Rogoff 1995). *Finally*, evidence of mean-reversion or a lack of it helps identify the shocks that characterize real exchange rate dynamics. For example, evidence of mean-reversion implies that nominal disturbances have only transitory impact on real exchange rate while a lack of such evidence implies that permanent real shocks are behind the real exchange rate movements.

Numerous empirical studies on the PPP hypothesis have been conducted and published over last several decades.[1] The results have been mixed. While some studies find evidence of mean reversion, others do not. The rejection of the PPP hypothesis has been broadly termed as the "PPP puzzle" (*a la* Rogoff 1996) and tremendous time and efforts have been expended on resolving this puzzle. A variety of datasets and empirical methods have been employed in this endeavor. Some studies have explored probable causes for the breakdown of the PPP hypothesis and have suggested a number of plausible explanations. They include: (i) tariff and

[1] Although the PPP theory has been around for several centuries, the empirical studies to test the theory started appearing in the late 1970s. With the development of new and sophisticated econometric techniques and ever-increasing computing power, there has been a flurry of empirical studies over last three decades or so. Rogoff (1996) provides a review of the earlier studies. Taylor and Taylor (2004) surveys the literature for the preceding three decades.

non-tariff trade barriers; (ii) transportation costs associated with moving goods from one country to another; (iii) the failure of nominal exchange rates to adjust to relative price-level shocks; (iv) the presence of nontraded goods prices in the calculation of general price levels; (v) existence of segmented markets.

On the methodological side, there have been several important developments with regards to the procedures employed to test for mean-reversion. Primarily after the publication of Perron's seminal work on structural break in 1989, adding shifts in the mean (that represent structural breaks) of a real exchange rate series has been used as a solution to the inability to reject the unit root.[2] Dornbusch and Vogelsang (1991), Perron and Vogelsang (1992), Culver and Papell (1995), and Hegwood and Papell (1998 & 2002) are some of the notable early examples along this line of research. However, these studies include only one structural break. Lumsdaine and Papell (1997) and Papell and Prodan (2006) extend this analysis by adding a second break into the unit root test framework. There have been a number of recent studies (e.g, Dimitriou and Simos 2013) that include one or more structural breaks in the investigation of the PPP hypothesis.[3]

Incorporating structural breaks in the panel context represents the next development. For example, using several panels of between 11 and 20 real exchange rates, Papell (2002) conducts unit root tests with multiple structural breaks that correspond to specific major depreciations and appreciations of the US dollar. While the results are mixed, there is some evidence of PPP when those breaks are included in some of the panels. Im et al. (2005) also incorporates structural breaks in several panels and are able to reject the unit root null for each of them.

[2] A rejection of the unit root null has been interpreted as evidence in support of PPP in the literature.
[3] There are other studies that examine nonlinear adjustment to PPP. For example, see Baum et al.(2001) Sollis et al (2002); Sollis (2009); Chang et al (2012). Tiwari and Shahbaz (2014) use threshold cointegration and nonlinear unit root test to examine the PPP hypothesis in the context of India.

Narayan (2008) tests a panel of 16 OECD countries. While incorporating a single break does not allow a unit root rejection, adding a second break does. More recently, Lin and Lee (2010) are able to reject the unit root in a panel of G7 real exchange rates by incorporating multiple structural breaks.

In this paper, we examine the dynamic properties of bilateral real exchange rates between India and 16 of its trading partner countries using annual data for a period between 1960 and 2010. During this period, India has moved from a low growth trajectory to a high growth trajectory. In 1991, India carried out major market-oriented reforms and trade liberalization. As part of the economic liberalization, India moved to a market-determined floating exchange rate regime in 1993.[4] In last two decades, the GDP share of trade has increased from about 16 % in 1990 to 46% in 2010. The flow of international capital has increased manifold. Thus, it is important to investigate the dynamic behavior of India's real exchange rates.[5]

We use panel unit root tests with and without structural breaks to examine if there is evidence in India's bilateral real exchange rates data to support the PPP hypothesis.[6] While the unit root null is rejected in all three cases - with no structural break, one structural break, and two structural breaks - at least at the 5% level of significance, the evidence is much stronger in the cases with structural breaks. We further report unbiased estimates of half-life. We correct for small sample bias and time aggregation bias to obtain these unbiased half-life estimates. In the case with no structural break, although we find evidence of mean reversion,

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[4] Between 1950 and 1973, India followed an exchange rate regime with Indian Rupee (INR) linked to British Pound Sterling (GBP). When GBP floated in 1972, INR's link to the British currency was maintained. In 1975, INR's ties to GBP were broken. India conducted a managed float exchange regime with INR's effective rate placed on a controlled, floating basis and linked to a "basket of currencies" of India's major trading partners. This regime continued until the early 1990s.

[5] Previous studies (e.g. Baghestani 1997; Kohli 2002; Narayan 2006) have examined exchange rate behavior in India. The current study is more akin to Narayan (2006) in its coverage and focus.

[6] The methods used in the current study are similar to those used by Hegwood and Nath (2013) and Nath and Sarkar (2014). However, these studies examine city relative price convergence within the U.S. and Australia respectively.

an unbiased half-life estimate of about 8 years implies extremely slow speed of mean reversion. However, when we consider the cases with structural breaks, the unbiased half-life estimates are greatly reduced. With two structural breaks, the unbiased half-life estimate is about one year.

The rest of the paper is organized as follows. Section 2 describes the data. In Section 3, we present the results of panel unit root test procedures. We first report the results with no structural break and we then report the test results with structural breaks. Section 4 presents the unbiased estimates of half-life. Section 5 includes our concluding remarks.

2. Data

We obtain annual data on nominal exchange rates and consumer price indices (CPIs) for India and 16 countries in our sample for the period between 1960 and 2010 from four different sources: *International Financial Statistics* (IFS) compiled and published by International Monetary Fund (IMF); *Penn World Table Version 7.0* (Heston, Summers, and Aten); *Office for National Statistics*, U.K. (statistics.gov.uk); and *Measuring Worth.com* (Officer 2011).[7] The base year for CPI was 2005. The sample of 16 countries includes Australia, Canada, France, Germany, Hong Kong, Italy, Japan, Korea, Malaysia, New Zealand, Pakistan, Philippines, Sri Lanka, Thailand, the United Kingdom (U. K.), and the United States (U. S.). For each country, we obtain annual data on CPI and nominal exchange rate with the U. S. dollar (USD). We then divide the

[7] It has been suggested that we should use high frequency (daily, weekly, monthly) exchange rate data. Since we are examining real exchange rate, we will also need high frequency data on CPI. To the best of our knowledge, there are no daily and weekly CPI data even for the developed countries where data collection practices are most advanced. For most developing countries (our sample includes a few), it is not available even at monthly frequency. Even high frequency nominal exchange rate data are not available for our entire sample period that begins in 1960. For developing countries, high frequency data are available only for last few years. Besides, the PPP hypothesis is about long-run behavior. Therefore, we believe that it would not be appropriate to test this hypothesis about the long-run behavior of real exchange rate with only a few years of noisy daily data.

nominal exchange rate between Indian rupee (INR) and USD by nominal exchange rate between the country's currency and USD to obtain bilateral nominal exchange rate between INR and that country's currency.[8] For example, in order to determine the bilateral nominal exchange rate between INR and Japanese yen (JPY), we use the following formula:

$$\textit{INR-JPY Nominal Exchange Rate} = \frac{INR-USD\ Nominal\ Exchange\ Rate}{JPY-USD\ Nominal\ Exchange\ Rate} \quad (1)$$

We then use this nominal exchange rate and CPIs in India and Japan to calculate the real exchange rate using the following formula:

$$\textit{INR-JPY Real Exchange Rate} = \frac{INR-JPY\ Nominal\ Exchange\ Rate \times India's\ CPI}{Japan's\ CPI} \quad (2)$$

Figure 1 plots the mean and standard deviation of India's bilateral real exchange rates with these 16 countries over the sample period. We make the following observations. *First*, the average real exchange rate was continuously declining until 1991 with some volatility in the mid-1960s and the mid-1970s and it has become more stable since then. *Second*, the cross-country variation in India's bilateral real exchange rates also declined substantially after 1990. Note that India moved to a market determined floating exchange rate regime in 1993.[9]

[Insert Figure 1]

The choice of these countries is primarily dictated by the availability of data.[10] These 16 countries together accounted for about 29% of India's total trade in 2011-2012, as we can see from Table 1 below. Further, 9 out of these 16 countries are among the top 25 trading partners

[8] Although data on bilateral nominal exchange rates of INR are available for a few countries in recent years, they are not available for all the years in our sample.
[9] However, the Reserve Bank of India (RBI) did not relinquish its right to intervene in the market in order to maintain orderly control.
[10] This set of countries was previously used by Narayan (2006).

of India.[11] The U.S. alone accounts for more than 11% of India's exports, 5% of imports, and more than 7% of total trade.

[Insert Table 1]

3. Panel Unit Root Tests

We use panel unit root test procedures to examine mean reversion in real exchange rate. The univariate unit-root tests (e.g. Augmented Dickey-Fuller Test) are known to have low power in certain circumstances (including the case when the sample size is small). Therefore, researchers have developed and used panel unit root test procedures. Since the panel data combine both time series and cross-section dimensions, such procedures usually have high power. This also provides the motivation for using panel test procedure for the current study.[12]

Since we are interested in examining the importance of structural changes, we first conduct the panel unit root tests with no structural breaks. A comparison of these results with those from test procedures that include structural breaks will help us highlight their significance.

3.1 With no Structural Break

We first run a panel unit root test that does not incorporate structural change so that we can evaluate the effects of such break(s). The test involves running the following regression:

$$\Delta r_{i,t} = \mu_i + \rho_i \, r_{i,t-1} + \sum_{j=1}^{k_i} \beta_{i,j} \Delta r_{i,t-j} + \varepsilon_{i,t} \tag{3}$$

[11] Note that 7 out of 25 top trading partners of India, not included in our sample, are oil rich countries of the Middle East and Africa and oil is the major import items from these countries.

[12] Although some researchers may argue that 51 years of annual data make it a long enough sample period to use univariate time series technique, others may disagree. There is no consensus as to how many time series observations constitute a long enough sample period for which such techniques can be used without worrying about low power or lack of precision in the estimates. There are studies that use panel data techniques even with substantially long sample period. For example, Cecchetti et al (2002) use annual price data for a panel of 17 U.S. cities for 78 years from 1918 to 1995 for examining mean reversion in intra-national real exchange rates across those cities.

where $r_{i,t}$ is the bilateral real exchange rate between India and country i ($i = 1, 2, \ldots, n$) in period t ($t = 1, 2, \ldots, T$). We allow the intercepts, μ_i, and lag lengths, k_i to vary across countries. Feasible generalized least squares (FGLS) seemingly unrelated regression (SUR) is used to estimate Eq.(3).[13] This method is particularly useful as it accounts for contemporaneous as well as serial correlations that are likely to be present in bilateral real exchange rates. Following the suggestions of Campbell and Perron (1991) and Ng and Perron (1995), we use the general-to-specific method to determine the number of lagged differences, k_i, for each country i. This method involves setting a maximum lag length, k^i_{max}, and paring it down to the number of lags where the lagged difference is significant. We start with a maximum lag of 4 years for each country.

The null hypothesis is H_0: $\varrho_i = 0$ for all i, that is, each series contains a unit root. The alternative hypothesis is that all of the series are stationary: H_1: $\varrho_i = \varrho < 0$. Furthermore, this alternative hypothesis requires a homogenous ϱ, as in Levin et al. (2002).[14] Note that the distribution of the panel unit root test statistic is not standard. Therefore, we use Monte Carlo simulations involving 5000 replications to calculate critical values. These simulations retain both the number of countries in the panel and the number of observations, and also account for both serial and contemporaneous correlations.[15]

[Insert Table 2]

As shown in Table 2, although the unit root null hypothesis is rejected at the 5% level of significance, it cannot be rejected at the 1% level. Thus, there is some evidence that each bilateral real exchange rate series is stationary around its long run mean. This result is not

[13] See Murray and Papell (2000).

[14] A less restrictive alternative hypothesis that at least one of the series is stationary, which allows ϱ to be heterogeneous, as in Im et al. (2003) would not be any more informative if we do reject the null, which is the case in this paper.

[15] For the details of this method, see Hegwood and Papell (2007)

consistent with the results reported in Narayan (2006) who uses bilateral real exchange rate for the same set of countries, though for a shorter sample period between 1960 and 2000.[16]

3.2 With Structural Breaks

Since Indian economy has gone through important structural changes during the sample period, we further conduct panel unit root tests that allow for structural breaks. Instead of incorporating exogenous structural breaks, we use test procedure that endogenously determines common structural breaks in the bilateral real exchange rates between India and the 16 countries in our sample. Thus, we first admit one, and then two structural breaks into our panel unit root test. One limitation of this test procedure is that it imposes common break(s) across countries. It is plausible that the structural breaks in India's bilateral exchange rates with the countries in our sample are not synchronized. However, by identifying common breaks we will be able to link and highlight events that took place in India and that have long-run implications for its bilateral real exchange rates.[17]

We utilize an Additive Outlier (AO) model framework that allows for instantaneous change(s).[18] This model has been adapted for non-trending data incorporating one or two shifts of the intercept.[19] The panel unit root test with structural breaks comprises two stages. The first stage in a test with one break involves running the following regression on the panel of real exchange rates:

$$r_{i,t} = \mu_i + \delta_i DU_t + u_{i,t} \tag{4}$$

[16] However, in an alternative specification with time trend in the test equation he finds most exchange rates to be stationary.
[17] There are unit root test procedures (Lee and Strazicich 2003; Narayan and Popp 2010) that would allow for heterogeneous, country specific structural breaks. However, in this study, our focus is on India.
[18] Hegwood and Papell (2007) use a similar framework to incorporate intercept and trend breaks to study the movements in real GDP in three groups of advanced countries.
[19] This is a panel adaptation of the univariate tests in Perron and Vogelsang (1992). They included an additional set of "crash" dummies.

The intercept break dummy variable, DU_t, equals 1 for all t greater than the break date, TB, and zero otherwise.[20] In the second stage, the residuals, $u_{i,t}$'s are regressed against their lagged value and lagged differences as follows:

$$\Delta u_{i,t} = \rho u_{i,t-1} + \sum_{j=1}^{k_i} \beta_{i,j} \Delta u_{i,t-j} + \varepsilon_{i,t} \qquad (5)$$

As in the panel unit root test with no structural break, the number of lagged differences, k_i, is determined by the general-to-specific method. Equation (4) and (5) are estimated sequentially for each possible break year, $TB = k+2, \ldots T-1$, where T is the number of observations. The year that minimizes the t-statistic on ρ is chosen to be the break date. The unit root null hypothesis is rejected if the absolute value of the minimum t-statistic on ρ is greater than the appropriate critical value. As before, the critical values are calculated using Monte Carlo simulations. The result of this panel unit root test with a single structural break as shown in the first row of Table 3 indicates that the unit root null is rejected at the 1% level with the break in 1984.

[Insert Table 3]

It is likely that the behavior of bilateral real exchange rates is characterized by more than one structural break. In order to examine this possibility and the resulting stochastic trending properties, we now extend our analysis to include a second mean shift.[21] We use the same AO model framework but simply include a second dummy variable for a second intercept shift.

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[20] We impose a restriction by forcing the break date(s) to be the same for all cities. However, allowing different breaks for each country will reduce the degrees of freedom and the power of the test. Furthermore, common breaks are usually easy to interpret.

[21] In principle, we can include more structural breaks. But, the interval between two breaks may be so short that they may simply reflect the temporary effects of large shocks. As an experiment, we included three breaks and they were determined to be in 1971, 1980, and 1988. A visual inspection of the graphs indicates that the break in 1980 may have been generated by large swings in real exchange rates for a few countries like Hong Kong, Pakistan, and Sri Lanka.

Appropriate critical values are calculated as before. The results are reported in Table 3. We reject the null hypothesis at the 1 % level with mean shifts in 1971 and 1988.[22]

Overall, these results provide strong evidence of mean-reversion in real exchange rates and are consistent with the results reported by other studies in the literature. The break dates: 1984 with a single break, and 1971 and 1988 with two breaks, warrant some explanations as to the significance of those particular years. However, since these breaks are endogenously determined strictly based on statistical criteria, it is often very difficult to speculate on one or more particular reasons for these permanent shifts without further investigation. It is more so because these permanent mean shifts may result from a combination of a number of factors/events. In terms of significant events with potential impact on real exchange rates, following the floating of USD in 1971, India announced that the official rate of INR 7.50 per USD would remain unchanged, thus effecting a *de facto* devaluation.

As for the significance of 1988, according to some researchers, the growth trajectory of over 6 % growth rate took off in 1988.[23] The late 1980s witnessed piecemeal economic liberalization and fiscal expansion financed by external debt, which eventually led to the balance of payments crisis of 1991 and subsequent market reforms. Furthermore, the break in 1984 under one break scenario may be a reflection of the political turmoil following the assassination of then Prime Minister of India, Ms. Indira Gandhi.[24] After her death, Indian National Congress came to power with decisive mandate and Rajiv Gandhi, son of the slain leader, was appointed the Prime Minister of India. Immediately after coming to power, he

[22] We also examine the possibility of a third break. Our results indicate that, in addition to 1971 and 1988, there is a third break in 1980. However, visual inspection indicates that this break does not look prominent for several countries and, therefore, we do not report the results. Interested reader can contact the corresponding author for the results with three breaks.

[23] See Panagariya (2008)

[24] We are grateful to an anonymous reviewer for pointing this out.

quickly moved to solve a number of vexing political problems in different parts of India. On economic front, he introduced policies to promote science and technology and associated industries and to reduce taxes, tariffs, and import quotas on technology-based industries. Mr. Gandhi started the process of gradual dismantling of the *License Raj* that put heavy bureaucratic restrictions on businesses investment and imports and thereby stifled growth. However, this process took several years and a major balance of payments crisis to culminate into widespread economic reforms and liberalization in 1991.

[Insert Figure 2]

We plot India's bilateral real exchange rate for each country with two structural breaks in Figure 2 to have a visual sense of how real exchange rate behavior changes around these breaks.[25] It is clear from this figure that the common breaks that we have identified capture the major structural shifts in most bilateral exchange rates reasonably well. The real exchange rates meander around the shifting means in most cases with little tendency to deviate away. We make a few observations. *First*, visually, there were significant downward shifts in mean for all but three countries in 1971 as well as in 1988. In contrast, the mean shifted upward for Hong Kong in both years. For India's bilateral real exchange rates with Pakistan and Sri Lanka, the mean shifted upward in 1971 and downward in 1988. *Second*, India's bilateral real exchange rates with the developed countries in the sample had very similar movements and those movements have been smooth and less volatile since the early 1990s. *Third*, there were large swings in India's real exchange rates with Hong Kong, Pakistan, and Sri Lanka.

[25] We present the graphs with two structural breaks as an illustration. In comparison to one break, two breaks seem to fit the data better. To save space, we do not include the plots with one break. However, they can be obtained from the authors.

4 Unbiased Half-Life Estimates with Structural Breaks

The half-life estimates are commonly used as a measure of the speed of mean-reversion. Half-life is the time required for any deviation from long run PPP to dissipate by one half. In an AR(1) case, half-life is calculated as follows:

$$h(\rho) = \frac{-ln(2)}{ln(\rho)} \tag{6}$$

where *h*( ) is the half-life and ρ is the AR coefficient. In the international PPP literature, the commonly accepted range of half-life is 3 to 5 years.

Choi et al. (2006) discusses three sources of potential biases in panel data estimation of the half-life. *First*, in small samples, inclusion of a constant in the estimation of a dynamic regression leads to a downward bias. Nickell (1981) discusses this small-sample bias in the context of panel data and, therefore, it is known as the "Nickell bias". *Second*, an upward bias potentially arises from the fact that the real exchange rates are period averages of commodity and service prices, rather than point-in-time sampled prices.[26] This time-averaging (also referred to as *time aggregation*) process introduces a moving average structure into the regression error. This is often ignored in the panel estimation of the autoregressive models of real exchange rates. *Finally*, if there is sufficient heterogeneity in the dynamic behavior of India's real exchange rates across countries (that is, the autoregressive coefficients are significantly different across countries), then panel estimation of a common autoregressive coefficient will be biased upward and so will be the implied half-life. Because the magnitude of half-life is very sensitive to the value of autoregressive coefficients, failure to correct for those biases in panel estimation of these coefficients can lead to inaccurate measure of the half-life.

[26] For a discussion, see Imbs et al. (2005)

In our panel unit root tests above, we have restricted the autoregressive coefficients to be homogeneous across countries under the alternative hypothesis. Since our test results indicate that the null of unit root is rejected in favor the alternative in all three cases, the possibility of an upward bias due to the heterogeneity in dynamic behavior of real exchange rate is no longer a concern. Thus, the panel estimates of autoregressive coefficient and half-life for India's bilateral real exchange rates involve only two potential biases: a downward bias due to small sample size and an upward bias due to the moving average error term introduced by time aggregation of data.

We use a fixed effects panel generalized least squares (GLS) estimation technique that incorporates structural breaks and also controls for cross-sectional dependence.[27] To sketch an outline of the procedure, suppose India's real exchange rate with country *i* follows an AR(1) process:

$$r_{i,t} = \alpha_i + \sum_{j=1}^{m} \delta_j DU_j + \rho_i r_{i,t-1} + u_{i,t} \tag{7}$$

where a_i is a country-specific constant; $i = 1, 2, \ldots., n$; $m = 1$ or 2 depending on whether we include one structural break or two; and $t = 1, 2, \ldots., T$. DU_j is a dummy variable for structural breaks where $DU_j = 1$ if $t > TB_j$ for $j = 1, 2$ and 0 otherwise. In the presence of time aggregation, the regression error has a moving average (MA) structure. Suppose $u_{i,t}$ follows an MA(1) process:

$$u_{i,t} = \upsilon_{i,t} + \lambda \upsilon_{i,t-1} \text{ and } \upsilon_{i,t} = \gamma_i \theta_t + \zeta_{i,t} \tag{8}$$

where γ_is are factor loadings, θ_t is the common shock, and $\zeta_{i,t}$s are serially and mutually independent. We estimate the factor loadings and the error covariance matrix by iterative

[27] This technique has been adapted from Phillips and Sul (2004) to include structural breaks and has already been used by Hegwood and Nath (2013) and Nath and Sarkar (2014)

method of moments, and then use the estimated covariance matrix to obtain the feasible GLS estimate of ϱ. Note that this estimated covariance matrix includes both the contemporaneous and the long-run covariance. We then adjust the estimated autoregressive coefficient for the Nickell bias, the time aggregation bias, and the combined Nickell and time aggregation bias as discussed in Choi et al. (2006) and use these bias-corrected estimates of autoregressive coefficient in Equation (6) to obtain various unbiased estimates of the half-life to real exchange rate mean-reversion. [28]

[Insert Table 4]

The results reported in Table 4 indicate that the inclusion of structural breaks lowers the half-life estimate from 12.98 years to 1.74 years with a single break and to 1.66 year with two breaks. When the autoregressive coefficient estimates are corrected for Nickell and time aggregation bias, the estimated half-life is further reduced from 7.9 years with no break to 1.43 and 0.99 years with one and two breaks respectively.

Overall, the results reported in this paper suggest that nominal disturbances have only transitory impact on real exchange rate in India. Furthermore, structural breaks go a long way in resolving the puzzling result of very slow mean reversion in India's bilateral real exchange rates. Bias correction further reduces the magnitude of estimated half-life. Since the global factors drive movements in nominal exchange rates, particularly after India's move to a market-determined exchange rate regime in the early 1990s, our results suggest that global disturbances are likely to have only transitory impact on real exchange rates. In contrast, domestic factors, such as structural rigidities (as reflected, for example, in higher inflation

[28] Time aggregation of the data introduces an interaction between the Nickell bias and the time aggregation bias, which requires additional adjustment in the estimation of the autoregressive coefficient. For a discussion, see Choi *et al.* (2006). The combined Nickell and time aggregation bias correction incorporates this adjustment. Nath and Sarkar (2009) use these bias corrections to examine relative price convergence across cities in the U.S.

rates), are likely to constrain real exchange rate from reverting to its long-run equilibrium within a short span of time.

5. Concluding Remarks

In this paper, we examine the dynamic properties of bilateral real exchange rates between India and 16 of its trading partner countries using annual data from 1960 to 2010. We use panel unit root tests with and without structural breaks to examine if there is evidence in India's bilateral real exchange rates data to support the PPP hypothesis. While the unit root null is rejected in all three cases - with no structural break, one structural break, and two structural breaks - at least at the 5% level of significance, the evidence is much stronger in the cases with structural breaks. We further report unbiased estimates of half-life. We correct for small sample bias and time aggregation bias to obtain these unbiased estimates. In the case with no structural break, although we find evidence of mean reversion, an unbiased half-life estimate of about 8 years implies extremely slow speed of mean reversion. However, when we consider the cases with structural breaks, the unbiased half-life estimates are greatly reduced. With two structural breaks, the unbiased half-life estimate is about one year.

Thus, our results suggest that nominal disturbances have only transitory impact on real exchange rate in India. If we appropriately control for structural breaks, any deviation from the long-run parity dissipates rather quickly. In recent years, the movements in real exchange rate in India have been at the core of many policy debates, particularly in assessing the correct value of India's nominal exchange rate. The overvaluation and undervaluation of India's nominal exchange rate play a significant input in Indian central bank's policy decisions. Thus, the results presented in this paper reveal some important aspects of the real exchange rate movements that are relevant for policy making.

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Table 1. India's exports, imports, and total trade with 16 countries in 2011-12 (Values are in millions of current USD)

Sl. No.	Country	Exports		Imports		Total Trade	
		Value	%Share	Value	%Share	Value	%Share
		(1)	(2)	(3)	(4)	(5)	(6)
1	Australia	2,477	0.81	14,890	3.04	17,367	2.18
2	Canada	2,054	0.67	2,898	0.59	4,951	0.62
3	France	4,558	1.49	4,339	0.89	8,897	1.12
4	Germany	7,943	2.60	16,276	3.33	24,218	3.05
5	Hong Kong	12,932	4.23	10,647	2.18	23,579	2.96
6	Italy	4,883	1.60	5,427	1.11	10,310	1.30
7	Japan	6,329	2.07	12,101	2.47	18,429	2.32
8	Korea	4,352	1.42	13,099	2.68	17,451	2.19
9	Malaysia	3,980	1.30	9,558	1.95	13,538	1.70
10	New Zealand	252	0.08	825	0.17	1,076	0.14
11	Pakistan	1,542	0.50	401	0.08	1,943	0.24
12	Philippines	993	0.32	456	0.09	1,449	0.18
13	Sri Lanka	4,379	1.43	721	0.15	5,100	0.64
14	Thailand	2,961	0.97	5,384	1.10	8,345	1.05
15	U. K.	8,590	2.81	7,666	1.57	16,256	2.04
16	U. S. A.	34,742	11.35	24,470	5.00	59,212	7.45
	Total for 16 countries	102,965	33.65	129,156	26.40	232,121	29.19
	Total	**305,964**	**100.00**	**489,319**	**100.00**	**795,283**	**100.00**

Source: Department of Commerce; Ministry of Commerce and Industry, India

Table 2. Panel unit root test result: no structural break

	Estimated test statistic	Critical values		
		1%	5%	10%
	(1)	(2)	(3)	(4)
Panel unit root test with no structural break	-7.31	-7.71	-6.54	-5.92

Note: The critical values are generated from Monte Carlo simulations

Table 3. Panel unit root test results: structural breaks

	Estimated test statistic	Critical values		
		1%	5%	10%
	(1)	(2)	(3)	(4)
One structural break in 1984	-13.08	-9.07	-8.30	-7.94
Two structural breaks in 1971 and 1988	-17.08	-12.52	-11.71	-11.34

Note: The critical values are generated from Monte Carlo simulations

Table 4. Panel feasible GLS estimation of ϱ and implied half-life

	No bias corrections		Nickell and time aggregation bias corrected	
	$\hat{\rho}$	Half-life	$\hat{\rho}$	Half-life
	(1)	(2)	(3)	(4)
No structural break	0.948	12.98	0.916	7.90
One structural break in 1984	0.671	1.74	0.498	1.43
Two structural breaks in 1971 and 1988	0.656	1.66	0.616	0.99

Figure 1. Average and standard deviation of India's bilateral real exchange rate with 16 other countries: 1960 – 2010

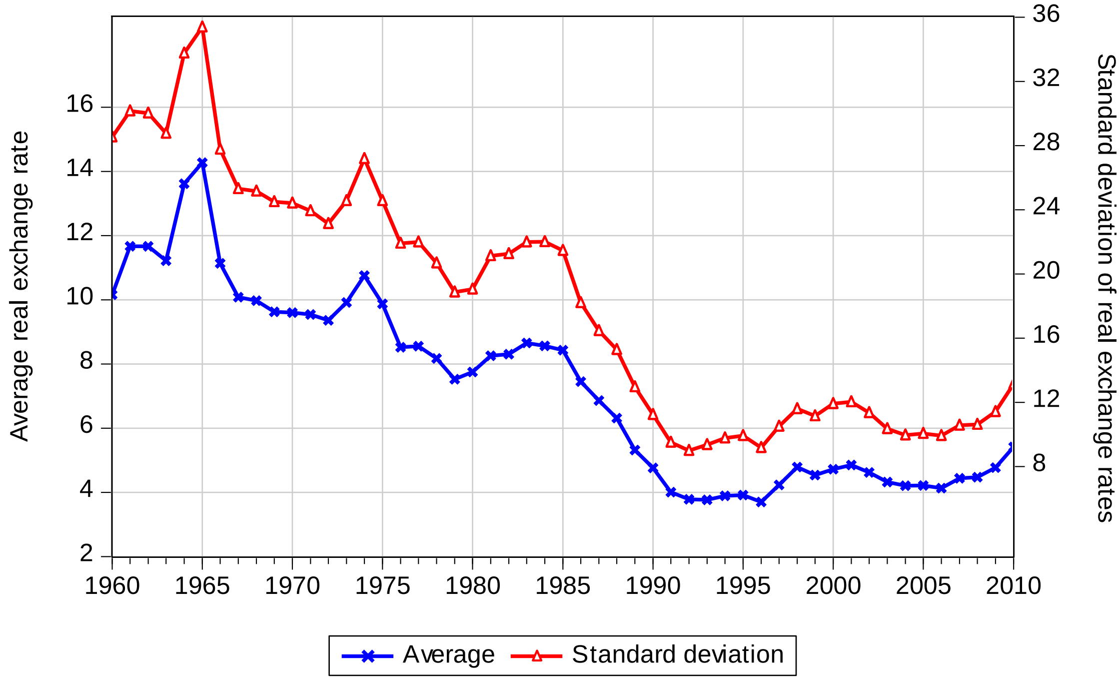

Figure 2. India's bilateral real exchange rates with two structural breaks in 1971 and 1988 for 16 countries during 1960 - 2010

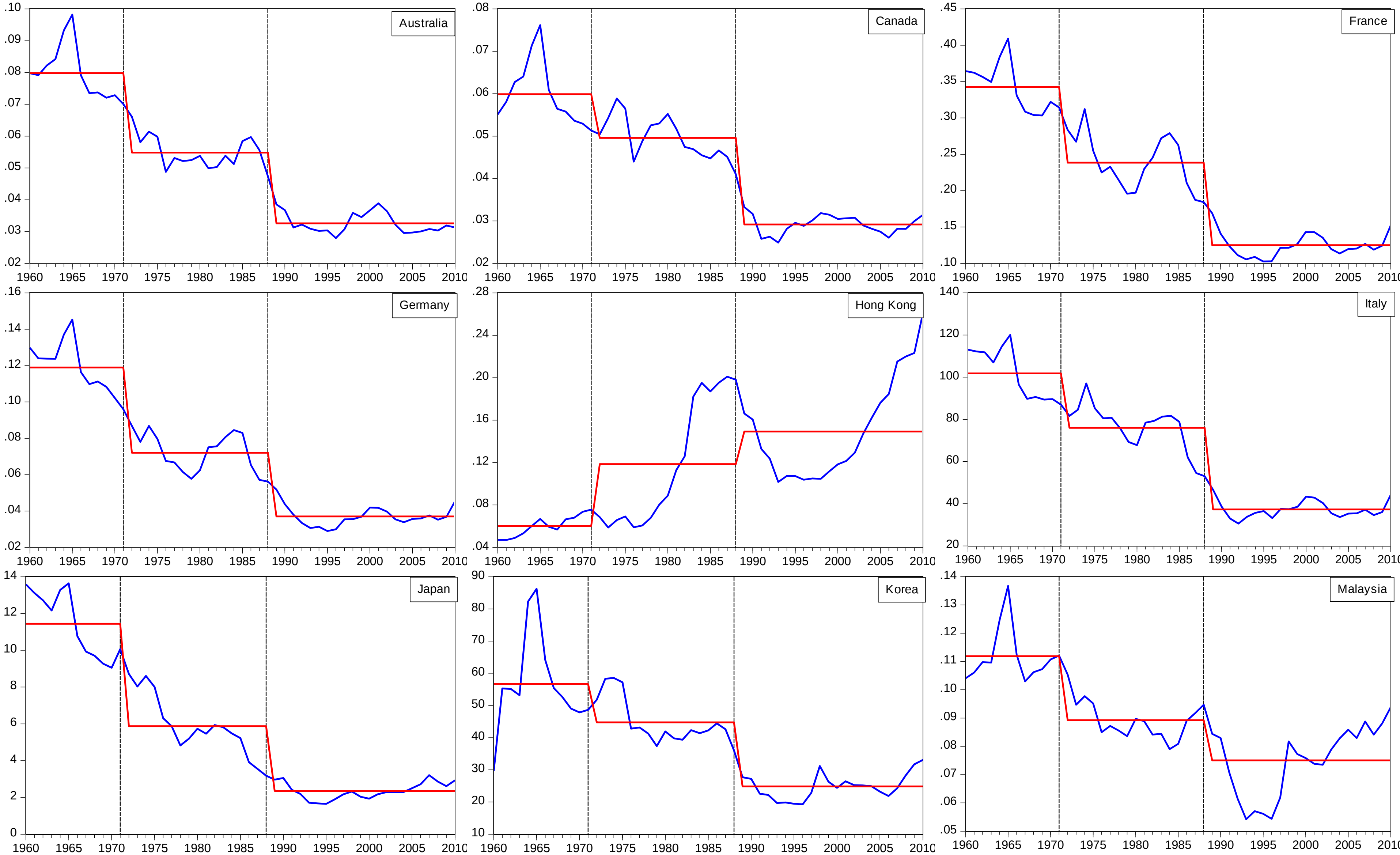

Figure 2. India's bilateral real exchange rates with two structural breaks in 1971 and 1988 for 16 countries during 1960 – 2010 (contd.)