Purchasing Power Parity and Half Life: Another Look

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Abstract

In this paper, we investigate the long-run mean reverting behavior of the real exchange rate with its six different definitions for 27 economies using annual data from 1974 to 2003. We find that PPP holds better and the half-life of the real exchange rate is shorter when the wholesale price index rather than consumer price index is used as price level measure. Somewhat surprisingly, there is no evidence that PPP holds better with trade-weighted real exchange rates than with bilateral ones regardless of the price index used. Strong evidence for PPP emerges only with the use of Im, Pesaran, and Shin (2003) panel tests but not with the Levine, Lin, and Chu (2002) test. The estimated half-life varies with the definition of the real exchange rate and is 2 to 3 years, which is shorter than the consensus view.

Keywords: Purchasing power parity; Real exchange rate; Half-life; Panel tests

1. Introduction

Purchasing power parity (PPP) is one of the most important building blocks in modeling an open economy. It has been studied in a voluminous literature. An emerging consensus after decades of extensive research is that the real exchange rate is stationary but its mean reversion takes an implausibly long time. Studies by Frankel (1986), Abuaf and Jorion (1990), Diebold, Husted, and Rush (1991), Cheung and Lai (1994), and Lothian and Taylor (1996) all reach a similar conclusion. Their estimates of the half-life of the PPP deviations fall between 3 and 5 years.[1] Rogoff (1996) calls the lengthy half-lives in the presence of a high degree of exchange rate volatility "the PPP puzzle." This is puzzling because real shocks cannot account for the majority of the short-run volatility of real exchange rates while nominal or monetary shocks can only have strong effects over a time frame during which wages and prices are sticky. The half-lives of monetary shocks under nominal rigidity would be predicted 1 to 2 years (Rogoff, 1996).

More recent research examines various aspects of the half-life measurement including uncertainty about point estimates (Rossi, 2005), the bias associated with inappropriate aggregation across heterogeneous coefficients (Taylor, 2001), time aggregation of commodity prices (Imbs et al., 2005), and downward bias in estimates of dynamic lag coefficients (Choi et al., 2006). Chortareas and Kapetanios (2005) propose an alternative measure which focuses on the cumulative effects of the shocks. Some are able to find that half-lives are shorter than the "consensus" while others merely confirm the consensus or show that the half-life is even longer. It would be fair to say that the puzzle largely remains unresolved.[2] In this paper, we investigate the PPP puzzle and the long-run mean reverting behavior of the real exchange rate in its six alternative definitions. We consider the trade-weighted effective real exchange rate as well as the bilateral rate vis-à-vis the US dollar while using both the CPI and the WPI as price indices. We compare the conventional univariate tests and the panel tests. In panel tests, we employ both the test of Levine, Lin, and Chu (LLC, 2002) and the more recent test by Im, Pesaran, and Shin (IPS, 2003).

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[1] The half-life in the above studies is 4.6 years in Frankel (1986), 3.3 years in Abuaf and Jorion (1990), 6 years for dollar-sterling and 3 years for franc-sterling in Lothian and Taylor (1996).
[2] Nonlinear models are not considered in this brief literature survey.

In addition, we investigate the behavior of the relative price of nontraded goods to traded goods and the impact of the Balassa-Samuelson effect on the real exchange rate using the *Penn World Table* (PWT) data. The rest of this paper is organized as follows. Section 2 reviews the six alternative definitions of the real exchange rate and the data used to generate them. Section 3 discusses the empirical methodology and estimation results. Section 4 ends with concluding remarks.

2. The Definitions of the Real Exchange Rate

Annual data from 1974 to 2003 are collected for 27 industrial countries and emerging market economies in East Asia and Latin America, yielding between 511 and 811 observations depending on the definition of the real exchange rate. Data for the nominal exchange rates, CPI and WPI for each country are obtained from *International Financial Statistics* (IFS) and the PPP data set is from the PWT. We consider six alternative definitions of the real exchange rate. The first index of the real exchange rate, RX1, is obtained in the following way.

$$q_t = e_t - p_t + p_t^*$$

e_t is the nominal bilateral exchange rate against the US dollar (an increase thus means a depreciation of the domestic currency), p_t is the domestic CPI and p_t^* is the US CPI.[3] All variables are in logarithm.

The second index, RX2, is the trade-weighted real effective exchange rate. It is obtained as the trade-weighted average of the bilateral real exchange rates as defined in RX1. The weights are calculated for five major trading partners during the period from 1985 to 1987, based on the total volume of trade, the data for which are from the *Direction of Trade Statistics* (DOT). The third and the fourth indices of the real exchange rate (RX3, RX4) are defined in a way similar to the first and the second, with the CPI replaced by the WPI. When the WPIs of trade partners are not available, we use the CPIs instead.

RX5 is defined as the relative price of tradables to non-tradables in the country. It is defined as,

$$q_t = p_t^T - p_t^N = e_t + p_t^{T*} - p_t^N$$

where the p_t^{T*} stands for the international prices of tradables and p_t^N is the domestic prices of nontradables. Following the tradition, we employ the CPI of the domestic country and the WPI of the base country as the proxy for the price of nontradables and the foreign price of tradables, respectively. (Edwards, S., 1989; Chowdhury, 2004)

The sixth index of the real exchange rate, RX6, is constructed by the PPP ratio obtained from the PWT and the bilateral dollar exchange rate. The PPP ratio is defined as "the number of currency units required to buy goods equivalent to what can be bought with one unit of the base country. That is, the national currency value of GDP divided by the real value of GDP in international dollars".[4] It is thus similar to the ratio of the domestic and the foreign price indices. The main difference is that, unlike the CPIs or the WPIs that use each country's own weighting systems, both indices are calculated using the same weighting scheme. Thus, using them helps reduce an important source of the index number problem that is inherent in the PPP study. RX6 is obtained by dividing the PPP ratio by the actual nominal exchange rate.

3. Empirical Results

3.1 The Unit-Roots Tests

We first perform unit-root tests using the standard Dickey-Fuller (DF) and the augmented Dickey-Fuller test (ADF). The lag length for the ADF test is selected by the Akaike Information Criterion (AIC). We also employ specifications with and without a time trend in the two tests. For space reasons, the results of these univariate unit-root tests are omitted.[5] They indicate that we cannot reject the null of nonstationarity with the RX1 index for any country at the 5 percent significance level. With the other definitions, only a small number of cases support that the real exchange rate is stationary. With the ADF test, we are able to find some more cases that support PPP. Nevertheless, the evidence does not seem to be overwhelming enough to reject the nonstationarity of the real exchange rate and accept PPP. These results are consistent with what has been reported in numerous studies including Messe and Rogoff (1988), Lothian and Taylor (1994), and Taylor (2002). Frankel (1986), Froot and Rogoff (1995), and Lothian and Taylor (1996) attribute the failure of PPP to the low power of the test.

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[3] When the CPI is not available, the GDP deflator is used.

[4] An international dollar has the same purchasing power over total US GDP as the US dollar in a given base year (PWT data appendix in Summers and Heston, 1991).

[5] Complete results are available upon request.

One approach to improving the power of PPP testing is to use a longer data span as in Frankel (1986), Abuaf and Jorion (1990), Kim (1990), Lothian and Taylor (1996), Frankel and Rose (1996), and Taylor (2002). Another approach is to use panel data as in, Oh (1996), Wu (1996), and Lothian (1997). Oh (1996) and Wu (1996) employ the test developed by LLC (2002). It may be viewed as a pooled ADF test in which all the first-order autoregressive coefficients of the unit-root tests are assumed to be equal and have a standard normal distribution. The more recent test developed by IPS (2003) relaxes the strong restriction of the equality of the first-order autogressive coefficients as in the LLC test and pools separate cross-section estimates.[6] The $\bar{t}$ statistic of the IPS test is the simple mean of the t-statistics from univariate regressions for individual countries.[7] We apply both the LLC and the IPS panel unit-roots tests. We estimate two models: one without lags, AR(1), and one with optimal lag selected by the AIC, AR(p).[8]

Table 1. Estimation Results with the LLC (2002) Test

	With AR(1) Assumption		**With AR(p) Assumption**	
	t-statistic	Coefficient	t-statistic	Coefficient
RX1	3.67	0.8431	0.71	0.8136
RX2	1.30	0.9145	1.13	0.9153
RX3	3.25	0.7897	2.21	0.7685
RX4	1.77	0.9294	1.50	0.9273
RX5	4.42	0.8288	2.08	0.7936
RX6	1.23	0.8531	-1.59*	0.8384

***** Note: The critical values are -2.32 (1 percent), -1.64 (5 percent), and -1.28 (10 percent). The maximum lag is set to six for the AR(p) model.

Table 2. Estimation Results with the IPS (2003) Panel Unit-Roots Test

	With AR(1) Assumption		**With AR(p) Assumption**	
	$\bar{t}$ statistic	$Z_{\bar{t}}$ statistic	$\bar{t}$ statistic	$Z_{\bar{t}}$ statistic
RX1	-1.82***	-1.72**	-2.15***	-3.63***
RX2	-1.86***	-1.93**	-1.81***	-1.68**
RX3	-2.10***	-2.86***	-2.40***	-4.26***
RX4	-1.89***	-1.78**	-1.98***	-2.21**
RX5	-1.74**	-1.10	-2.09***	-2.84***
RX6	-1.78**	-1.49*	-2.11***	-3.40***

* Note: This test is for 27 countries for RX1, RX2 and RX6, 20 countries for RX5 and 19 for RX3, RX4. The critical values for t-test are -1.80 (1 percent), -1.73 (5 percent), and -1.69 (10 percent). The critical values for z-test are -2.33 (1 percent), -1.64 (5 percent), and -1.28 (10 percent). The maximum lag is set to six for the AR(p) model.

Tables 1 and 2 provide the empirical results of the two panel unit-root tests. Table 1 shows that the t-statistic from the LLC test provides no support for PPP at the 5 percent significant level whether we employ the AR(1) or AR(p) assumption. Also all estimated first-order auto regressive coefficients are greater than 0.7 and close to 1, implying near-nonstationarity of the real exchange rate. In a remarkable contrast, Table 2 presents strong evidence for the stationarity of the real exchange rate in all six definitions. First of all, under the assumption of the AR(1) model, we can reject the null at the 5 percent significance level with the $\bar{t}$ statistic in all cases. With an optimal lag length for each country, we can reject the null of nonstationarity for all real exchange rate indices using either statistic at the 5 percent significant level. This suggests that the power and the efficiency of the test clearly matters when testing for PPP. These IPS test results are consistent with results in Wu and Wu (2001). Another interesting finding is that the null hypothesis is more strongly rejected with the WPI-based real exchange rates (RX3 and RX4) than with the CPI-based ones (RX1 and RX2). This finding is in line with our expectation and previous findings such as those of Kim (1990), Froot and Rogoff (1995), and Wu (1996).

[6] Both tests also assume that countries are cross section independent.

[7] See Fleissig and Strauss (2001). In other words, $\bar{t} = (\sum_{i=1}^{N} t_i) / N$, where $t_i = \gamma_i / \sqrt{Var(\gamma_i)}$ and γ_i is the first-order autoregressive coefficient of each country i. The $Z_{\bar{t}}$ statistic, $Z_{\bar{t}} = \sqrt{N(\bar{t} - \mu)} / \sigma$, of the IPS test is distributed as standard normal where $E(t_i) = \mu$, $Var(t_i) = \sigma^2$.

[8] We use Matlab for the IPS tests with the maximum lag length for the AR(p) model restricted to six.

Somewhat surprisingly, there is a weaker support for PPP with the trade-weighted real exchange rates than with the bilateral ones whether the real exchange rate is defined with the CPI or the WPI.[9]

3.2 The Half-life of Deviations from PPP

The autoregressive representation of the real exchange rate can be used to compute the half-life – the time period for a shock to decay to half of its initial size. Table 3 presents the estimates of half-life for individual countries obtained with the AR(p) model.[10] Following Cecchetti *et al*., (2002) and Murray and Papell (2002), we report the mean and median of half-life estimates.[11] The presence of outliers and negative estimates in the case of RX2 and RX5 suggests that the mean is a less reliable guide than the median as a summary statistic.

Table 3. Half-life with the IPS Estimation with the AR(p) Model

Country	RX1	RX2	RX3	RX4	RX5	RX6
Algeria	32.66	31.74	-	-	-	15.33
Argentina	1.18	1.06	-	-	-	0.88
Australia	2.48	3.36	1.62	1.94	1.48	3.86
Bangladesh	5.91	1.54	-	-	-	10.04
Brazil	2.48	2.74	2.61	2.68	2.51	4.92
Canada	4.13	4.02	1.70	1.54	4.55	3.79
Chile	3.32	2.84	-	1.58	2.08	3.39
Colombia	5.28	84.18	6.57	121.26	3.11	9.60
Denmark	1.68	1.56	2.12	1.56	3.18	2.26
Egypt	4.44	9.74	3.41	12.12	1.79	3.71
Finland	1.86	3.11	2.14	7.97	2.84	2.00
France	1.57	1.73	-	-	-	1.77
Germany	1.93	2.42	-	-	-	2.12
Greece	2.16	4.48	1.69	1.36	5.22	4.49
Hungary	24.59	-2.10	8.25	8.81	-40.18	8.02
India	9.05	10.03	7.92	11.56	4.31	14.15
Indonesia	8.33	8.56	2.34	3.30	4.85	4.61
Ireland	1.87	2.20	1.76	3.32	4.71	3.60
Italy	1.39	2.32	-	-	-	3.36
Korea	1.09	1.22	1.32	1.94	0.95	2.66
Mexico	1.29	1.27	2.55	2.57	1.95	2.35
Netherlands	1.53	1.97	1.54	7.14	1.95	1.65
New Zealand	1.03	5.08	1.26	0.81	2.35	1.40
Norway	2.30	1.27	-	-	3.61	1.94
Portugal	3.10	7.01	-	-	-	5.95
Sweden	2.94	2.97	1.23	2.42	1.93	1.94
Thailand	2.91	4.27	1.36	1.94	0.72	7.01
Mean	**4.91**	**7.43**	**2.85**	**10.31**	**0.70**	**4.70**
Median	**2.48**	**2.84**	**1.94**	**2.57**	**2.43**	**3.60**

[9] The reason for this finding is not immediately clear. It might be that countries target their real exchange rate against the US dollar and try to keep it stable for international competitiveness or other reasons.

[10] In the case of the simple AR(1) process, the half-life can be obtained as $\ln(1/2)/\ln(\gamma+1)$, which is the solution to T in the equation $(\gamma+1)^T = 0.5$ where γ is the estimated first-order autoregressive coefficient. For higher autoregressive models, the measurement of half-life is more complicated. Rossi (2005) suggests that the half-life be calculated by $\ln(1/2)b(1)/\ln(\gamma+1)$ where $b(1)$ is the sum of the estimated AR coefficients.

[11] For the IPS test, Cecchetti *et al*., (2002) average half-life across individual countries.

The results indicate, first of all, in all cases except RX6, the median of the estimated half-life is shorter than 3 years. In the case with RX3, it is less than 2 years. Even with RX6, which has the longest median, it is less than 4 years. Second, the half-life for RX3 is shorter than that for RX1 in the majority of cases. The median is also considerably shorter for RX3 than for RX1. It is consistent with the conventional results that show that PPP holds better with the WPI than with the CPI. Third, the traded-weighted real exchange rates (RX2 and RX4) show longer half-lives and slower convergence than the bilateral rates in most sample countries regardless of the definition of the real exchange rate. For instance, the half-life is longer (shorter) with RX2 than with RX1 in 18 (9) cases. The half-life is longer (shorter) with RX4 than with RX3 in 14 (4) cases. Fourth, the half-life for RX6 appears somewhat longer than for RX1 or RX3. The table that the half-life is longer (shorter) with RX6 than with RX1 in 19 (8) cases and with RX3 in 15 (3) cases. To the extent that RX6 eliminates some biases due to index number problems arising from using the price indices reported by individual countries, this result seems to suggest that biases and index number problems may not be a major reason for the failure of PPP as reported in previous studies.

4. Conclusion

In this paper we have re-examined the PPP hypothesis with various definitions of the real exchange rate for the post-Bretton Woods period of floating exchange rates. Some of important findings of this paper can be summarized as follows: 1) PPP holds better and the half-life of the real exchange rate is shorter when the WPI rather than the CPI is used as the price index; 2) Somewhat surprisingly, there is no evidence that PPP holds better with trade-weighted real exchange rates than with bilateral ones regardless of the price index used; 3) In general, we are unable to reject the unit-root null in univariate tests. Strong evidence for PPP emerges only with the use of IPS panel tests. In marked contrast, the LLC panel tests provide no evidence on PPP, perhaps due to its homogeneity restriction on the parameter; 4) We find the median of half-live estimates to be less than 3 years, which shorter than the current consensus; 5) Finally, the half-life with estimated the IPS method is shorter than 3 years in all cases except RX6. This is shorter than 3-5 years as surveyed in Rogoff (1996) although, in most cases, still longer than the 1-2 years estimates from models incorporating sticky prices.

References

Abuaf, Niso and Philippe Jorion, 1990, "Purchasing Power Parity in the Long Run," *Journal of Finance,* 45(1), 157-174.

Cecchetti, Stephen, Nelson Mark, and Robert J. Sonora, 2002, "Price Index Convergence among United States Cities," *International Economic Review,* 43(4), 1081-1099.

Cheung, Yin-Wong and Kon S. Lai, 1994, "Mean Reversion in Real Exchange Rates," *Econ. Letters,* 46(3), 251-256.

Choi, C.V., N. Mark, and D.Sul, 2006, "Unbiased Estimation of the Half-life to PPP Convergence in Panel Data," *Journal of Money, Credit and Banking,* 38 (4), 921-938.

Chortareas, Georgios and George Kapetanios, 2005, "How Puzzling is the PPP puzzle? An Alternative Half-life Measure of Convergence to PPP," *Money Macro and Finance (MMF) Research Group Conference,* 36.

Chowdhury, Mamta Banu, 2004, *Resources Booms and Macroeconomic Adjustments in Developing Countries*, Ashgate Publishing, Ltd.

Diebold, F., Steven Husted, and Mark Rush, 1991, "Real Exchange Rate under the Gold Standard," *Journal of Political Economy,* 99(6), 1252-1271.

Edwards, S.,1989. "Exchange Rate Misalignment in Developing Countries", *World Bank Res Obs.,* 4, 3-21.

Fleissig, Adrian and Jack Strauss, 2001, "Panel Unit-Root Tests of OECD Stochastic Convergence", *Review of International Economics,* 9(1), 153-162.

Frankel, Jeffery A., 1986, "International Capital Mobility and Crowding Out in the US Economy: Imperfect Integration of Financial Market or of Goods Markets?," in *How open is the US. economy*?, edited by Ruth W. Hafer, 33-67. Lexington, Mass.

Frankel, Jeffery A., and Andrew K. Rose, 1996, "A Panel Project on Purchasing Power Parity: Mean Reversion Within and Between Countries," *Journal of International Economics,* 40(1-2), 209-224.

Froot, K.A., and K.S. Rogoff, 1995, "Perspectives on PPP and Long Run Real Exchange Rates," In G. M. Grossman and K.S. Rogoff, eds., *Handbook of International Economics,* III (Amsterdam: North-Holland).

Imbs, J., Ravin Mumtaz, M. and H.Rey, 2005, "PPP strikes Back: Aggregation and the Real Exchange Rate," *Quarterly Journal of Economics,* 120, 1-43.

Im, Kyung So, M. Hashem Pesaran, and Yongcheol Shin, 2003, "Testing for Unit-Root in Heterogeneous Panels," *Journal of Econometrics,* 115, 53-74.

Kim, Yoonbai, 1990, "Purchasing Power Parity in the Long Run: A Cointegration Approach." *Journal of Money, Credit, and Banking*, 22(4), 491-503.

Levin, Andrew, Chien-Fu Lin, and Chia-Shang James Chu, 2002, "Unit-Root Test in Panel Data: Asymptotic and Finite Sample Properties", *Journal of Econometrics,* 108, 1-24.

Lothian, James R., 1997, "Multi-Country Evidence on the Behavior of Purchasing-Power Parity under the Current Float," *Journal of International Money and Finance,* 16(1), 19-35.

Lothian, James R. and Mark Taylor, 1996, "Real Exchange Rate Behavior: The Recent

Float from the Perspective of the Past Two Centuries," *Journal of Political Economy,* 104(3), 488-509.

Meese, R. and K.S. Rogoff, 1988, "Was it Real? The Exchange rate-Interest Rate Differential Relation over the Modern Floating –Rate Period," *Journal of Finance*, 37, 933-948.

Murray, Christian J. and David H. Papell, 2002, "The Purchasing Power Parity Persistence Paradigm", *Journal of International Economics*, 56, 1-19.

Oh, Keun-Yeob, 1996, "Purchasing-Power Parity and Unit-Root Tests using Panel Data," *Journal of International Money and Finance,* 15(3), 405-418.

Rogoff, Kenneth, 1996, "The Purchasing Power Parity Puzzle," *Journal of Economic Literature,* 34(2), 647-668.

Rossi, B., 2005, "Confidence Intervals for Half-life Deviations from Purchasing Power Parity," *Journal of Business and Economic Statistics*, 23(4), 432-442.

Summers, Lawrence and Allen Heston, 1991, "The Penn World Table Mark 5: An Expanded Set of International Comparisons, 1950-1988," *The Quarterly Journal of Economics*, 106(2), 327-368.

Taylor, A.M., 2001, "Potential Pitfalls for the Purchasing Power Parity Puzzle? Sampling and Specification Biases in Mean-Reversion Tests of the Law of One Price," *Econometrica,* 69(2), 473-498.

Taylor, Alan, 2002, "A Century of Purchasing Power Parity," *The Review of Economics and Statistics,* 84(1), 139-150.

Wu, Yangru, 1996, "Are Real Exchange Rates Nonstationary? Evidence from a Panel-Data Test," *Journal of Money, Credit and Banking,* 28(1), 54-63.

Wu, Jyn-Lin, Shaowen Wu, 2001, "Is Purchasing Power Parity Overvalued?," *Journal of Money, Credit and Banking,* 33(3), 804-812.