E C O N O M I C S B U L L E T I N

A Century of Purchasing Power Parity: Further Evidence

Mohsen Bahmani-Oskooee
University of Wisconsin-Milwaukee

Ali Kutan
Southern Illinois University-Edwardsville

Su Zhou
University of Texas at San Antonio

Abstract

Since the publication of Taylor's (2002) results supporting Purchasing Power Parity (PPP) theory using a century of data, several authors have tried to verify PPP using the same data set. While one study has rejected Taylor's strong conclusion, others have supported it. In this paper we use yet a different unit root testing procedure to determine whether Taylor's results are sensitive to switching the null hypothesis of stationarity with the alternative of non-stationarity. More precisely, we rely upon Kwiatkowski, et al. (1992) test and apply it to the real bilateral and real effective exchange rates of 20 countries in Taylor's sample. The results provide support for PPP in 18 of the 20 countries that are much closer to Taylor's findings than any other study.

Citation: Bahmani-Oskooee, Mohsen, Ali Kutan, and Su Zhou, (2007) "A Century of Purchasing Power Parity: Further Evidence." *Economics Bulletin*, Vol. 6, No. 31 pp. 1-9
Submitted: February 28, 2007. **Accepted:** August 14, 2007.
URL: http://economicsbulletin.vanderbilt.edu/2007/volume6/EB-07F30005A.pdf

I. Introduction

Since the introduction of unit-root tests, Purchasing Power Parity (PPP) theory has received a renewed attention. A common test applied by many researchers to determine whether real exchange rates are stationary, is the application of well-known Augmented Dickey-Fuller (ADF) test. Majority of the studies that applied the ADF test to validate the PPP were unsuccessful. The lack of success has been attributed either to low power of the ADF test or short span of data in terms of length or period of analysis but not in terms of frequency. To address at least one of these two shortcomings, recently Taylor (2002) employed a century of data from 20 countries in testing PPP. Taylor employed two measures of real exchange rate for each country and tested for their stationarity by the means of Dickey-Fuller (DF)-Generalized-Least-Squares (GLS) test of Elliott, Rothenberg and Stock (1996), rather than the standard ADF test. One measure of exchange rate was defined as the real bilateral exchange rate for each country against the U.S. dollar and the other one was the effective exchange rate for each country against "world" basket of currencies. The results that were not sensitive to definition of the real exchange rate provided strong support for PPP. Based on the supportive results Taylor concluded that "If PPP holds in the long run, it is no longer productive to devote further attention to the stationarity question" (p. 144).

Since the publication of Taylor's (2002) article three other papers have employed Taylor's data set and have tried to verify his findings. Lopez, Murray and Papell (2005) criticized Taylor's results on the ground that he did not employ any criterion in selecting optimum number of lags in applying unit root tests. After extending Taylor's data set by two more years through 1998, Lopez *et al.* employed lag selection criteria that was based on a general-to-specific method of Hall (1994) for ADF tests and a modified Akaike Information Criterion of Ng and Perron (2001) for DF-GLS tests. By relying only upon the stationarity of the bilateral real exchange rates of industrial countries in Taylor's sample, they found support for PPP in 9 out of 16 cases. Based on these findings they concluded that "We do not see how finding evidence of PPP for one more than half of the countries justifies describing the 20th century as a 'A Century of Purchasing Power Parity' (Lopez *et al*., 2005, p. 362)".

The standard ADF tests used by Taylor (2002) and Lopez *et al*. (2005) assume that adjustment of real exchange rates is in a linear fashion. However, a century of data includes two Wars and the Great Depression period which may introduce structural breaks into the relation between nominal exchange rate and relative prices. When data is subject to structural break, the adjustment could be non-linear in nature which requires application of non-linear unit root tests. [1] Bahmani-Oskooee *et al.* (2006a) address the issue of non-linearity and employ and alternative test suggested by Kapetanios, Shin and Snell (2003) who developed a new technique for the null hypothesis of a unit root against an alternative of nonlinear stationary smooth transition autoregressive (STAR) process.[2] After including all developed and three developing countries

[1] Non-linearity in real exchange rates could also be caused by transactions costs in international arbitrage. Transaction costs are said to create band of no arbitrage for the real exchange rate. For different transaction costs see Bahmani-Oskooee and Das (1985).

[2] Hasan (2004), Liew *et al*. (2004), and Bahmani-Oskooee *et al.* (2006b) have applied the non-linear unit root test to the bilateral real exchange rates of India, Japan, and a group of Asian countries, respectively.

used in Taylor (2002) in their analysis, Bahmani-Oskooee *et al*. (2006a) show that non-linear unit root test validates PPP in 16 of 19 countries in the sample, hence supporting Taylor.

Finally, Taylor's results were further confirmed by Wallace and Shelley (2006) who used a different methodology than applying unit-root tests to real exchange rates. They basically relied upon Fisher and Seater (1993) method according to which in the regression of nominal exchange rate on the relative prices, the slope coefficient should converge to unity within a confidence interval as observations are increased in the sample. Indeed, when this method was applied, in majority of the cases the coefficient obtained for price level satisfied Fisher and Seater's criterion for convergence, providing support for Taylor and PPP in majority of the cases.[3]

As the above review shows, two of the papers trying to verify Taylor's results have used linear ADF (Lopez *et al*. 2005) and non-linear ADF (Bahmani-Oskooee *et al*. 2006a) tests. One common feature of these tests is that they both test the null of unit root or non-stationarity against an alternative of stationarity. We wonder if the results would change if we switch the null with the alternative. Indeed, such a test which is said to have relatively more power is developed by Kwiatkowski *et al.* (1992), also known as KPSS test. It assumes the null to be stationarity of a variable and the alternative to be a unit root. Therefore, in this paper we try to verify Taylor's support for PPP by applying the KPSS test to the real exchange rate data of all countries included in Taylor. The results could be best summarized by saying that KPSS test supports PPP in almost 90% of the cases. To show this, we introduce the KPSS test in Section II and present the results in Section III. A summary is provided in Section IV.

II. The Method[4]

As indicated in the previous section, in this section we introduce a unit-root testing procedure in which the null hypothesis is stationarity of a time series variable and the alternative hypothesis is non-stationarity or a unit root of the same variable. Let the variable in question be the real exchange rate denoted by REX_t. Kwiatkowski *et al.* (1992) show that such a time-series variable could be decomposed into the sum of a deterministic trend (T), a random walk R_t, and a stationary error ε_t as in (1):

$$REX_t = \text{a T} + R_t + \varepsilon_t \qquad (1)$$

Where R_t is assumed to follow a random walk process that can be specified as follows:

$$R_t = R_{t-1} + u_t \qquad (2)$$

where u_t is a random error term. They then demonstrate that we can test for stationarity of REX_t by testing whether the variance of u_t is equal to zero, i.e., $\sigma_u^2 = 0$. To test whether $\sigma_u^2 = 0$ the residuals (call them e_t) from the regression of REX_t on a constant term (for testing the null of level

[3] Note that rather than regressing nominal exchange rate on relative prices, Wallace and Shelley (2006) regressed nominal exchange rate adjusted by the domestic price level on the foreign price level and showed that the coefficient obtained for the foreign price level converges to unity within 95% confidence intervals as observations are updated. This approach was mostly due to the fact that for some periods and in some countries the nominal exchange rate was fixed and the adjustment by domestic price level introduces some variability in the dependent variable.

[4] This section closely follows Bahmani-Oskooee (1998).

stationarity) or on a constant term and a trend term (for testing the null of trend stationarity) are used to form the following KPSS statistic:[5]

$$T^{-2} \Sigma S_t^2 / s^2(\ell) \qquad (3)$$

where $S_t = \sum_{i=1}^{t} e_i$ and $s^2(\ell) = T^{-1} \sum_{t=1}^{T} e_t^2 + 2\, T^{-1} \sum_{s=1}^{\ell} w(s, \ell) \sum_{i=s+1}^{T} e_t e_{t-s}$. Note that we follow KPSS and use the Bartlett window in our analysis where $w(s, \ell) = 1 - s/(\ell + 1)$.

III. The Results

In this section we apply the KPSS test for each country in Taylor's (2002) sample using two different definitions of the real exchange rate. One rate is defined to be the real bilateral exchange rate using the U.S. dollar as base currency and the other is a concept similar to real effective exchange rate. Taylor's data set consists of annual nominal exchange rates and price levels, each for over 100 years, through 1996 for 20 countries.[6] The nominal exchange rates, E_{it}, are measured as domestic currency units per U.S. dollar and the price levels, P_{it}, are consumer price deflators or, if not available, GDP deflators. Following Taylor (2002), 19 real exchange rates relative to the U.S. dollar are generated as $q_{it} = r_{it} - r_{US,t}$, where $r_{it} = \log P_{it} - \log E_{it}$. Twenty real exchange rates relative to the "world" basket of currencies are constructed by $q_{it}^W = r_{it} - r_{it}^W$, where $r_{it}^W = \sum_{j \neq i} r_{jt} \big/ (N-1)$ and $N = 20$. The results of KPSS test at different truncation lag, ℓ, applied to real bilateral exchange rates against the U.S. dollar and against "world" basket are reported in Tables 1 and 2, respectively.

Tables 1 and 2 go about here

In each table there are two panels. The first panel reports the results for the null of level stationarity and the second panel reports the results for the null of trend stationarity. As a general rule if our calculated KPSS statistic is less than the 5% critical value, the null of stationarity cannot be rejected, implying that PPP is supported. We identify these cases by a * at the shortest possible truncation lag. From Table 1, Panel A we gather that PPP is supported only in 10 countries. The list includes Argentina, Brazil, Finland, Germany, Italy, Netherlands, Norway, Portugal, Spain and the U.K. When we shift to Panel B and consider the null of trend stationarity, now there are 11 countries in which PPP is validated. Putting both panels together, PPP is supported in 14 countries at least by one of the KPSS test statistics. The list includes the 10 countries mentioned above plus Belgium, Mexico, Sweden and Switzerland.

Let us now consider the results in Table 2. From Panel A we gather that only in seven countries (i.e., Argentina, Brazil, Finland, Germany, Italy, Norway and U.S.) the null of level stationarity of real effective exchange rate is not rejected, providing support for PPP. However, when we move to Panel B, number of countries in which PPP is supported more than doubles to 15. Once again, putting the two panels together, PPP is supported in 16 countries at least by one of the KPSS statistics. The list includes all 20 countries except Canada, Japan, Portugal and Spain. However, since PPP was supported in Panel A of Table 1 for Portugal and Spain, putting all four panels together, we are safe to conclude that PPP is supported in 18 of 20 countries at

[5] Outlined by equation (13) in Kwiatkowski, *et al*. (1992) on page 165.

[6] We are grateful to Alan Taylor for providing us his data set. See Table 1 for list of countries.

least by one of the four KPSS statistics with either the bilateral real exchange rates against the U.S. dollar or the real effective exchange rates, a result very close to Taylor's (2002) conclusion.[7]

IV. Summary and conclusion

In a recent article Taylor (2002) applied unit-root tests to a century of data on real bilateral and real effective exchange rates of 20 countries and provided strong support for Purchasing Power Parity (PPP) theory. Based on his findings, he concluded that "PPP has held in the long run over the twentieth century for my sample of 20 countries".[8] Since its publication, a few studies have tried to verify Taylor's findings. Lopez *et al.* (2005) criticized Taylor's results by pointing out that Taylor did not use any criterion in selecting optimum lags in the standard ADF test. They then used a criterion to select the optimum number of lags in the ADF test and were unable to come close to Taylor's results. However, Bahmani-Oskooee *et al.* (2006a) who employed a non-linear ADF test rather than the standard ADF test, provided support for PPP in most cases. Support for Taylor's results that PPP holds in majority of the countries in his sample was also provided by Wallace and Shelley (2006) who showed that in the regression of nominal exchange rate (adjusted by domestic price level) on foreign price level, the coefficient on the foreign price level converges to unity as observations increase over time in the long run.

Both the linear and non-linear ADF tests assume that the null hypothesis to be tested is non-stationarity of a variable and the alternative is stationarity. In this paper we try to determine how sensitive Taylor's results are to switching the null with the alternative. To this end, we rely upon a unit root test developed by Kwiatkowski *et al*. (1992) known as the KPSS test in which the null is stationarity of a time-series variable and the alternative is non-stationarity. Although the results were somewhat sensitive to the base currency, overall we find support for PPP in 18 of the 20 countries.

[7] Our results indicate that in some cases support for PPP depends on the choice of base currency. This is in line with Papell and Theodoridis (2001) and Coe and Serletis (2002).

[8] Taylor (2002, p. 144).

References

Bahmani-Oskooee, M., 1998. "Do Exchange Rates Follow a Random Walk Process in Middle Eastern Countries?" *Economics Letters,* 58, pp. 339-344.

Bahmani-Oskooee, M and Das, S. 1985. Transaction Costs and Interest Parity Theorem. *Journal of Political Economy*, 93, pp. 793-799.

Bahmani-Oskooee, Mohsen, Kutan, Ali M. and Zhou, Su, 2006a. "A Century of PPP: Supportive Results from Non-linear Unit Root Tests", memo.

Bahmani-Oskooee, Mohsen, Kutan, Ali M. and Zhou, Su, 2006b. "Testing PPP in the Non-linear STAR Framework", *Economics Letters,* forthcoming.

Coe, P.J., and A. Serletis, 2002. "Bounds Tests of the Theory of Purchasing Power Parity", *Journal of Banking and Finance*,, pp. 179-199.

Elliott, G., Rothenberg, T., Stock, J. H. 1996. Efficient Tests for an Autoregressive Unit Root. *Econometrica* 64, pp. 818-836.

Fisher, M.E., Seater, J.J., 1993. Long Run Neutrality and Superneutrality in an ARIMA Framework. *American Economic Review*, 83, pp. 402-415.

Hall, A., 1994. Testing for a Unit Root in Time Series with Pretest Data-based Model Selection. *Journal of Business and Economic Statistics* 12, pp. 461-470.

Hasan, M.S.,2004. "Univariate Time Series Behaviour of the Real Exchange Rate: Evidence from Colonial India", *Economics Letters*, 84, Issue 1, pp. 75-80

Kapetanios, G., Shin, Y., Snell, A., 2003. "Testing for a Unit Root in the Nonlinear STAR Framework", *Journal of Econometrics* 112(2), pp. 359-379.

Kwiatkowski, Denis; Peter C.B. Phillips; Peter Schmidt and Yongcheol Shin, 1992. "Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root", *Journal of Econometrics*, 54, pp. 159-178.

Liew , V. K. , A. Z. Baharumshah and T. T. Chong. 2004. "Are Asian Real Exchange Rates Stationary?" *Economics Letters*, 83 (3), pp. 313-316.

Lopez, C., Murray, C. J., Papell, D.H. 2005. State of the Art Unit Root Tests and Purchasing Power Parity. *Journal of Money, Credit and Banking* 37(2), pp. 361-369.

Ng, S., Perron, P, 2001. Lag length selection and the construction of unit root tests with good size and power. *Econometrica* 69, pp. 1519-1554.

Papell, D. H. and H. Theodoridis, 2001. The Choice of Numeraire Currency in Panel Tests of Purchasing Power Parity. Journal *of Money, Credit, and Banking*, pp. 790-803.

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

Wallace, F.H. and G.L. Shelley. 2006. An Alternative Test of Purchasing Power Parity, *Economics Letters,* 92, pp. 177-183.

Table 1: The KPSS Test Results for Real Bilateral Exchange Rates against U.S. Dollar									
Panel A:	**The KPSS Statistic for the Null of Level Stationarity**								
	Lag Truncation Parameter								
Country	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Argentina	0.25*	0.19	0.17	0.16	0.15	0.15	0.14	0.14	0.13
Australia	2.76	1.92	1.50	1.25	1.08	0.96	0.87	0.79	0.73
Belgium	1.74	1.28	1.05	0.91	0.82	0.76	0.71	0.67	0.64
Brazil	0.31*	0.22	0.17	0.15	0.13	0.11	0.11	0.10	0.09
Canada	2.00	1.43	1.15	0.98	0.87	0.80	0.73	0.69	0.65
Denmark	1.66	1.17	0.93	0.78	0.69	0.62	0.57	0.53	0.50
Finland	0.37*	0.30	0.26	0.25	0.23	0.23	0.22	0.21	0.21
France	2.60	1.85	1.48	1.26	1.10	0.99	0.90	0.83	0.77
Germany	1.13	0.79	0.61	0.51	0.45*	0.40	0.37	0.35	0.33
Italy	0.18*	0.13	0.10	0.09	0.08	0.08	0.07	0.07	0.07
Japan	4.36	2.96	2.27	1.85	1.57	1.37	1.22	1.10	1.01
Mexico	2.60	1.86	1.47	1.24	1.08	0.96	0.87	0.81	0.75
Netherlands	1.23	0.86	0.68	0.57	0.49	0.44*	0.40	0.37	0.35
Norway	1.08	0.76	0.61	0.52	0.46	0.42*	0.39	0.36	0.34
Portugal	1.50	1.06	0.84	0.71	0.62	0.56	0.51	0.47	0.44*
Spain	1.04	0.73	0.58	0.49	0.43*	0.38	0.35	0.32	0.30
Sweden	1.98	1.42	1.14	0.97	0.86	0.78	0.73	0.68	0.65
Switzerland	3.22	2.23	1.73	1.43	1.23	1.09	0.98	0.90	0.83
UK	1.31	0.94	0.75	0.64	0.57	0.52	0.48	0.44*	0.42
Panel B:	**The KPSS Statistic for the Null of Trend Stationarity**								
Country	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Argentina	0.13*	0.10	0.09	0.09	0.08	0.08	0.08	0.07	0.07
Australia	0.45	0.32	0.26	0.22	0.20	0.18	0.17	0.15	0.15
Belgium	0.15	0.11*	0.09	0.08	0.08	0.08	0.07	0.07	0.07
Brazil	0.31	0.22	0.17	0.15	0.13*	0.11	0.11	0.10	0.09
Canada	0.43	0.31	0.26	0.22	0.20	0.19	0.18	0.17	0.17
Denmark	0.56	0.40	0.32	0.27	0.24	0.22	0.21	0.20	0.19
Finland	0.12*	0.10	0.09	0.08	0.08	0.08	0.08	0.07	0.07
France	0.60	0.45	0.37	0.33	0.30	0.28	0.26	0.25	0.24
Germany	0.16	0.11*	0.09	0.07	0.06	0.06	0.05	0.05	0.05
Italy	0.15	0.11*	0.09	0.08	0.07	0.07	0.06	0.06	0.06
Japan	0.70	0.48	0.38	0.32	0.27	0.24	0.22	0.20	0.19
Mexico	0.15	0.11*	0.09	0.08	0.07	0.06	0.06	0.06	0.06
Netherlands	0.56	0.39	0.31	0.26	0.22	0.20	0.19	0.17	0.16
Norway	0.39	0.28	0.22	0.19	0.17	0.16	0.14*	0.14	0.13
Portugal	0.56	0.40	0.32	0.28	0.25	0.22	0.21	0.19	0.18
Spain	0.52	0.36	0.29	0.24	0.21	0.19	0.18	0.16	0.15
Sweden	0.15	0.11*	0.09	0.08	0.07	0.07	0.07	0.07	0.07
Switzerland	0.42	0.30	0.24	0.21	0.18	0.17	0.15	0.14*	0.14
UK	0.29	0.21	0.17	0.15	0.13*	0.12	0.11	0.11	0.10

Notes: The critical value of the KPSS statistic at the 5% level of significance for level stationarity is 0.46. The comparable figure for trend stationarity is 0.15. * denotes failure to reject the null at the 5% significance level with a shorter truncation lag length.

Table 2: The KPSS Test Results for Effective Exchange Rates									
Panel A: The KPSS Statistic for the Null of Level Stationarity of REERs									
	Lag Truncation Parameter								
Country	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Argentina	0.46	0.37*	0.34	0.32	0.31	0.30	0.29	0.28	0.27
Australia	3.02	2.14	1.70	1.44	1.26	1.14	1.04	0.96	0.90
Belgium	1.81	1.34	1.10	0.96	0.86	0.79	0.74	0.69	0.66
Brazil	0.34*	0.24	0.19	0.16	0.14	0.12	0.11	0.10	0.10
Canada	1.77	1.26	1.01	0.86	0.77	0.69	0.64	0.59	0.56
Denmark	1.35	0.98	0.81	0.72	0.66	0.62	0.59	0.56	0.53
Finland	0.09*	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06
France	3.11	2.22	1.78	1.51	1.34	1.21	1.11	1.02	0.95
Germany	0.63	0.43*	0.33	0.28	0.24	0.21	0.19	0.18	0.17
Italy	0.22*	0.15	0.12	0.11	0.10	0.09	0.08	0.08	0.08
Japan	4.37	2.97	2.27	1.85	1.58	1.38	1.23	1.11	1.02
Mexico	3.16	2.27	1.79	1.49	1.28	1.13	1.01	0.92	0.84
Netherlands	1.78	1.23	0.96	0.80	0.69	0.61	0.55	0.50	0.47
Norway	0.58	0.41*	0.33	0.28	0.25	0.23	0.21	0.20	0.19
Portugal	3.01	2.13	1.69	1.41	1.21	1.06	0.95	0.86	0.79
Spain	2.04	1.40	1.08	0.89	0.77	0.67	0.60	0.55	0.50
Sweden	1.58	1.11	0.88	0.74	0.65	0.59	0.54	0.50	0.47
Switzerland	3.99	2.72	2.08	1.70	1.44	1.26	1.12	1.02	0.93
UK	2.80	1.94	1.50	1.25	1.07	0.95	0.85	0.78	0.72
US	0.67	0.48	0.39*	0.34	0.30	0.28	0.26	0.25	0.24
Panel B: The KPSS Statistic for the Null of Trend Stationarity of REERs									
Country	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Argentina	0.06*	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Australia	0.15	0.11*	0.09	0.08	0.08	0.07	0.07	0.07	0.07
Belgium	0.09*	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05
Brazil	0.35	0.24	0.19	0.16	0.14*	0.13	0.12	0.11	0.10
Canada	0.48	0.35	0.28	0.25	0.22	0.20	0.19	0.18	0.17
Denmark	0.21	0.16	0.13*	0.12	0.12	0.12	0.12	0.11	0.11
Finland	0.08*	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05
France	0.08*	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Germany	0.29	0.20	0.15	0.13*	0.11	0.10	0.09	0.08	0.08
Italy	0.22	0.15	0.12*	0.11	0.10	0.09	0.08	0.08	0.08
Japan	0.52	0.36	0.29	0.24	0.21	0.19	0.17	0.16	0.15
Mexico	0.27	0.20	0.17	0.15	0.13*	0.12	0.11	0.10	0.10
Netherlands	0.26	0.18	0.14*	0.12	0.11	0.09	0.09	0.08	0.08
Norway	0.36	0.26	0.21	0.18	0.16	0.14*	0.13	0.13	0.12
Portugal	0.48	0.36	0.30	0.26	0.24	0.21	0.20	0.18	0.18
Spain	0.56	0.39	0.31	0.26	0.22	0.20	0.18	0.16	0.15
Sweden	0.40	0.29	0.23	0.20	0.18	0.17	0.16	0.15	0.14*
Switzerland	0.31	0.22	0.17	0.15	0.13*	0.12	0.11	0.10	0.09
UK	0.36	0.26	0.20	0.17	0.15	0.13*	0.12	0.11	0.11
US	0.43	0.31	0.25	0.22	0.19	0.18	0.17	0.16	0.15

Notes: The critical value of the KPSS statistic at the 5% level of significance for level stationarity is 0.46. The comparable figure for trend stationarity is 0.15. * denotes failure to reject the null at the 5% significance level with a shorter truncation lag length.