Testing for Purchasing Power Parity Using Stationary Covariates

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We test for Purchasing Power Parity in post Bretton Woods real exchange rate data from twenty developed countries using univariate tests and covariate augmented versions of the Augmented Dickey-Fuller (CADF) and feasible point optimal (CPT) unit root tests. The covariates are a combination of stationary variables - inflation, monetary, income, and current account. We perform a cross method comparison of the results. We find very strong evidence of PPP using the CPT test, rejecting the unit root null for 12 out of the 20 countries at the 5% significance level or better, and 6 more at the 10% level. We find much less evidence of PPP with the CADF and univariate tests.

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1. Introduction

The question of whether Purchasing Power Parity (PPP), the concept that real exchange rates revert to a constant mean following a shock, holds during the post-1973 flexible exchange rate period has been the subject of voluminous research during the past decade. The question of PPP is intimately connected with the topic of testing for unit roots in economic time series. If the unit root hypothesis can be rejected in favor of a level stationary alternative, then the real exchange rate is mean reverting and PPP holds

The starting point for this research is that, using Augmented-Dickey-Fuller (ADF) tests, the unit root null is rarely rejected for industrialized countries with the United States dollar as the numeraire currency. For example, Cheung and Lai (2000), Wu and Wu (2001), and Papell (2002) report zero or one rejection, out of 20 industrialized countries, at the 5% significance level. One rejection out of 20 at the 5% level is, of course, what you would expect to find if the unit root null was true and the test was correctly sized.

Failure to find strong evidence of PPP in the post-1973 period is often attributed to the low power of unit root tests over short time spans of data. Frankel (1986), Lothian and Taylor (1996), and Taylor (2002), among many others, use long horizon data spanning one to two centuries. Although they find strong evidence of mean reverting real exchange rate behavior, the issue with using long horizon data is that, as has been noted many times, it combines both fixed and floating rate data and cannot answer the question of whether PPP holds for flexible exchange rate regimes.

Panel unit root tests, notably those of Levin, Lin, and Chu (2002) and Im, Pesaran, and Shin (1997), exploit cross section and time series variation of the data in order to increase the power of the tests. Although early studies using these tests produced mixed results, more recent work that incorporates data through 1997 or 1998, including Higgins and Zakrajsek (1999), Wu and Wu (2001), and Papell (2002), finds strong evidence of PPP for panels of industrialized countries with the U.S. dollar as numeraire.

One issue with panel root tests, however, is that rejection of the unit root null in favor of the level stationary alternative does not necessarily provide evidence that all individual currencies exhibit mean reversion. There are two variants of panel unit root tests. The first variant imposes a homogeneous speed of mean reversion, so that the null hypothesis is that all real exchange rates have unit roots and the alternative hypothesis is that all real exchange rates are stationary. As shown by Breuer, McNown and Wallace (2002), these tests are oversized for panels that contain a mix of stationary and unit root real exchange rates. The second variant allows for heterogeneous speeds of mean reversion. With these tests, the null hypothesis is that all real exchange rates have unit roots and the alternative hypothesis is that at least one of the real exchange rates is stationary. As shown by Bowman (1999), these tests are even more oversized than the tests with homogeneous mean reversion.[1]

Another strategy to address the low power of ADF tests is to use higher power univariate tests, most notable the Dickey-Fuller generalized least squares (DF-GLS) and the feasible point optimal (PT) tests developed by Elliott, Rothenburg and Stock (1996). These methods improve the power of the tests to reject the null of unit root without the need to either include data outside the floating exchange rate period or to use panels. The results of these tests when applied to post-1973 real exchange rates, however, have been modest at best. Cheung and Lai (2000), using DF-GLS tests, find only one rejection at the 5% level.[2]

In addition to higher power univariate tests, covariate tests have been developed that include correlated stationary variables in the regression equations. Testing for unit roots using stationary covariates relies on examining variables from the same regime and exploiting the economic correlation between these variables. Hansen (1995) develops the covariate augmented Dickey Fuller (CADF) test, a modification of the ADF test using covariates.[3] The test provides substantial power gains over the conventional ADF test. Elliott and Jansson (2001) extend Hansen's work by developing the covariate augmented feasible point optimal (CPT) test, and report similar power gains over the DF-GLS and

[1] Bowman (1999) shows that the tests with heterogeneous speeds of mean reversion have higher power for mixed panels. In the context of testing for PPP, however, higher power to reject the unit root null in favor of the alternative that at least one real exchange rate is stationary is the same as worse size for the alternative that all real exchange rates are stationary.
[2] They find rejections for France at the 5% level and Italy, Germany, Netherlands, Norway, and the United Kingdom at the 10% level.
[3] Caporale and Pittis (1999) use CADF to analyze U.S. macroeconomic data as in Nelson and Plosser (1982) and in most cases end up reversing the finding of a unit root.

PT tests. The combination of incorporating GLS detrending and stationary covariates results in very large power gains for the CPT test when compared to the ADF test.

The CADF and CPT tests can give very misleading results if the covariates are not stationary. We perform two checks for stationarity. First, using ADF and DF-GLS tests, we test the unit root null for our potential covariates: money supply growth; income growth; current account growth (relative to income); and inflation; both individually and relative the U.S. aggregate, and use only those variables for which the unit root null can be rejected. Second, we run the nominal, as well as the real exchange rate. Assuming that the nominal (dollar) exchange rate has a unit root, a rejection with the CADF or CPT tests would be due to a spurious regression, and the covariate would not be stationary. We therefore do not count rejections with both nominal and real exchange rates as evidence against the unit root null.

We use univariate and covariate unit root tests on quarterly U.S. dollar real exchange rates from 1973 to 1998 to investigate PPP over the post Bretton-Woods flexible exchange rate regime.[4] In order to provide comparability with previous studies, we first run univariate tests. The results are not surprising. The unit root null can be rejected at the 5% significance level for 1, 3, and 4 countries with the ADF, DF-GLS, and PT tests, respectively. Allowing for weaker rejections, the null can be rejected at the 10% (or higher) significance level for 4, 12, and 8 countries with the ADF, DF-GLS, and PT tests. While the number of rejections is greater with the higher power DF-GLS and PT tests, the difference is mostly in the weak rejections at the 10% significance level.

The results do not improve with the CADF test. The unit root null can be rejected at the 5% significance level for 2 countries, and for 2 additional countries at the 10% level. These results are weaker than the results with the ADF, DF-GLS and PT tests. Using the PT test, the unit root null can be rejected at the 5% significance level for 4 of the 20 countries. Combining the PT test with the ADF and DF-GLS tests produces no additional rejections, and including the CADF test adds no rejections. In total, these tests provide rejections at the 5% level for only one-quarter of the countries.

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[4] The time period for the data is not extended beyond 1998 when the Euro was adopted and the nominal exchange rates within the Eurozone fixed.

We find much stronger results using the CPT test. The unit root null can be rejected at the 5% significance level for 12 of the 20 countries, and for 6 additional countries, Australia, Denmark, France, Germany, Japan, and Sweden, at the 10% level. Canada and Belgium are the only two countries for which there is no evidence against the unit root hypothesis in real exchange rates.

Elliott and Pesavento (2004) run ADF, DF-GLS, PT, and CPT tests on quarterly U.S. dollar real exchange rates for 15 industrialized countries from 1973 to 2003, and reject the unit root null in most cases with CPT tests. For countries in the European Union, the end of sample is 1998. They do not conduct CADF tests. This study surveys the univariate and covariate unit root tests used to investigate PPP and applies them to the post Bretton-Woods flexible exchange rate regime. This allows for a cross method comparison of results, and demonstrates that evidence of PPP with this data is not an artifact of the use of covariate tests, but is a consequence of the increased power of the CPT tests over both the univariate and the CADF tests.

2. Univariate and Covariate Tests

2.1 Univariate Methods

The first univariate test is the ADF test, which regresses the first difference of the logarithm of the real exchange rate data on a constant, the lagged level of the real exchange rate, and *k* lagged first-differences to account for serial correlation:
The ADF test takes the form:

$$q_t = \mu + \alpha q_{t-1} + \sum_{i=1}^{k} c_i \Delta q_{t-i} + \varepsilon_t$$

The null hypothesis of a unit root is rejected in favor of the alternative of level stationarity if α is significantly different from one. The value of *k* is selected using the recursive t-statistic procedure proposed by Hall (1994) – general-to-specific selection starting at a maximum value of *k* equal to 8. The ten percent value of the asymptotic normal distribution is used to determine significance (t = 1.645). Ng and Perron (1995) show that the recursive t-statistic procedure has better size and power properties than alternative procedures such as AIC and BIC methods for selecting *k*. The critical values are calculated using MacKinnon (1991) and adjusting for the sample size.

The second univariate test is the DF-GLS test, where local to unity GLS detrending of the data is used to improve power. For a series $\{q_t\}_{t=0}^{T}$, the GLS detrended series is

$\tilde{q}_t = q_t - \hat{\psi} Z_t$ where

$\hat{\psi} = (\sum Z_t^{\bar{\alpha}})^{-2} \sum Z_t^{\bar{\alpha}} q_t^{\bar{\alpha}}$,

$(q_0^{\bar{\alpha}}, q_t^{\bar{\alpha}}) = (q_0,(1-\bar{\alpha} L)q_t)$ for t = 1,…T, ,

and $(Z_0^{\bar{\alpha}}, Z_t^{\bar{\alpha}}) = (1,(1-\bar{\alpha} L) Z_t)$ where $Z_t = 1$

The DF-GLS statistic is the t statistic for testing $\beta_0 = 0$ from the following OLS regression:

$$\Delta\tilde{q}_t = \beta_0 \tilde{q}_{t-1} + \sum_{j=1}^{k} \beta_j \Delta\tilde{q}_{t-j} + \varepsilon_{tk}$$

The third univariate test is the point optimal test, PT, a univariate test developed by Elliot, Rothenburg, and Stock (1996) that yields substantial power gains over the ADF test by local to unity GLS detrending of the data. The point optimal test statistic is:

$P_T = [S(\bar{\alpha}) - \bar{\alpha} S(1)]/ s_{AR}^2$ where

$\bar{\alpha} = 1 + c/T$ and c = -7 for no time trend in exchange rate data.

$S(\bar{\alpha})$ and S(1) are the sum of squared residuals from two constrained GLS regressions of q, the real exchange rate, on Z. The first regression imposes $\alpha = \bar{\alpha}$ and the second, $\alpha = 1$. s_{AR}^2 is an autoregressive estimate of the spectral density at frequency zero.

For a series $\{q_t\}_{t=0}^{T}$, the GLS detrended series is $\tilde{q}_t = q_t - \hat{\psi} Z_t$ where

$\hat{\psi} = (\sum Z_t^{\bar{\alpha}})^{-2} \sum Z_t^{\bar{\alpha}} q_t^{\bar{\alpha}}$,

$(q_0^{\bar{\alpha}}, q_t^{\bar{\alpha}}) = (q_0,(1-\bar{\alpha} L)q_t)$ for t = 1,…T, ,

and $(Z_0^{\bar{\alpha}}, Z_t^{\bar{\alpha}}) = (1,(1-\bar{\alpha} L) Z_t)$ where $Z_t = 1$

The null hypothesis for PT is $\alpha = 1$ and the alternative is $\alpha = \bar{\alpha}$. The lag selection method is the modified AIC (MAIC) recommended by Ng and Perron (2001) that results in substantial size improvements over other selection methods. The maximum for the lag length starts at 8. The asymptotic critical values are those reported by the same authors.

2.2 Covariate Methods

To improve on the power of univariate tests, Hansen (1995) developed the covariate augmented Dickey Fuller (CADF) test.[5] The improvements in power are achieved by adding related stationary covariates and exploiting the information contained in the covariates. The covariate tests increase power by modeling correlated stationary economic variables with the dependent variable. The use of stationary covariates results in a new error variance that is smaller that the error variance of a univariate time series. This results in smaller confidence intervals and more powerful test statistics than those of the conventional unit root tests. Hansen essentially uses the augmented Dickey Fuller test and adds covariates to increase power. For real exchange rate q, and stationary covariates x, and allowing for a constant and no time trend, CADF takes the following form:

$$\Delta q_t = \mu + \alpha q_{t-1} + \sum_{i=0}^{k} \alpha_i \Delta q_{t-i} + \sum_{i=0}^{p} \beta_i \Delta x_{t-i} + \varepsilon_t$$

The value of the lag length, k for the exchange rate, is selected using Schwartz Bayesian information criterion (BIC). The null tested is $\alpha = 0$, for the presence of a unit root. The ρ^2 value, a nuisance parameter, represents the contribution of the covariate in explaining the movements of the exchange rate. A value of $\rho^2 = 0$ indicates perfect correlation and a value of $\rho^2 = 1$ indicates no correlation. The distribution of the critical values depend on the value of ρ^2. The critical values used are the values reported by Hansen (1995) in Table 1 for ρ^2 from .1 to 1 in .1 increments with intermediate values derived by interpolation. The assumption of stationarity is essential for the covariates. If the covariates are not stationary, the asymptotic distribution derived for the t statistic in

[5] Chang, Sickles, and Song (2001) apply CADF to covariates from the extended Nelson-Plosser data set for the post 1929 samples as well as postwar annual CPI based real exchange rates for 14 OECD countries.

Table 1 will not hold. Economic theory is used a guideline in selecting appropriate covariates.

The second covariate method is that developed by Elliott and Jansson (2000). This method, the covariate point optimal test (CPT) has greater power than the CADF. It essentially builds on the power gains of the point optimal test (PT) and adds covariates to further improve power. As in CADF, the covariates are assumed to be stationary. For the exchange rate, q, and stationary covariates x, the model is:

$Z_t = \beta_0 + \mu_t$

$Z_t = \begin{pmatrix} q_t \\ x_t \end{pmatrix}$

$\beta_0 = \begin{pmatrix} \beta_{q0} \\ \beta_{x0} \end{pmatrix}$

With

$A(L)\begin{pmatrix} (1-\rho L)\mu_{q,t} \\ \mu_{x,t} \end{pmatrix} = e_t$

Where A(L) is a finite polynomial of order k in the lag operator L. K is selected using BIC.

The test statistic for CPT is

$CPT(1,\bar{\rho}) = T(tr[\tilde{\Sigma}(1)^{-1}\tilde{\Sigma}(\bar{\rho})] - (m+\bar{\rho}))$ where

$\bar{\rho} = 1 + \bar{c}/T$ and $\bar{c}$ = -7 for the case without time trend and m is the number of covariates used. The variance covariance matrices of the residuals are constructed by detrending the data under the null and alternative, $\rho = (1, \bar{\rho})$ and running a VAR under the null and alternative.

The test for the null is $\rho = 1$ for a unit root, with the alternate $\rho = \bar{\rho}$ implying stationarity. The R^2 value represents the contribution of the covariate in explaining the movements of the exchange rate. A value of $R^2 = 1$ indicates perfect correlation and a value of $R^2 = 0$ indicates no correlation. The distribution of the critical values depends on R^2. The critical values used are the values reported by Elliott and Jansson (2000) in Table 1 for R^2 from .1 to .9 in .1 increments with intermediate values derived by interpolation. Again, the assumption of stationarity for the covariates is essential. If the covariates are not stationary, the asymptotic distribution derived for the t-statistic in Table 1 of Elliott and Jansson (2000) will not hold.

The CADF and CPT tests are run for both real and nominal exchange rates. The real exchange rate is the variable of interest in testing for PPP. Following Elliott and Pesavento (2004), tests are also run for nominal exchange rates for test validation and as an indication of the test behavior. It is generally accepted that, as an asset price, the nominal exchange rate contains a unit root. If the covariate test with the nominal exchange rate rejects the unit root null, indicating that the nominal exchange rate is stationary, the covariate becomes suspect and the corresponding rejection using real exchange rates is disregarded.

Our testing procedure can be summarized as follows: First, we test the covariates for stationarity. Second, using only those covariates for which the unit root null can be rejected, we run covariate augmented tests for both real and nominal exchange rates. We find evidence of stationarity for a real exchange rate only if, for a given covariate, the unit root null *can* be rejected for the real exchange rate and the unit root null *cannot* be rejected for the nominal exchange rate.

3. Empirical Results

The data used to test the unit root hypothesis is the quarterly, nominal, average of period exchange rate data for twenty industrialized countries. The data for Iceland and Luxemburg is not used because of the gaps in Iceland CPI and the monetary union between Luxemburg and Belgium. The data is from the International Monetary Fund's *International Financial Statistics* September 2002. The data starts in the first quarter of 1973 and ends in the fourth quarter of 1998 for a total of 104 quarterly observations. The U.S. dollar is used as the numeraire currency. We do not extend the data past 1998 because the national currencies of about half of the countries were eliminated with the establishment of the Euro.

The real dollar exchange rate is calculated as

$$q = e + p^{*} - p$$

where q is the logarithm of the real exchange rate, e is the logarithm of the nominal (dollar) exchange rate, p^* is the logarithm of the U.S. CPI, and p is the logarithm of the domestic CPI for each country. For Greece and Ireland, some of the data used to construct covariates are not available and, in that case, the associated covariate test is not calculated.

With the ADF test, there is little evidence against the unit root hypothesis. Of the twenty countries in the sample, we reject the unit root null for one country, New Zealand, at the 5% level and for three additional countries, Norway, Sweden, and Finland, at the 10% level. This is comparable to earlier results. Wu and Wu (2001) reject the unit root null only for Sweden at the 5% level and Papell (2002) rejects only for the United Kingdom at the 5% level. While Cheung and Lai (1998) find no rejections for the 20 industrialized countries, they use the AIC as the lag selection method resulting in lower lag lengths, and ADF tests have low power when the lag length is low. Table 1 presents the results of all the univariate tests.

Reflecting the higher power of the DF-GLS test, we find greater evidence against the unit root using DG-GLS than ADF. We reject the unit root null for a total of 12 countries, three at the 5% level and nine more at the 10% level. In contrast, Cheung and Lai (1998) using monthly data reject only for five countries. However, the sample period they use is shorter, April 1973 to December 1994, and the lag selection criterion is AIC, resulting in lower lag lengths than using MAIC. These two factors would affect the power of the test. The results using the PT test are similar to those obtained using the DF-GLS test. The unit root null is rejected for a total of eight countries, four at the 10% level and four more at the 5% level.

The choice of covariates to use for the CADF and CPT tests is motivated by Elliott and Pesavento (2004) and Jansson (2002) with the analysis extended to twenty countries. Since the only restriction for choice of covariates is stationarity, Elliott, Pesavento, and Jansson justify their choice based on stationarity and economic theory. If the covariates have unit root or near unit root behavior they will be spuriously correlated with the real exchange rates and cause an over rejection of the null.

Economic models suggest the existence of a correlation between monetary variables and the real exchange rates. Dornbush (1976) indicates that a monetary expansion will result in the depreciation and subsequent appreciation of the real exchange rate. Obstfeld and Rogoff (1995) show that monetary shocks can lead to current account imbalances that affect exchange rates. Thus the exchange rate functions as a channel for monetary policy. Since the money supply is generally (although not universally) considered to be I(1), we use the growth rate of the U.S. money supply Δm_{us} and the growth rate of the home country money supply Δm_h as covariates.

Following Balassa (1964) and Samuelson (1964), countries with high productivity in traded goods relative to non-traded goods grow faster and are often thought to have appreciating exchange rates. Income, as reflected by GDP, is used as a measure of relative productivity and as an influence on exchange rates. Since there is much disagreement over whether GDP is I(0) or I(1) and our sample is too short to reject a unit root null in the level of GDP, we use the growth rate of home country income Δy_h and the growth rate of US income Δy_{us} as covariates.

There is some empirical evidence that the wealth effect of a change in current account influences real exchange rates. Krugman (1990) argues that the current account can result in significant real exchange rate changes due to the transfer of wealth across borders. For example, a temporary production shock, by causing a rise in savings and a change in a country's terms of trade, results in a change in the current account. The covariate used is the growth rate of the current account relative to income of the home country $\Delta(ca_h / y_h)$.[6]

Jansson (2002) proposes that inflation, the rate of change of the consumer price index, be used as a covariate for real exchange rates. Since there is much disagreement over whether inflation is I(0) or I(1) and we found little evidence against a unit root null in inflation, we use the first difference of the U.S. inflation rate $\Delta\Pi_{us}$ and the first difference of the home inflation rate $\Delta\Pi_h$ as covariates.

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[6] The growth rate of the current account of the U.S. relative to the income of the U.S. $\Delta(ca_{us}\, y_{us})$ is not used because of its low variance.

Table 2 presents the results of the stationarity tests for the covariates. While we conducted both ADF and DF-GLS tests, only the ADF results are presented since the DF-GLS tests did not add to the rejections. The unit root null can be rejected in most of the cases, as would be expected since we have differenced the covariates (when necessary) to increase stationarity. In some cases, however, the unit root null cannot be rejected and, in others, the data for the covariate is not available. Those cases are not used in the subsequent analysis.

The results of the CADF and CPT tests are presented in Tables 3 - 7. Tables 3 and 5 provide the results for the nominal exchange rate and Tables 4 and 6 provide the results for the real exchange rate. We only conduct covariate augmented tests with the covariates for which, in Table 2, we could reject the unit root null. Table 7 summarizes the results. We only report rejections of the unit root null for the real exchange rate with a given covariate if we both reject the unit root null for the real exchange rate (Tables 3 and 5) and fail to reject the unit root null for the nominal exchange rate (Tables 4 and 6).

The CADF test does not provide strong evidence of PPP. The unit root null is rejected for 2 countries at the 5% level and 2 additional countries at the 10% level. These results are presented in Tables 3, 4, and 7. While this the same number of rejections as found with the ADF test, it is fewer rejections than found with the DF-GLS and PT tests. The covariates that are useful in rejecting are a mixture of income, money, inflation, and current account covariates. Ireland rejects for income and money. Italy rejects for income. Finland rejects for income, inflation, money, and current account. Denmark rejects for current account. The rejections for Italy and Denmark are weak, rejecting at the 10% level and for one covariate only.

The CPT test provides very strong support for PPP. The unit root null is rejected at the 1% level for five countries, at the 5% level for 7 countries, and at the 10% level for 6 additional countries for at least one covariate. These results are depicted in Tables 5, 6, and 7. Canada and Belgium are the two countries that fail to reject the unit root. Japan has one rejection at the 10% level for U.S. money growth and Denmark has one rejection at the 10% level for income. Even though Australia, France, Germany and Sweden reject at the 10% level, the rejections are for 2 covariates and can be considered stronger rejections that those of Japan and Denmark. The unit root is rejected for 16 countries with income covariates, 14 countries with inflation covariates, 10 countries with money covariates, and 3 countries with current account covariates.

There is wide variation in which covariates produce rejections. Denmark and Finland reject for income covariates. Japan rejects for a money covariate. Australia, Austria, France, Germany, Switzerland, and Portugal reject for income and inflation. Greece, Ireland, New Zealand, Sweden, U.K. and the Netherlands reject for income, money, and inflation. Italy rejects for income, money, inflation, and current account. Norway and Spain reject for all covariates.

The results are summarized in Tables 7 and 8. Table 7 organizes the rejections by the type of test. The CPT test clearly provides the most evidence against the unit root null, followed by the DF-GLS and PT tests and then by the ADF and CADF tests. Table 8 organizes the rejections by the type of covariate. Since there were no cases for which the rejections were stronger for the CADF test than for the CPT test, the reported rejections are all for the CPT test. The inflation and output covariates produce the most rejections, followed by the money supply and current account covariates.

4. Conclusion

The paper attempts to answer the following question: Does the use of unit root tests with stationary covariates result in significant support for PPP in a span of data, post-1973 real exchange rates among industrialized countries with the U.S. dollar as the numeraire currency, where univariate tests have not provided such support? The answer is negative for the CADF test and positive for the CPT test, and highlights the importance of using powerful tests with relatively low spans of persistent data. The econometric results of Elliott, Rothenburg and Stock (1996) and Hansen (1995) show that there are power gains from using the DF-GLS, PT and CADF tests rather than the ADF test, and Elliott and Jansson (2003) demonstrate further power gains from using the CPT test. The empirical results in this paper illustrate the practical importance of these econometric studies. While there are few rejections of the unit root null for the ADF and CADF tests, and only somewhat more rejections for the DF-GLS and PT tests, the CPT test provides very strong evidence for PPP, with the unit root null rejected for 18 of the 20 countries.

In conclusion, it appears that the lack of evidence of PPP in post-1973 real exchange rates has been the low power of the available tests. A useful extension of this study would be the use of other empirical determinants of PPP such as government spending and productivity as covariates. Since the U.S. based covariates are so important in rejecting the unit root, the CPT test could be used to test for mean reversion in countries where data is incomplete by using U.S. based covariates. It may also be interesting to test for stationarity using currencies other than the USA dollar as the numeraire.

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Table 1: Univariate Tests

	ADF		PT		DF-GLS	
	k		*k*		*k*	
Australia	3	-2.02	0	10.1	6	-0.73
Austria	1	-2.03	1	6.91	1	-1.43
Belgium	3	-2.16	1	3.63*	1	-1.85*
Canada	3	-0.96	5	8.24	4	-0.23
Denmark	3	-2.22	1	4.9	1	-1.63*
Finland	7	-2.88*	1	5.61	1	-1.62*
France	7	-2.42	1	2.43**	1	-2.30**
Germany	7	-2.27	1	3.14**	0	-2.03*
Greece	4	-2.33	5	4.13*	5	-1.75*
Ireland	1	-2.53	2	4.18*	0	-1.81*
Italy	3	-2.52	1	2.36**	0	-2.27**
Japan	1	-1.7	1	14.69	1	-0.74
Netherlands	7	-2.38	1	3.56*	1	-1.93*
New Zealand	8	-3.39**	1	2.26**	1	-2.36**
Norway	7	-2.63*	2	5.09	1	-1.68*
Portugal	4	-1.99	5	4.92	0	-1.56
Spain	2	-2.13	1	8.01	2	-1.34
Sweden	7	-2.61*	0	7.67	1	-1.68*
Switzerland	3	-2.5	1	8.6	1	-1.22
UK	6	-2.51	0	6.74	1	-1.42

Note: The ADF critical values are from MacKinnon (1991) adjusted for 104 obs.
The PT and DF-GLS critical values are from Ng and Perron (2001).

Table 2: Testing for stationarity of the covariates using ADF

	Δy	Δm	$\Delta \Pi$	Δ(ca/y)
Australia	-4.02***	-4.42***	-5.12***	-55.53***
Austria	-4.64***	na	-5.63**	-4.58***
Belgium	-10.18***	na	-6.10***	-5.32***
Canada	-3.07**	-2.84*	-10.13***	-2.95**
Denmark	-10.03***	-2.47**	-4.95***	-11.76***
Finland	-2.44	na	-3.08**	-7.82***
France	-2.84*	-2.79*	-5.60***	-3.21**
Germany	-3.40**	-4.36***	-13.66***	-2.86*
Greece	na	na	-4.07***	-2.55
Ireland	na	na	-11.39***	na
Italy	-2.29	-2.46	-2.84*	-4.49***
Japan	-2.89*	-2.41	-6.13***	-4.22***
Netherlands	-10.15***	-9.74***	-12.29***	-3.21**
New Zealand	-10.15***	-2.89**	-4.87***	-5.17***
Norway	-2.11	-2.72*	-4.91***	-5.32***
Portugal	-2.56	-8.96***	-2.72*	-1.85
Spain	-2.90**	-3.05**	-5.50***	-7.50***
Sweden	-2.96**	-2.02	-5.64***	-6.19***
Switzerland	-9.71***	-10.94***	-11.45***	na
UK	-3.48**	-10.37***	-8.51***	-4.41***
USA	-3.25**	-2.89**	-4.10***	na

Note: *** reject at 1%, ** reject at 5%, * reject at 10%

Table 3: CADF test for real exchange rates

	Δy_{us}	Δy_h	Δm_{us}	Δm_h	$\Delta \pi_{us}$	$\Delta \pi_h$	$\Delta(ca_h/y_h)$
Australia	-1.82 (1,0)	-1.77 (4,0)	-1.85 (4,0)	-1.72	-1.64 (3,0)	-1.81 (3,0)	-1.66 (3,0)
Austria	-1.96 (1,0)	-2.91 (4,0)***	-2.02 (4,0)	na	-2.07 (3,0)	-1.76 (3,0)	-1.79 (4,0)
Belgium	-1.47 (1,0)	-2.63 (2,0)**	1.56 (4,0)	na	-2.05 (3,0)	-1.54 (3,0)	-0.86 (3,0)
Canada	0.06 (1,0)	-0.56 (1,0)	-0.35 (4,0)	-0.29 (0,0)	-0.18 (3,2)	-0.06 (3,0)	-0.25 (4,0)
Denmark	-1.76 (1,0)	-1.92 (1,0)	-1.82 (4,0)	-	-2.11 (3,0)	-1.80 (3,0)	-2.65 (3,0)*
Finland	-2.72 (1,3)*	-	-2.77 (4,0)*	na	-2.90 (3,0)**	-2.67 (3,0)*	-2.70 (4,3)*
France	-1.86 (1,0)	-1.92 (2,0)	-2.43 (4,0)*	-2.08 (2,0)	-2.13 (3,0)	-1.78 (3,0)	-2.33 (2,0)
Germany	-1.82 (1,0)	-1.93 (0,0)	-1.90 (4,0)	-2.03 (2,0)	-2.21 (3,0)	-1.92 (3,0)	-1.91 (4,0)
Greece	-1.79 (1,0)	na	-1.92 (4,0)	na	-1.83 (3,0)	-1.61 (3,0)	na
Ireland	-2.75 (1,0)**	na	-2.81 (4,0)*	na	-2.47 (3,0)	-2.50 (3,0)	na
Italy	-2.28 (1,0)*	-	-1.79 (4,0)	-	-2.10 (3,0)	-1.84 (3,0)	-1.96 (0,0)
Japan	-1.73 (1,0)	-1.96 (4,0)	-1.81 (4,0)	1.70 (4,0)	-1.52 (3,0)	-1.60 (3,0)	-0.68 (4,0)
Netherlands	-1.59 (1,0)	-1.77 (0,0)	-1.71 (4,0)	-1.87 (0,0)	-2.13 (3,0)	-1.84 (3,0)	-
New Zealand	-2.00 (1,0)	-1.11 (1,0)	-2.19 (4,0)	-	-2.14 (3,0)	-1.98 (1,0)	-1.19 (3,0)
Norway	-1.95 (1,0)	-	-2.02 (4,0)	-2.00 (3,0)	-2.11 (3,0)	-1.98 (3,0)	-1.92 (3,0)
Portugal	-1.62 (1,0)	-	-2.24 (4,0)	-1.03 (0,0)	-1.37 (3,0)	-1.26 (3,0)	-
Spain	-1.68 (1,0)	-0.91 (4,0)	-1.82 (4,0)	-1.57 (4,0)	-1.93 (3,0)	-1.48 (3,0)	-1.39 (4,0)
Sweden	-1.46 (1,0)	-2.63 (4,3)**	-1.45 (4,0)	-	-1.58 (3,0)	-1.43 (3,0)	-2.23 (0,3)
Switzerland	-2.14 (1,0)	-2.39 (0,0)	-2.52 (4,0)*	-2.11 (0,0)	-2.29 (3,0)	-2.03 (3,0)	na
UK	-2.05 (1,0)	-1.63 (3,0)	-2.17 (4,0)	-1.90 (0,0)	-1.92 (3,0)	-1.88 (3,0)	-2.58 (4,0)*

Table 4: CADF test for 1973-1998 nominal exchange rates

	Δy_{us}	Δy_h	Δm_{us}	Δm_h	$\Delta \pi_{us}$	$\Delta \pi_h$	$\Delta(ca_h/y_h)$
Australia	-1.89 (1,0)	-1.41 (4,0)	-1.56 (4.0)	-1.62 (4,0)	-1.57 (3,0)	-1.71 (3,0)	-1.59 (3,0)
Austria	-2.17 (1,0)	-3.16 (4,0)***	-2.25 (4,0)	na	-1.84 (3,0)	-1.54 (3,0)	-1.71 (4,0)
Belgium	-1.58 (1,0)	-2.77 (2,0)**	-1.68 (4,0)	na	-1.97 (3,0)	-1.41 (3,0)	-0.71 (3,0)
Canada	-0.68 (1,0)	-1.78 (1,0)	-1.00 (4,0)	-1.23 (0,0)	-1.05 (3,0)	-0.98 (3,0)	-1.06 (4,0)
Denmark	-1.44 (1,0)	-1.81 (1,0)	-1.56 (4,0)	-	-1.92 (3,0)	-1.53 (2,0)	-2.23 (3,0)
Finland	-2.06 (1,1)	-	-1.99 (4,0)	na	-2.22 (3,0)	-2.17 (3,0)	-2.17 (4,1)
France	-1.50 (1,0)	-1.53 (2,0)	-2.29 (4,0)*	-1.70 (2,0)	-1.72 (3,0)	-1.48 (3,0)	-2.52 (2,0)
Germany	-2.00 (1,0)	-1.48 (0,0)	-2.02 (4,0)	-1.52 (2,0)	-1.80 (3,0)	-1.53 (3,0)	-1.50 (4,0)
Greece	-0.34 (1,0)	na	-0.43 (4,0)	na	-1.07 (3,0)	-1.08 (3,0)	na
Ireland	-2.06 (1,0)	na	-1.94 (4,0)	na	-2.52 (3,0)*	-2.56 (3,0)*	na
Italy	-1.12 (1,0)	-	-2.35 (4,0)	-	-2.18 (3,0)	-2.03 (3,0)	-2.14 (0,0)
Japan	-0.98 (1,0)	-1.88 (4,0)	-1.00 (4,0)	-1.28 (4,0)	-0.99 (3,0)	-1.00 (3,0)	-0.65 (4,0)
Netherlands	-2.08 (1,0)	-1.43 (0,0)	-2.28 (4,0)	-1.57 (0,0)	-1.84 (3,0)	1.52 (3,0)	-
New Zealand	-1.50 (1,0)	-1.26 (1,0)	-1.78 (4,0)	-	-2.43 (3,0)	-2.17 (3,0)	-1.22 (3,0)
Norway	-1.39 (1,0)	-	-1.38 (4,0)	-1.46 (3,0)	-1.66 (3,0)	-1.53 (3,0)	-1.45 (3,0)
Portugal	-1.22 (1,0)	-	-2.97 (4,0)**	-3.01 (0,0)**	2.63 (3,0)*	-2.46 (3,0)	-
Spain	-1.17 (1,0)	-2.29 (4,0)*	-1.07 (4,0)	-2.80 (4,0)*	-1.65 (3,0)	-1.40 (3,0)	-1.64 (4,0)
Sweden	-1.08 (1,0)	-2.95 (4,3)**	-1.04 (4,0)	-	-1.27 (3,0)	-1.08 (3,0)	-1.82 (0,3)
Switzerland	-1.98 (1,0)	-2.05 (0,0)	-2.67 (4,0)**	-1.77 (0,0)	-2.23 (3,0)	-1.08 (3,0)	na
UK	-2.48 (1,0)	-2.73 (3,0)**	-2.05 (4,0)	-2.50 (0,0)	2.27 (3,0)	-2.45(3,0)	-2.95 (4,0)*

Note: *** reject unit root at 1%, ** reject unit root at 5%, * reject unit root at 10%.
The first number in the parenthesis is the lag for the covariate. The second is the lag for the exchange rate.
- covariate is not stationary   na data is not available

Table 5: CPT test for real exchange rates

	Δy_{us}	Δy_h	Δm_{us}	Δm_h	$\Delta \pi_{us}$	$\Delta \pi_h$	$\Delta(ca_h/y_h)$
Australia	6.95 (1)	4.94 (3)*	7.25 (4)	9.83 (0)	4.46 (3)**	5.02 (4)	4.97 (3)
Austria	2.97 (1)**	-0.15 (4)***	2.23 (4)**	na	1.91 (3)**	2.91 (3)**	1.66 (4)***
Belgium	4.41 (1)*	1.91 (4)**	2.46 (4)**	na	1.55 (3)**	4.05 (3)*	3.77 (3)*
Canada	19.90 (1)	14.76 (1)	8.36 (4)	8.51 (4)	4.85 (3)	9.34 (3)	9.32 (4)
Denmark	4.20 (2)*	2.70 (3)**	2.26 (4)**	-	1.57 (3)**	2.56 (3)**	0.01 (3)***
Finland	3.06 (1)**	-	2.83 (4)**	na	2.80 (3)**	3.03 (3)**	2.69 (4)**
France	3.55 (1)*	5.12 (2)	1.47 (4)***	4.09 (0)*	1.09 (3)***	3.65 (2)*	0.47 (4)***
Germany	4.94 (1)*	5.72 (0)	3.19 (4)**	3.04 (4)**	1.65 (3)**	4.12 (3)*	3.22 (4)**
Greece	4.39 (1)*	na	2.77 (4)**	na	3.78 (4)*	3.89 (3)*	na
Ireland	3.01 (2)**	na	1.91(4)***	na	3.20 (3)**	2.68 (3)**	na
Italy	1.84 (1)***	-	1.81 (4)***	-	1.24 (3)**	4.30(3)*	3.06 (0)**
Japan	11.57 (2)	7.40 (3)	4.54 (4)*	5.35 (4)	2.25 (3)**	7.84 (3)	7.87 (0)
Netherlands	3.58 (1)*	4.50 (0)***	2.45 (4)**	1.53 (4)***	1.40 (3)***	4.54 (3)*	-
New Zealand	2.63 (1)**	2.20 (3)**	2.20 (4)**	-	0.45 (4)***	4.08 (1)*	5.32 (3)*
Norway	3.63 (2)*	-	2.75 (4)**	3.37 (4)**	2.38 (3)**	2.87 (3)**	2.97 (3)**
Portugal	4.18 (1)*	-	1.07 (4)***	43.16 (0)	4.20 (3)*	6.01 (3)	-
Spain	4.94 (1)*	3.29 (4)**	2.91 (4)**	3.25 (4)	3.95 (3)**	3.35 (3)**	2.25 (4)**
Sweden	6.11 (1)	-11.74 (4)***	4.22 (4)*	-	3.25 (4)*	4.40 (3)*	6.10 (0)
Switzerland	3.58 (1)*	4.58 (0)***	2.35 (4)**	5.50 (0)	4.15 (3)**	4.50 (3)*	na
UK	4.50 (2)*	3.10 (3)**	2.37 (4)**	3.03 (4)**	4.98 (4)	2.84 (3)**	1.28 (1)***

Table 6: CPT test for nominal exchange rates

	Δy_{us}	Δy_h	Δm_{us}	Δm_h	$\Delta \pi_{us}$	$\Delta \pi_h$	$\Delta(ca_h/y_h)$
Australia	23.77 (1)	60.37 (0)	21.25 (4)	12.46 (4)	-1.19 (3)***	9.73 (4)	11.54 (3)
Austria	6.96 (1)	0.49 (4)***	3.78 (4)*	na	4.99 (3)*	5.85 (3)	3.88 (4)*
Belgium	3.65 (1)*	1.19 (4)***	2.33 (4)**	na	1.91 (3)**	3.79 (3)*	2.79 (3)**
Canada	30.75 (1)	8.67 (3)	10.75 (4)	53.23 (4)	4.71 (3)***	10.63 (3)	11.02 (4)
Denmark	5.81 (1)	2.63 (1)**	3.55 (4)*	-	2.34 (3)**	3.17 (3)**	1.05 (3)***
Finland	6.75 (1)	-	3.71 (4)*	na	2.37 (3)**	1.59 (3)**	3.94 (4)**
France	9.56 (1)	12.20 (2)	2.25 (4)**	3.34 (4)**	3.52 (3)**	6.35 (2)	1.02 (4)***
Germany	5.35 (1)	10.60 (0)	3.16 (4)**	4.17 (4)*	4.02 (3)*	5.45 (3)	4.91 (4)*
Greece	76.54 (1)	na	17.35 (4)	na	15.68 (4)	25.15 (3)	na
Ireland	16.92 (1)	na	9.2	na	7.26 (3)	7.13 (3)	na
Italy	28.60 (1)	-	12.52 (4)	-	15.13 (3)	3.39 (4)*	72.53 (0)
Japan	18.57 (2)	7.78 (3)	6.08 (4)	5.96 (4)	1.64 (3)**	10.02 (3)	12.13 (4)
Netherlands	4.43 (1)*	6.66 (0)	2.16 (4)**	8.22 (0)	3.50 (3)*	5.63 (3)	-
New Zealand	19.69 (1)	1.32 (2)*	21.75 (4)	-	9.60 (4)	38.63 (1)	4.85 (3)*
Norway	8.19 (1)	-	6.40 (4)	5.84 (4)	2.44 (3)**	6.56 (3)	6.20 (3)
Portugal	84.43 (1)	-	4.20 (4)*	67.07 (0)	19.44 (3)	20.55 (3)	-
Spain	22.18 (1)	7.63 (4)	8.69 (4)	1.58 (4)	7.75 (3)	10.16 (3)	9.00 (4)
Sweden	13.91 (1)	-21.73 (4)*	8.62 (4)	-	6.33 (4)	9.86 (3)	27.80 (0)
Switzerland	14.93 (1)	29.04 (0)	4.51 (4)*	7.94 (4)	4.69 (3)*	10.91 (3)	na
UK	11.96 (2)	7.64 (3)	10.05 (4)	23.06 (0)	6.86 (4)	7.83 (3)	0.63 (1)***

Note: *** reject unit root at 1%, ** reject unit root at 5%, * reject unit root at 10%.
- covariate is not stationary
na data is not available

Table 7: Summary of strongest rejections of the unit root for univariate and covariate tests

	ADF	DF-GLS	PT	CADF	CPT
Australia					10%
Austria					5%
Belgium		10%	10%		
Canada					
Denmark		10%		10%	10%
Finland	10%	10%		5%	5%
France		5%	5%		10%
Germany		10%	5%		10%
Greece		10%	10%		5%
Ireland		10%	10%	5%	1%
Italy		5%	5%	10%	1%
Japan					10%
Netherlands		10%	10%		1%
New Zealand	5%	5%	5%		1%
Norway	10%	10%			5%
Portugal					10%
Spain					5%
Sweden	10%	10%			10%
Switzerland					1%
UK					5%

Table 8: Summary of covariates that reject unit root for the CPT test

	Δy_{us}	Δy_h	Δm_{us}	Δm_h	$\Delta \pi_{us}$	$\Delta \pi_h$	$\Delta(ca_h/y_h)$
Australia		10%					
Austria	5%					5%	
Belgium							
Canada							
Denmark	10%						
Finland	5%						
France	10%					10%	
Germany	10%					10%	
Greece	10%		5%		10%	10%	
Ireland	5%		1%		5%	5%	
Italy	1%		1%		5%		5%
Japan			10%				
Netherlands	10%			1%		10%	
New Zealand	5%		5%		1%	10%	
Norway	10%		5%	5%		5%	5%
Portugal	10%				10%		
Spain	10%	5%	5%		5%	5%	5%
Sweden			10%		10%	10%	
Switzerland	10%	1%				10%	
UK	10%	5%	5%	5%		5%	