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Getting PPP Right: Identifying Mean-Reverting Real Exchange Rates in Panels*

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Abstract

Recent advances in testing for the validity of Purchasing Power Parity (PPP) focus on the time series properties of real exchange rates in panel frameworks. One weakness of such tests, however, is that they fail to inform the researcher as to which cross-section units are stationary. As a consequence, a reservation for PPP analyses based on such tests is that a small number of real exchange rates in a given panel may drive the results. In this paper we examine the PPP hypothesis focusing on the stationarity of the real exchange rates in up to 25 OECD countries. We introduce a methodology that when applied to a set of established panel-unit-root tests, allows to identify the real exchange rates that are stationary and poolable without trading-off any test power. We apply procedures that account for cross-sectional dependence. Our results reveal evidence of mean-reversion that is significantly stronger as compared to those obtained by the existing literature, strengthening the case for PPP. Moreover, our approach allows to provide half-lives estimates for the mean-reverting real exchange rates and so find that the half-lives are shorter than the literature consensus and therefore that the PPP puzzle is less pronounced than initially thought.

Key Words: PPP, real exchange rates, half-lives, panel unit root tests.

JEL Classification: C12, C15, C23, F31

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1 Introduction

Given the central role of the Purchasing Power Parity (PPP) concept in theoretical open economy models (both in traditional and New Open Economy Macroeconomics) and the inconclusive results of the existing empirical literature on its validity, it should not be surprising that during the last two decades it has emerged as the most popular topic of empirical research in international macroeconomics¹. The most recent advances in the relevant research focus on nonlinearities and on the time series properties of real exchange rates in panel frameworks. Testing for unit roots in real exchange rates using panels is popular not only because of the econometric advantages but also because the results of such studies tend to uncover more evidence for PPP. In addition to their enhanced power, other advantages of panel unit root tests include the ability to mitigate problems that bewildered research work on real exchange rates, such as the "survivorship bias" and the structural shifts in exchange rate behavior.

Notwithstanding the dramatic improvement in the power of tests, panel frameworks are not free of drawbacks and most recent developments emphasized those relating to cross-sectional dependence. From an economist's point of view, however, possibly the major weakness of the existing unit root panel methodologies is that the null of non-stationarity is a joint hypothesis for all the real exchange rates included in the panel. As a consequence the null hypothesis of a unit root may be rejected even if only one of the real exchange rates is stationary.² Thus, the possibility emerges that some cross-sectional units with particular characteristics (e.g., high-inflation countries, small groups of countries sharing particular features, and so on) drive the results. In addition, the test results can be sensitive to the selection of series included in the panel. This problem, therefore, seems to be the "Achilles heel" of PPP studies based on panel-unit-root tests

In this paper we consider the PPP hypothesis in panels of up to 25 OECD countries using an approach that overcomes the limitations mentioned above. In particular, we introduce a methodology that when applied to a battery of panel-unit-root tests, allows to identify the real exchange rates that are stationary within the panel. Moreover, we apply those procedures to a set of tests that accounts for a number of other potential pitfalls in panels, such as cross-sectional dependence. In addition, we introduce a procedure that evaluates the poolability of the real exchange rates series in panels -a dimension usually overlooked. Our results reveal evidence of mean-reversion that is significantly stronger compared to that obtained by standard stationarity tests, strengthening the case for PPP. Our approach has

¹A casual search for "purchasing power parity" in EconLit shows more than 750 entries from 1990 to today.

²Taylor and Sarno (1998) emphasize this point.

some straightforward advantages compared to the standard panel test methodologies. While we exploit all advantages of the panel structure (such as the enhanced power of panel unit root tests), we are able to identify the stationary real exchange rates within the panel. This allows a direct comparison of the panel test results with the univariate tests results, i.e., focusing on individual real exchange rates - something that the existing literature on real exchange rates and PPP was not able to do so far.

Our contribution to the literature has more than one dimension, however. First, we identify the stationary real exchange rates in panel unit root tests without trading-off any of the standard panel tests advantages. Second, we evaluate/consider the legitimacy of pooling given sets of real exchange rates in a panel using a new methodology. One implication of those methodological innovations for our results is that we take care of the possibility that particular characteristics of some cross-sectional units within the panel may drive the results. Third, we apply those methodological innovations to state-of-the-art panel tests which are free from a number of pitfalls such as cross-sectional dependence. Fourth, we revisit the so-called “PPP puzzle” in the light of our new results providing half-life estimates that pertain only to the stationary real exchange rates of the panel and compare them with those based on the full panels. Finally, we discuss the implications for a number of issues including the validity of PPP across different policy/exchange rate regimes, the role of the numeraire currency, the temporal aggregation problem and its implications for the robustness of the results.

Our results reveal significantly enhanced evidence of mean reversion as compared to univariate tests. They also identify which real exchange rates are stationary and which follow random walks. This evidence is strong, especially during the post-Bretton Woods era, where earlier studies failed to uncover evidence for PPP. This allows us to focus on the half-lives of the mean-reverting real exchange rates. We find that the half-lives are shorter than the prevailing literature consensus.

The next section provides a brief discussion of the evidence and the issues that emerge from recent studies on PPP that use panel unit root tests. Section 3 describes the methodology for separating stationary from nonstationary and poolable from nonpoolable series in panel unit root tests. Section 4 presents and discusses the results of our analysis. Section 5 revisits the “PPP puzzle” utilizes the results of section 4. Finally, Section 6 concludes.

2 A Review of Some Issues Related to PPP

The relevance of PPP for policy purposes is important in both traditional and new approaches in open economy macroeconomics. In the traditional framework for example, whether PPP

holds is a valuable piece of information for policymakers who want to assess the effects of a devaluation, since under PPP the effects of the devaluation on competitiveness will disappear in the long-run. In the recent new open economy macroeconomics literature PPP is a required condition for market completeness and the equalization of the marginal utility of home and foreign currency that in turn allows for perfect risk sharing. A stylized fact of the post-Bretton Woods float, however, is the difficulty of distinguishing real exchange rate behavior from random walks and therefore the relatively weak evidence for PPP. Empirical research has successively relied on various methodological approaches to consider the validity of PPP, including cointegration tests for nominal exchange rates and prices, variance ratios tests, and unit root tests on real exchange rate series³ but despite the voluminous literature the profession's conventional wisdom concerning PPP remains, in general, inconclusive.

Hakkio (1984) and Abuaf and Jorion (1991) represent early attempts to utilize panel data sets as a means of increasing the power of unit root tests in PPP studies. Tests for unit roots within heterogeneous panels, however, are currently well established, and most of them utilize the frameworks of Levin and Lin (1992), and Im, Pesaran, and Shin (2003) (IPS).⁴ Until the emergence of nonstationary panel techniques the evidence supporting the existence of PPP had not only been weak (see Macdonald (1995)) but also lacked robustness. In particular, the results tended to depend on the length of the sample period, the frequency of the series, the choice of countries in the sample, and the choice of numeraire currency, to name a few aspects. Evidence in favour of PPP was more likely to be found if the tests were based on long samples (of around 100 years) of annual data and if the US dollar was not used as a numeraire.⁵

Studies of PPP using panel unit-root tests reversed the relatively gloomy for PPP picture. Research focusing on industrial countries provided increased evidence of real exchange stationarity using panel frameworks (see Frankel and Rose (1996), MacDonald (1996), Oh (1996), Papell (1997), Taylor and Sarno (1998) and so on).⁶

Despite the increased ability to uncover evidence that validates PPP when panel data are used⁷ the existing evidence of panel data studies are yet inconclusive. A set of evidence based

³A wide range of methodologies has been employed to examine the stationarity properties of the real exchange rate. Such approaches include Augmented Dickey-Fuller (ADF) tests, with one or multiple and exogenous or endogenous structural breaks, fractionally integrated processes, tests where stationarity is the null hypothesis, test that allow for nonlinearities in mean reversion, and panel data tests. For surveys see Boucher Breuer (1994), Froot and Rogoff (1995), and Mark (2001).

⁴Other approaches exist in testing for the presence of unit roots in heterogeneous panels, such as, e.g., Harris and Tzavalis (1999) and so on.

⁵For example, Papell and Theodoridis (2001) find that the numeraire currency is important in the rejections of the null and that using the DM as the numeraire results to more evidence for real exchange rate stationarity as compared to using the US dollar.

⁶With the the exception of Papell (1997) all the above studies rely primarily on the use of the IPS tests. We use the same test as well.

⁷Infuential papers with such findings include those of Abuaf and Jorion (1991), Frankel and Rose (1996)

on panel data methodologies exists that is less favorable to PPP (O'Connell (1998), Papell and Theodoridis (1998), Papell and Theodoridis (2001)). In summary, while the results on balance are supportive of PPP, the fact that a number of studies employing panel tests fail to always rescue the PPP hypothesis makes the issue more contentious.

A critical issue that emerges when panel unit roots are employed is the problem of cross-sectional dependence. As O'Connell (1998) suggests, the non-zero covariances of the errors across the units in panel tests for unit roots (and cointegration) imply short-run linkages among the units.⁸ Using a generalized least squares (GLS) approach to control for intercountry dependence O'Connell produces results that are not supportive to PPP. Subsequent studies that employed GLS, however, -including Papell and Theodoridis (1998) and Taylor and Sarno (1998)- came to the rescue of PPP. Papell (1997), using Levin and Lin (1992) tests, shows that the rejection of the unit root hypothesis depends critically on the size of N , and whether or not the critical values have been adjusted to account for serial correlation.

The theoretical developments in econometrics have not produced the tools yet for addressing this problem definitively but recent advances have provided sophisticated methods which are clearly advantageous to the conventional practice of simply de-meaning the series. Being aware that one cannot completely eliminate cross-sectional dependence, we use some of the most efficient tests that account for this possibility, as put forward by Chang (2002). In particular, Chang (2002) discusses a panel unit root test where the use of nonlinear covariates in a Dickey-Fuller unit root regression context makes the test robust to cross-sectional dependence. The nonlinear covariates are designed to be uncorrelated in the presence of cross-sectional dependence. We also consider a further modification of the test, as discussed in Chang and Song (2002) where the nonlinear covariates are uncorrelated even in the presence of cointegration in the series.

Many authors, however, have pointed out some fundamental problems in using panel unit-root tests (e.g., Mark (2001), Taylor and Sarno (1998)). In particular, attention has been drawn to the fact that the null hypothesis in such tests is specified as a joint nonstationarity hypothesis. Thus, cases may exist where the panel appears as stationary but a (possibly large) number of individual series display unit roots. In fact, even one stationary series may suffice to reject the unit root null for the whole panel. In this case one may incorrectly conclude that the panel is on balance stationary or -in the best case- they will not be able to distinguish which are the cross-sectional units that display stationarity. While some

and Taylor and Sarno (1998).

⁸More recently, Banerjee, Marcellino, and Osbat (2003) suggest that since the panel unit root tests assume away the presence of cross-section cointegrating relationships, if this assumption is violated the tests become oversized.

attempts have been made to circumvent this problem (Taylor and Sarno (1998)), to our knowledge there is no formal procedure available so far that directly considers stationarity of the individual cross-sectional units in a panel framework.

Another closely related dimension of analyzing PPP issues in panels that has received scant -if any- attention refers to the validity of pooling specific sets of real exchange rate series. Applying panel methods on a set of real exchange rates that are not poolable may lead to wrong conclusions. We avoid such potential pitfalls using a new methodology that tests for the poolability of the series. Our results show that almost all series we find stationary are also poolable.

The ability to separate stationary from nonstationary and poolable from nonpoolable series becomes particularly important when a relatively large number of countries is considered. In such cases the size of the panel and the choice of the countries included can be a contentious issue when standard panels are employed. When discretion is exercised in removing or adding cross-section units in the panel the (summary) result can be affected. Rogoff (1998), for example, expresses reservations along these lines for the 150-country study of Frankel and Rose (1996). Our approach, however, is immune to such problems not only because we provide evidence for each individual real exchange rate but also because we conduct tests that validate the poolability of the series.

The methodological innovations of our analysis render it immune to a number of other weaknesses that plague many PPP studies. Rogoff (1998), for example, questions some favorable-to-PPP results obtained with panel tests on the basis that they include a large number of high-inflation countries. This is a special case where a subsection of cross-section units sharing some specific features drive the results. Providing an analysis of the time series properties of individual series removes any scepticism about the results based on such concerns.

3 Methodology and Data

An attractive feature of panel unit root tests is the ability to exploit coefficient homogeneity under the null hypothesis of a unit root for all series involved in order to obtain a more powerful test of the unit root hypothesis. However, under the alternative hypothesis of heterogeneous panel unit root tests such as, e.g., IPS, of at least one series being stationary, the results are not illuminating enough. In particular if one rejects the unit root hypothesis he cannot know which series caused the rejection.

We introduce a new procedure to the PPP literature that enables us to distinguish the set of series into a group of stationary and a group of nonstationary series following

the work of Kapetanios (2003b). This method uses a sequence of panel unit root tests to distinguish between stationary and nonstationary series. If more than one series are actually nonstationary then the use of panel methods to investigate the unit root properties of the set of series is indeed more efficient compared to univariate methods.

The proposed method starts by testing the null of all series being unit root processes along the lines considered in many heterogeneous panel unit root tests such as, e.g., the IPS panel unit root test. We use this test as a vehicle for illustrating our method below -which is nevertheless compatible with any other panel unit root test. We first implement this test to all real exchange rates in the panel and if the null is not rejected we accept the nonstationarity hypothesis and the procedure stops. If the null is rejected then we remove from the set of series the one with the minimum individual DF t-test and redo the panel unit root test on the remaining set of series. The procedure is continued until either the test does not reject the null hypothesis or all the series are removed from the set. The end result is a separation of the set of variables into a set of stationary variables and a set of nonstationary variables.

An additional and highly related issue that emerges when panel data sets are employed, however, is the assumption of poolability, i.e. the validity of the assumption that panel units described by a given model have a common parameter subvector for that model. This assumption is typically being overlooked in the literature. Relevant econometric work, however, has concentrated on whether a given dataset is poolable as a whole, i.e., whether the null hypothesis $H_0 : \beta_j = \beta, j = 1, \dots, N$ holds, where β is the assumed common parameter subvector of the N cross-sectional units of the dataset. In that vein a common approach, discussed, in some detail, in Baltagi (2001), is to use an extension of the Chow (1960) parameter stability test on the pooled dataset. Other tests for this null hypothesis have been developed by Ziemer and Wetzstein (1983) and Baltagi, Hidalgo, and Li (1996).

If such tests reject the null hypothesis, however, the researcher is left with a problem mirroring that of the distinguishing the stationary from nonstationary series in a panel. In other words, although one knows that the null hypothesis of poolability in the panel can be rejected, he cannot identify the series that caused the rejection. Thus, the need for a method that allows the distinction of the set of series into a group of poolable and a group of nonpoolable series emerges. If more than one series are actually poolable then the use of panel methods to investigate the properties of this set of series is indeed more efficient compared to univariate methods. Such methods seems indeed possible and one has been suggested by Kapetanios (2003a).

The method starts by testing the null of all series having a common parameter subvector. If the test rejects the null hypothesis of poolability, then the series with the maximum

difference between the individual estimate of the vector β and its estimate obtained using the pooled dataset, suitably normalized, is considered as non-poolable and is removed from the dataset. We then apply the poolability test to the remaining series and continue in this vein until the poolability test does not reject the null hypothesis for some subset of the original set of series or we are left with a set of one series. The methodology for separating stationary from nonstationary series within a panel and the methodology for determining the poolability of the series is discussed, in more detail, in the following two subsections.

3.1 Separating stationary from nonstationary series

Before we apply the new methodology to the IPS heterogeneous panel unit root test of real exchange rates we provide a few expository details of the method employed following Kapetanios (2003b). Consider a sample of N cross sections observed over T time periods and let the stochastic process $y_{j,t}$ be generated by

$$y_{j,t} = (1 - \phi_j)\mu_j + \phi_j y_{j,t-1} + \epsilon_{j,t}, \quad j = 1, \dots, N, \quad t = 1, \dots, T \quad (1)$$

where initial values $y_{j,0}$ are given. We are interested in testing the null hypothesis of $\phi_j = 1$ for all j . Rewriting (1) as

$$\Delta y_{j,t} = (1 - \phi_j)\mu_j + \beta_j y_{j,t-1} + \epsilon_{j,t} \quad (2)$$

where $\beta_j = \phi_j - 1$, the null hypothesis becomes

$$H_0 : \beta_j = 0, \quad \forall j \quad (3)$$

The test is based on the average of individual Dickey-Fuller (DF) statistics. The standard DF statistic for the j -th unit is given by the t -ratio of β_j in the regression of $\Delta \mathbf{y}_j = (\Delta y_{j,1}, \dots, \Delta y_{j,T})'$ on a matrix of deterministic regressors $\boldsymbol{\tau}_T$ and $\mathbf{y}_j = (y_{j,0}, \dots, y_{j,T-1})'$. $\boldsymbol{\tau}_T$ could include just a constant, i.e. $\boldsymbol{\tau}_T = (1, \dots, 1)'$ or a constant and a time trend, i.e. $\boldsymbol{\tau}_T = ((1, 1)', (1, 2)', \dots, (1, T)')$.

Denoting the t -statistic by $t_{j,T}$ we have

$$t_{j,T} = \frac{\Delta \mathbf{y}_j' \mathbf{M}_\tau \mathbf{y}_j}{\hat{\sigma}_{j,T} (\mathbf{y}_j' \mathbf{M}_\tau \mathbf{y}_j)^{1/2}} \quad (4)$$

where $\mathbf{M}_\tau = \mathbf{I}_T - \boldsymbol{\tau}_T (\boldsymbol{\tau}_T' \boldsymbol{\tau}_T)^{-1} \boldsymbol{\tau}_T'$ and

$$\hat{\sigma}_{j,T} = \frac{\Delta \mathbf{y}_j' \mathbf{M}_\tau \mathbf{y}_j}{T} \quad (5)$$

Then the panel unit root test is based on the following test statistic

$$\bar{t}_T = 1/N \sum_{i=1}^N t_{i,T} \quad (6)$$

which we will refer to as the \bar{t} -statistic.

For one version of the panel unit root test this statistic is normalized to give

$$z_{\bar{t}} = \frac{\sqrt{N}(\bar{t}_T - E(t_T))}{\sqrt{Var(t_T)}} \quad (7)$$

As Im, Pesaran, and Shin (2003) discuss, this test has a standard normal distribution if $N \rightarrow \infty$. $E(t_T)$ and $Var(t_T)$ denote the first and second central moments of the null distribution of $t_{i,T}$. These are functions of T only and can be obtained via simulation. Further for fixed N the distribution of $z_{\bar{t}}$ is nuisance parameter free but has no closed form solution. Critical values can be obtained however using simulations as discussed in IPS. This method will be denoted by SPSM.

For further use define the following. Let $\mathbf{Y}_i = (\mathbf{y}_{j_1}, \dots, \mathbf{y}_{j_M})$, $\mathbf{i} = \{j_1, \dots, j_M\}$ and $\mathbf{t}_i = (t_{j_1,T}, \dots, t_{j_M,T})'$. Also define $\mathbf{i}^j = \{j\}$, $\{1, \dots, N\} \equiv \mathbf{i}^{1,N}$ and \mathbf{i}^{-j} such that

$$\mathbf{i}^{-j} \cup \mathbf{i}^j = \mathbf{i}$$

We now define the object we wish to estimate. For every series $y_{j,t}$ define the binary object \mathcal{I}_j which takes the value 0 if $\beta_j = 0$ and 1 if $\beta_j < 0$. We do not consider the case $\beta_j > 0$. Then, $\mathcal{I}_i = (\mathcal{I}_{j_1}, \dots, \mathcal{I}_{j_M})'$. We wish to estimate $\mathcal{I}_{i^{1,N}}$. We denote the estimate by $\hat{\mathcal{I}}_{i^{1,N}}$.

To do so we consider the following procedure.

1. Set $j = 1$ and $\mathbf{i}_j = \{1, \dots, N\}$.
2. Calculate the $z_{\bar{t}}$ -statistic for the set of series $\mathbf{Y}_{\mathbf{i}_j}$. If the test does not reject the null hypothesis $\beta_i = 0$, $i \in \mathbf{i}_j$, stop and set $\hat{\mathcal{I}}_{\mathbf{i}_j} = (0, \dots, 0)'$. If the test rejects go to step (3).
3. Set $\hat{\mathcal{I}}_{\mathbf{i}_j} = 1$ and $\mathbf{i}_{j+1} = \mathbf{i}_j^{-l}$, where l is the index of the series associated with the minimum $t_{s,T}$ over s . Set $j = j + 1$. Go to step (2).

In other words, we estimate a set of binary objects that indicate whether a series is stationary or not. We do this by carrying out a sequence of panel unit root tests on a reducing

dataset where the reduction is carried out by dropping series for which there is evidence of stationarity. A low individual t -statistic is used as such evidence. The asymptotic properties of this method are discussed in detail in Kapetanios (2003b).

3.2 Separating poolable from nonpoolable series

To illustrate the methodology, consider the following panel data model

$$y_{j,t} = \alpha_j + \beta_j x_{j,t} + \epsilon_{j,t}, \quad j = 1, \dots, N, \quad t = 1, \dots, T. \quad (8)$$

where $x_{j,t}$ is a k -dimensional vector of predetermined variables. This is a standard panel data model where we do not need to specify the nature of the cross sectional individual effect α_j . Our discussion carries through both for fixed and random effect models. The poolability test is concerned with the null hypothesis

$$H_0 : \beta_j = \beta, \quad \forall j \quad (9)$$

A test that $\beta_j = \beta$ for a given j may be based on the test statistic

$$S_{T,j} = (\hat{\beta}_j - \tilde{\beta})' Var(\hat{\beta}_j - \tilde{\beta})^{-1} (\hat{\beta}_j - \tilde{\beta}) \quad (10)$$

This is a Hausman type statistic. If the panel estimator, $\tilde{\beta}$, were efficient then, under the null hypothesis we know from Hausman (1978) that

$$Var(\hat{\beta}_j - \tilde{\beta}) = Var(\hat{\beta}_j) - Var(\tilde{\beta}) \quad (11)$$

However, the estimator is not assumed to be efficient and hence the variance is given by

$$Var(\hat{\beta}_j - \tilde{\beta}) = Var(\hat{\beta}_j) - 2Cov(\hat{\beta}_j, \tilde{\beta}) + Var(\tilde{\beta}) \quad (12)$$

However, from the \sqrt{NT} -consistency of $\tilde{\beta}$, and the \sqrt{T} -consistency of $\hat{\beta}_j$, the term $Var(\hat{\beta}_j)$, which is $O(T^{-1})$, dominates the terms $Cov(\hat{\beta}_j, \tilde{\beta})$ and $Var(\tilde{\beta})$ which are $O(T^{-1}N^{-1/2})$ and $O(T^{-1}N^{-1})$ respectively, and are therefore asymptotically negligible for the test as $N \rightarrow \infty$. An appropriate estimate of $Var(\hat{\beta}_j - \tilde{\beta})$ may then be based on a consistent estimate of the variance of $\hat{\beta}_j$. Then, it follows from our assumption of asymptotic normality of the estimators that as $T \rightarrow \infty$

$$S_{T,j} \xrightarrow{d} \chi_k^2 \quad (13)$$

for each unit j .

The poolability test is based on the $S_{T,j}$ statistics. In particular Kapetanios (2003a) suggests that $S_T^s = \sup_j S_{T,j}$ be used as a test statistic for the test of the null hypothesis H_0 .

As before, let $\mathbf{Y}_i = (\mathbf{y}_{j_1}, \dots, \mathbf{y}_{j_M})$, $\mathbf{i} = \{j_1, \dots, j_M\}$ and $\mathbf{i}^j = \{j\}$, $\{1, \dots, N\} \equiv \mathbf{i}^{1,N}$ and \mathbf{i}^{-j} such that

$$\mathbf{i}^{-j} \cup \mathbf{i}^j = \mathbf{i}$$

We now define the object we wish to estimate. To simplify the analysis we assume that there exists one cluster of series with equal $\beta_j = \beta$. If all series have different β_j then without loss of generality we assume that $\beta_1 \equiv \beta$. For the time being we will assume that there exists just one cluster of series with equal β_j and all the rest of the series have different β_j . The more general case is straightforward to deal with and will be discussed briefly later. For every series $y_{j,t}$ (and associated set of predetermined variables $x_{j,t}$) define the binary object \mathcal{I}_j which takes the value 0 if $\beta_j = \beta$ and 1 if $\beta_j \neq \beta$. Then, $\mathcal{I}_i = (\mathcal{I}_{j_1}, \dots, \mathcal{I}_{j_M})'$. We wish to estimate $\mathcal{I}_{1,N}$. We denote the estimate by $\hat{\mathcal{I}}_{1,N}$.

To do so we consider the following procedure.

1. Set $j = 1$ and $\mathbf{i}_j = \{1, \dots, N\}$.
2. Calculate the S_T^s -statistic for the set of series $\mathbf{Y}_{\mathbf{i}_j}$. If the test does not reject the null hypothesis $\beta_i = 0$, $i \in \mathbf{i}_j$, stop and set $\hat{\mathcal{I}}_{\mathbf{i}_j} = (0, \dots, 0)'$. If the test rejects go to step (3).
3. Set $\hat{\mathcal{I}}_{i^l} = 1$ and $\mathbf{i}_{j+1} = \mathbf{i}_j^{-l}$, where l is the index of the series associated with the maximum $S_{T,s}$ over s . Set $j = j + 1$. Go to step (2).

In other words, we estimate a set of binary objects that indicate whether a series is poolable or not. We do this by carrying out a sequence of poolability tests on a reducing dataset where the reduction is carried out by dropping series for which there is evidence of nonpoolability. A large individual $S_{T,j}$ -statistic is used as such evidence. Note that we do not need to use the poolability test introduced in the previous section. The method can be equally applied using any available poolability test in Step 2 of the algorithm. The asymptotic properties of this method are discussed in detail in Kapetanios (2003a).

3.3 Data

We construct the bilateral real exchange rate q against the i -th currency at time t as $q_{i,t} = s_{i,t} + p_{j,t} - p_{i,t}$, where $s_{i,t}$ is the corresponding nominal exchange rate (i -th currency units per one unit of the j -th currency), $p_{j,t}$ the price level in the j -th country, and $p_{i,t}$ the price level of the i -th country. That is, a rise in $q_{i,t}$ implies a real appreciation of the j -th country against the i -th currency.

The 26 currencies considered are those of Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Italy, Japan, Korea, Luxembourg, Malta, Mexico, Netherlands, New Zealand, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, the United Kingdom, and the United States. All data are quarterly, spanning from 1957Q1 to 1998Q4 and the bilateral nominal exchange rates against the currencies other than the US dollar are cross-rates computed using the US dollar rates. More specifically we consider two different panels each one of which consists of up to 25 country pairs and corresponds to a different numeraire currency (US dollar, DM). We use the average quarterly nominal exchange rates and the price levels are consumer price indices (not seasonally adjusted). All variables are in logs. All data are from the International Monetary Fund's *International Financial Statistics* in CD-ROM.

We confine our focus on the \$US and the DM only as numeraires since the Yen's behavior has been considered as exceptional in the post WWII era.⁹ The yen experienced trend like appreciation and it is likely that tests that allow for structural break or nonlinearities may be better equipped to capture the corresponding real exchange rate dynamics.¹⁰ The length of the data was dictated by the availability of the IFS/IMF data. We stop at 1998 when a number of the countries in our sample joined the European Monetary Union (EMU) and shared a common currency. Considering more recent data would result either in using a smaller number of cross-sectional units or using only the relative price levels for the EMU member countries.

4 Results

In presenting our results we arrange each table so that the first three columns correspond to three different specifications of the corresponding/benchmark univariate unit-root test i.e., with a model with no constant and trend, a model with constant only, and a model with constant and trend. The next three columns provide the results from the methodology outlined in section 3 as applied to the panel data in order to obtain the country specific stationarity results. The results of the standard panel unit root tests (i.e., without applying our methodology) are not reported because since proceeding with the new methodology to identify the stationary series implies that the series as a panel were found stationary (as described in section 3). We assume a typical four-lag structure since the data are quarterly.

Tables 1-4 provide the results from applying our procedure to standard Augmented

⁹Similar results, however, are obtained when using the British pound and the Swiss franc as numeraires (results area available upon request).

¹⁰For a recent analysis of the yen real exchange that uncovers evidenc of stationarity taking into account nonlinear behavior see G. E. Chortareas and Kapetanios (2004).

Dickey-Fuller (ADF) tests (first three columns) and the IPS panel-unit-root tests (last three columns). Table 1 provides the results for 22 bilateral real exchange rates against the US dollar from 1957Q to 1998Q4 (the full period for which the IMF data are available). The standard univariate DF test specifications provide up to two rejections of the null hypothesis out of the 22 series in our sample. The panel unit root tests suggest stationarity of the panel and applying the new methodology we show that up to nine out of the 22 series are stationary. Those are the real exchange rates of four large European countries (France, Italy, Spain, and the UK), two small European economies (Cyprus and Malta), and those of New Zealand, South Africa and Japan. Note that the stationarity of the three real exchange rates indicated from the DF2 and DF3 tests is confirmed from the corresponding panel tests.

The structure of Table 2 is similar to that of Table 1 but they refer to the post-Bretton Woods period only (again up to the end of 1998). The panel now includes 25 countries (Denmark, Korea and Mexico have been added in the sample since more data are available for this period). Again the panel tests provide much more evidence for stationarity. While the conventional ADF tests show at most two series being stationary the panel tests shows up to 15 stationary real exchange rates (SPSM2) -more that half of the series. The countries whose bilateral real exchange rate with the US dollar is stationary include the large European economies (France, Germany, Italy, UK), and a number of smaller European developed economies (Belgium, The Netherlands, etc.). The real exchange rate of Japan does not emerge as stationary in the post Bretton-Woods period but the null of a unit root could be rejected in the full sample (Table 1).

We repeat the analysis to the bilateral real exchange rates using the German Mark as the numeraire currency and we provide the results in Tables 3 and 4 whose structure mirrors that of Tables 1 and 2 respectively. That is in Table 3 we provide the results from three specifications of the conventional ADF tests and three specifications of the IPS panel unit root test (modified as described in the methodology section to allow consideration of the individual series' properties).

As Table 3 shows the evidence in support of the PPP hypothesis is scant regardless the tests and specification used. The results for the post-Bretton Woods era with the DM as the numeraire (provided in Table 4) completely reverse the picture. Now up to seven of the 25 real exchange rates appear to be stationary when the conventional tests are used and up to 15 out of the 25 stationary real exchange rates are identified when the panel methodology is used. This difference in the results when considering the two different periods using the DM as the numeraire may seem quite striking but is consistent (especially the post-Bretton Woods period) with other evidence (e.g., Papell and Theodoridis (2001)).

One potential weakness of panel tests of unit roots is that linkages among the units may

exist. For example O'Connell (1998) suggests that non-zero covariances of the errors across the units imply short-run linkages among the units. If such dependency exists among cross sections then many panel unit tests including the IPS test are invalid. In order to avoid this problem we also use tests that are designed to be correctly sized even in the presence of cross-sectional dependency. In Tables 5-8 we provide the results of three specifications for a univariate version of the Chang (2002) tests as well as three specifications for the panel Chang (2002) test. The nonlinear function is chosen to be a Hermite polynomial following Chang (2002). We apply the methodology outlined in section 3.1 to this test. Overall these tests seem to reject more easily the null of nonstationarity as compared to the Dickey Fuller and IPS tests. The modified procedure panel tests again indicate stronger evidence of mean reversion as compared to the univariate tests (which correspond to the conventional Dickey-Fuller tests) both when the full period is covered and when only the floating exchange rate period is covered.

More specifically the univariate test results for the full sample when the US dollar is the numeraire show that up to nine out of 22 real exchange rates are stationary while the multivariate/panel test results show that up to 17 out of 22 series are stationary (see Table 5). During the post Bretton-Woods period the rejections of nonstationarity are more frequent with both the univariate and panel tests rejecting the null up to 14 and 18 times respectively in 25 series (see Table 6). When the DM is used as the numeraire currency for the period that includes the fixed exchange rates the univariate tests reject the unit root-null in up to five out of the 22 cases and the panel tests reject the unit root null in up to eight out of the 22 cases. Focusing on the flexible exchange rate period, however, the evidence against the unit root null get much stronger. In particular the univariate tests reject the nonstationarity null in up to 11 out of 25 countries and the panel tests in up to 15 out of the 25 countries.

The results are consistent across the various tests in the sense that all the real exchange rates which are found stationary with the univariate tests are also found stationary with the panel tests (this is the case for both periods and both numeraires, i.e. Tables 5, 6, 7 and 8). Moreover, the results for specific real exchange rates appear consistent across the various tests. That is, some real exchange rates emerge as stationary and some as nonstationary regardless of the test used. For most of the real exchange rates we consider, however, the use of panel tests is decisive in uncovering evidence for PPP. To our knowledge, the existing literature on panel unit root tests does not allow for making such comparisons since focusing on the time series properties of individual real exchange rates is not feasible.

Consider the real exchange rates against the dollar for example. Some of them appear consistently stationary regardless of whether one uses univariate or multivariate tests. Such are the real exchange rates of small open economies, such as Denmark, Finland, Malta, the

Netherlands and New Zealand. Clearly for those real exchange rates it does not make a great difference whether one uses consider their stationarity using univariate or multivariate methods). Another set of exchange rates appears almost invariably as nonstationary and includes those of Australia, Canada, Korea, Norway, and Portugal. The typical panel unit root tests which show that the null for the panel can be rejected are therefore misleading. Another set of real exchange rates includes those where the choice to use univariate or multivariate approaches affects the results. This is a "gray area" where the usefulness of distinguishing between stationary and non stationary series in a given panel becomes critical. We find that the ability to reject the nonstationarity null is enhanced in eleven countries. For some of them (Cyprus, France, Germany and Italy), the evidence suggests that the real exchange rate is on balance stationary with the panel tests further strengthening the case. In other cases, however, (Greece, Japan, Switzerland, and the UK) the use of multivariate methodologies becomes crucial in obtaining evidence of stationarity on balance. The use of panel tests allows for a more dramatic overturn of the results in the real exchange rates of Austria, Belgium and Spain, where the multivariate tests indicate stationarity while all the univariate would someone to accept the null. The panel tests are critical in obtaining the stationarity results.

Banerjee, Marcellino, and Osbat (2003) suggest that since the panel unit root tests assume away the presence of cross-section cointegrating relationships, if this assumption is violated the tests become oversized. Such relationships/linkages can emerge because of common factors or omitted variables. The test by Chang (2002) is itself not valid under cointegration. To correct for this possibility we employ a test introduced by Chang and Song (2002) that takes into account the possibility that cointegrating relationships between the cross-sectional units may exist. Again, Hermite polynomial are used (in this case different ones for every cross-sectional unit). We provide the results of this test in Tables 9-12. The results are not identical but in general the results point to the same direction as those of Tables 1-8. That is, using multivariate tests produces significantly more evidence of real exchange rate stationarity. One problem with the Chang and Song (2002) tests with cointegration, however, is that their results may be sensitive to the ordering of the series. This is because different functional forms are used for different cross-sectional units. Indeed if we run the same test where the series are introduced in reverse order (Tables 13-16) the results are slightly affected. Thus, we use those results only as indicative and not as definitive.

5 How Bad is the PPP Puzzle?

PPP is not inconsistent with temporary deviations from it. Theory suggests that the predominant causes for such departures from PPP should be sought in monetary and financial shocks when price stickiness exists. The observed high degree of short-term volatility in (nominal and real) exchange rates would be also be consistent with such nominal stickiness. Consequently the real exchange rate persistence that one should expect to observe should more or less match the period of price (and/or wage) adjustment to shocks. In reality, however, the degree of persistence in real exchange rates exceeds the magnitudes that would be consistent with adjustment to nominal shocks and seems to be more easily reconcilable with real shocks (e.g., shocks to productivity and tastes). This, however, is not consistent with high degree of short-term exchange rate volatility. This inconsistency has been termed the "PPP puzzle" by Rogoff (1998).

The measure of real-exchange-rate persistence that dominates the literature is the half-life of PPP deviations which indicates how long it takes for the impact of a unit shock to dissipate by half. Half-lives are typically estimated from autoregressive processes. We use a standard formula for the half-life given by $H = T \log 2$, where T is the life time of the process. One can further derive a relationship relating the life time with the speed of adjustment parameter β in an autoregressive process of order one, of the real exchange rates as $T = -1/(\log \beta)$. Then the half-life that utilizes the speed of adjustment parameter can be written as¹¹

$$H = -\log 2 / (\log \beta)$$

Studies of PPP typically find a high degree of persistence in real exchange rates with half-lives usually ranging between three to five years (see Rogoff (1998)).¹² Frankel and Rose (1996) for example, in a study covering 150 countries find a half-life of four years. Abuaf and Jorion (1991) multivariate approach indicates half-lives of 3.3 years, Wei and Parsley find half-lives well in excess of four years, Frankel and Rose (1996) finds that the £/\$ half-life is 4.6, years, and so on.

Those results typically refer to the average half-life estimates of based on autoregressive models of *all* real exchange rates. That is, both the stationary and nonstationary ones. Including the half-lives of the nonstationary real exchange rates, however, may be misleading since one cannot expect their persistence to die out. The nonstationary real exchange rates

¹¹Typically an $AR(1)$ process is assumed but for an $AR(q)$ process one can use the approximation $H = -\log 2 / (\log |\beta_1|)$.

¹²Studies exist, nevertheless that either exceed or fall short of those bounds. For example, Lothian and Taylor (1996) find that the half-life for the \$/£ real exchange rate is 5.9 years and Papell (1997) finds that the half-lives of the real exchange rates in Europe can be as low as 1.9 years. Also Cumby (1996) puts this number close to 1 but the methodology he uses is different, focusing on Big Mac indices.

do not revert to their PPP values and therefore the estimated half-lives for those process are of little relevance. Therefore, it is more meaningful to focus only on the half-lives of the stationary real exchange rates when of assessing the speed of adjustment to PPP.

Existing PPP studies that use multivariate methodologies are not able to identify the individual real exchange rates that make it possible to reject the null. Therefore it has not been feasible to obtain half-lives estimates of the stationary-only series. Our analysis, however, allows us to do so, and as we show below the results are striking.

We compare the average half-lives for all real exchange rates within a given panel with the average half-lives for the stationary-only real exchange rates. We consider the sets of stationary series that emerge from applying our methodology to the IPS and Chang (2002) tests. The results in Table (20) indicate that when only stationary series are considered the half-lives of adjustment to PPP become shorter by up to one year for the \$US real exchange rate and by up to 2.5 years for the DM real exchange rate. The gains in the speed of mean reversion for both the £US and the DM real exchange rates are more pronounced when the full period is considered. They are also more pronounced when the IPS test is used as compared to the Chang tests, except in the case of the post-Bretton Woods DM real exchange rates.

A similar pattern emerges when we consider the half-life of the series estimated as a panel. To do this we fit an AR(1) model to the whole panel. In one case we estimate the half-life when all series are included in the panel. This is a usual practice in the literature. On the other hand we estimate the model when the panel contains only stationary series which have also been found to be poolable following the methodology of section 3.2. The results of the poolability methodology are presented in Table 17. Note that for the purposes of constructing the stationary dataset we use a version of the test that has both a constant and a trend in the case of the full sample but only a constant for the Post Bretton Woods sample. The half-lives that emerge are very close to the aggregate half-lives when the AR processes for real exchange rates are estimated individually. Table (21) shows that when we include all the real exchange rates the resulting half-lives for the four datasets under consideration vary from 3.66 to 3.87 years. This is consistent with the surveying of the literature by Mark (2001) which shows an average half-life of 3.7. When we consider the panels that include only the stationary real exchange rates the adjustment process becomes faster by 0.33 to 1.62 years with the half-lives varying between 1.83 and 3.45 when the IPS test is used and between 2.65 and 3.45 when the Chang test is used. To be more specific when only the stationary real exchange rates are considered as they emerge from the IPS and the Chang tests respectively the half-lives become shorter by 0.85 and 0.35 years for the full sample of the \$US real exchange rates, by 0.43 and 0.75 years for the post-Bretton Woods

\$US real exchange rates, by 1.65 and 0.85 for the full sample of the DM real exchange rates, and by 0.45 and 1 for the post-Bretton Woods DM real exchange rates. Thus, we find that the persistence of deviations from PPP may have been overstated in previous research and that, on balance, the so-called PPP-puzzle is less pronounced when one focusses only the stationary real exchange rates.

6 Conclusion

We consider the stationarity of real exchange rates in up to 25 OECD economies in order to assess the case for PPP focusing on the recent float and using the \$US and the DM as numeraires. We implement a new set of procedures that allows to identify the mean-reverting series within a panel. This procedure is applied to panel unit root tests, both to conventional as well as to recently developed tests that account for cross-sectional dependence. In addition we introduce a methodology that formally evaluates the legitimacy of pooling particular sets of real exchange rates together.

Our results show increased evidence of mean-reversion in real exchange rates and therefore strengthen the case for PPP for the real exchange rates of 25 OECD countries. Those results are particularly strong for the \$US real exchange rates during the current float -a period for which earlier work has typically failed to find support for PPP. What makes our work interesting is that we are able to identify the stationary real exchange rates in the panels without trading-off any test power. Moreover, when we perform tests for cross-sectional dependence our results remain robust.

Being able to identify the stationary real exchange rates in our panels allows us to focus only the half-lives focusing of the mean-reverting series. We show that when one focuses on the stationary real exchange rates within the panel the half-lives become shorter. The PPP-puzzle does not disappear but it becomes less pronounced and the resulting half-lives estimates become more compatible with those predicted by typical sticky-price models. We conclude that the so-called "PPP-puzzle" may have been overstated. Further issues remain open, however, pertaining to further explaining and understanding the stylized facts of the empirical literature such as those related to the source and nature of the deviations from PPP.

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Table 1Stationary Series according to ADF and IPS Tests, \$US, Full sample¹³

DF1	DF2	DF3	SPSM1	SPSM2	SPSM3
Swe	NZ	Mal		Bg	Cyp
	SAf	SAf		Gr	Fr
				Ita	Ita
				NZ	Jap
				SAf	Mal
					NZ
					SAf
					Sp
					UK

Table 2

Stationary Series according to ADF and IPS Tests, \$US, Post- Bretton Woods

DF1	DF2	DF3	SPSM1	SPSM2	SPSM3
Swe	Fin			Aut	Mal
	Neth			Bg	Neth
				Cyp	SAf
				Den	
				Fin	
				Fr	
				Ger	
				Ita	
				Mex	
				Mal	
				Neth	
				NZ	
				SAf	
				Swi	
				UK	

Table 3

Stationary Series according to ADF and IPS Tests, DM, Full sample

DF1	DF2	DF3	SPSM1	SPSM2	SPSM3
NZ	Por	Aus			Aus
		Por			Por
		SAf			

¹³Aus: Australia, Aut: Austria, Bg: Belgium, Can: Canada, Cyp: Cyprus, Den: Denmark, Fin: Finland, Fr: France, Ger: Germany, Gr: Greece, Ita: Italy, Jap: Japan, Kor: Korea, Lux: Luxembourg, Mal: Malta, Mex: Mexico, Neth: Netherlands, NZ: New Zealand, Nor: Norway, Por: Portugal, SAf: South Africa, Sp: Spain, Swe: Sweden, Swi: Switzerland, UK: United Kingdom, US: United States

Table 4

Stationary Series according to ADF and IPS Tests, DM, Post-Bretton Woods

DF1	DF2	DF3	SPSM1	SPSM2	SPSM3
NZ	Aut	Aut	Swe	Aus	Aus
Swe	Cyp	Bg		Aut	Aut
	Den	Cyp		Bg	Bg
	Fin	Fr		Cyp	Cyp
	Fr	Por		Den	Den
	Swe	Swi		Fin	Fr
	Swi			Fr	Por
				Mex	Swi
				NZ	
				Nor	
				Por	
				Swe	
				Swi	
				UK	
				US	

Table 5

Stationary Series according to Chang Tests, \$US, Full sample

C1	C2	C3	SPSM1	SPSM2	SPSM3
Swe	Bg	Cyp		Bg	Aut
	Cyp	Fr		Cyp	Bg
	Fin	Ita		Fin	Cyp
	Fr	Jap		Fr	Fin
	Gr	Mal		Gr	Fr
	Ita	NZ		Ita	Ger
	Lux	SAf		Lux	Gr
	NZ	UK		NZ	Ita
	SAf			SAf	Jap
	UK			UK	Lux
					Mal
					NZ
					SAf
					Sp
					Swe
					Swi
					UK

Table 6

Stationary Series according to Chang Tests, \$US, Post Bretton Woods

C1	C2	C3	SPSM1	SPSM2	SPSM3
Swe	Aut			Aut	Neth
	Bg			Bg	SAf
	Den			Cyp	
	Fin			Den	
	Fr			Fin	
	Ger			Fr	
	Gr			Ger	
	Ita			Gr	
	Lux			Ita	
	Mal			Kor	
	Neth			Lux	
	NZ			Mal	
	Swi			Neth	
	UK			NZ	
				SAf	
				Sp	
				Swi	
				UK	

Table 7

Stationary Series according to Chang Tests, DM, Full sample

C1	C2	C3	SPSM1	SPSM2	SPSM3
Neth	Fin	Aus		Nor	Aus
NZ	Nor	Can		Por	Can
Swe	Por	Jap		UK	Jap
	UK	Por			Nor
		SAf			Por
					SAf
					UK
					US

Table 8

Stationary Series according to Chang Tests, DM, Post-Breton Woods

C1	C2	C3	SPSM1	SPSM2	SPSM3
Neth	Aus	Kor	Swe	Aus	Aus
NZ	Bg	Por		Bg	Fin
Swe	Can			Can	Kor
	Fin			Cyp	NZ
	Fr			Fin	Por
	Kor			Fr	Swi
	NZ			Gr	
	Nor			Kor	
	Por			NZ	
	UK			Nor	
	US			Por	
				SAf	
				Sp	
				UK	
				US	

Table 9

Stationary Series according to Chang Tests (Cointegration Robust), \$US, Full sample

C1	C2	C3	SPSM1	SPSM2	SPSM3
Fin	Bg	Cyp	Fin	Bg	Aut
Ger	Cyp	Fr	Ger	Fin	Bg
Gr	Fin	Ita	Mal	Gr	Cyp
Mal	Fr	Lux		Swi	Fin
	Gr	Mal			Fr
	Lux				Ger
	NZ				Gr
	Swi				Ita
					Jap
					Lux
					Mal
					Sp

Table 10

Stationary Series according to Chang Tests (Cointegration Robust), \$US, Post-Bretton
Woods

C1	C2	C3	SPSM1	SPSM2	SPSM3
Fin	Aut			Aut	
Kor	Bg			Bg	
Swi	Den			Cyp	
	Fin			Den	
	Fr			Fin	
	Ger			Fr	
	Lux			Ger	
	Mal			Gr	
	Neth			Lux	
				Mex	
				Mal	
				Neth	

Table 11

Stationary Series according to Chang Tests (Cointegration Robust), DM, Full sample

C1	C2	C3	SPSM1	SPSM2	SPSM3
Neth	Fin	Aus	Nor		Aus
NZ	Nor	Can			Can
Nor	Por	Jap			Jap
		Por			Lux
					Nor
					Por

Table 12

Stationary Series according to Chang Tests (Cointegration Robust), DM, Post Bretton
Woods

C1	C2	C3	SPSM1	SPSM2	SPSM3
Aut	Aus	Por	Aus	Aus	Por
Gr	Bg		Aut	Bg	
Kor	Can		Gr	Can	
Neth	Fin		Jap	Cyp	
NZ	Fr		Kor	Fin	
Por	NZ		Neth	Fr	
Sp	Nor		NZ	Gr	
	Por		Por	NZ	
	Swe		SAf	Nor	
			Sp	Por	
				Sp	
				Swe	
				UK	

Table 13

Stationary Series according to Chang Tests (Cointegration Robust (reverse order)), \$US,
Full sample

C1	C2	C3	SPSM1	SPSM2	SPSM3
Neth	UK	UK	Neth	NZ	UK
Mal	NZ	SAf	Mal	Gr	Swi
Ger	Lux	Mal	Ger	Bg	Swe
Fr	Gr	Lux	Fr		Sp
Fin	Fin	Ita	Fin		SAf
	Bg	Fr			NZ
		Cyp			Mal
					Lux
					Jap
					Ita
					Ger
					Fr
					Cyp

Table 14

Stationary Series according to Chang Tests (Cointegration Robust (reverse order)), \$US,
Post-Bretton Woods,

C1	C2	C3	SPSM1	SPSM2	SPSM3
Kor	UK			UK	
	Swi			Swi	
	Neth			Sp	
	Mal			Neth	
	Lux			Mal	
	Ger			Lux	
	Fr			Ger	
	Fin			Fr	
	Cyp			Fin	
	Bg			Cyp	
				Bg	

Table 15

Stationary Series according to Chang Tests (Cointegration Robust (reverse order)), DM,
Full Sample

C1	C2	C3	SPSM1	SPSM2	SPSM3
Nor	UK	SAf	NZ		US
NZ	Por	Por	Gr		UK
Neth	Nor	Aus			SAf
Ita	Fin				Por
Gr					Nor
Can					Jap
					Aus

Table 16

Stationary Series according to Chang Tests (Cointegration Robust (reverse order)), DM,
Post-Bretton Woods

C1	C2	C3	SPSM1	SPSM2	SPSM3
Swe	US	Por	Swe	US	Por
Nor	UK		Nor	UK	Kor
NZ	Por		NZ	Sp	
Neth	Nor		Neth	Por	
Gr	NZ		Gr	Nor	
Can	Fr		Can	NZ	
	Fin			Gr	
	Bg			Fr	
				Fin	
				Cyp	
			Bg		

Table 17

Poolable Series¹⁴

D1	D2	D3	D4	D5	D6	D7	D8
Cyp	Aut	Aus	Aus	Aut	Aut	Aus	Aus
Fr	Bg	Por	Bg	Bg	Bg	Can	Bg
Ita	Cyp		Cyp	Cyp	Cyp	Jap	Can
Jap	Den		Den	Fin	Den	Nor	Cyp
Mal	Fin		Fin	Fr	Fin	Por	Fin
NZ	Fr		Mex	Ger	Fr	SAf	Fr
SAf	Ger		NZ	Gr	Ger	UK	Gr
Sp	Ita		Nor	Ita	Gr	US	Kor
UK	Mex		Por	Jap	Ita		NZ
	Mal		Swi	Lux	Kor		Nor
	Neth		UK	Mal	Lux		Por
	NZ		US	NZ	Mal		SAf
	SAf			SAf	Neth		Sp
	Swi			Sp	NZ		UK
	UK			Swe	SAf		US
				Swi	Sp		
				UK	Swi		
					UK		

¹⁴D1: \$US, Full sample, IPS test; D2: \$US, Post Bretton Woods, IPS test; D3: DM, Full sample, IPS test; D4: DM, Post Bretton Woods, IPS test; D1: \$US, Full sample, Chang test; D2: \$US, Post Bretton Woods, Chang test; D3: DM, Full sample, Chang test; D4: DM, Post Bretton Woods, Chang test;

Table 18
Individual Half Lives (HL), \$US

\$US Full Sample	HL	\$US Post-BW	HL
Aus	6.154	Aus	5.583
Aut	4.161	Aut	3.112
Bg	4.011	Bg	4.289
Can	74.051	Can	-
Cyp	3.352	Cyp	3.557
Fin	2.546	Den	3.386
Fr	3.282	Fin	2.668
Ger	4.649	Fr	3.186
Gr	3.338	Ger	3.244
Ita	2.952	Gr	3.400
Jap	4.167	Ita	3.069
Lux	5.003	Jap	4.238
Mal	2.302	Kor	3.297
Neth	5.631	Lux	4.341
NZ	3.128	Mex	4.191
Nor	6.571	Mal	3.016
Por	4.850	Neth	1.359
SAf	1.733	NZ	3.107
Sp	3.882	Nor	2.327
Swe	4.545	Por	5.148
Swi	4.165	SAf	3.035
UK	2.103	Sp	4.041
		Swe	5.997
		Swi	2.497
		UK	2.282

Table 19
Individual Half Lives (HL), DM

DM Full sample	HL	DM Post-BW	HL
Aus	1.651	Aus	2.683
Aut	2.655	Aut	5.678
Bg	7.018	Bg	3.301
Can	3.441	Can	3.892
Cyp	15.676	Cyp	2.535
Fin	2.446	Den	2.636
Fr	2.016	Fin	4.398
Gr	5.123	Fr	1.216
Ita	6.210	Gr	0.987
Jap	1.642	Ita	4.176
Lux	2.823	Jap	4.354
Mal	11.647	Kor	1.520
Neth	6.302	Lux	3.604
NZ	2.399	Mex	3.359
Nor	3.745	Mal	4.801
Por	2.327	Neth	4.350
SAf	1.688	NZ	1.494
Sp	1.815	Nor	3.432
Swe	8.756	Por	4.250
Swi	2.513	SAf	2.837
UK	4.108	Sp	3.023
US	4.658	Swe	9.143
		Swi	3.111
		UK	3.250
		US	3.253

Table 20

Average Half-Life Measure				
	\$US Full	\$US post-BW	DM Full	DM post-BW
All RERs	3.93	3.51	4.57	3.49
Only Stationary RERs (IPS)	2.98	3.07	1.89	3.24
Only Stationary RERs (Chang test)	3.49	3.16	2.91	2.36

Table 21

Panel Half-Life Measure				
	\$US Full	\$US post-BW	DM Full	DM post-BW
All RERs	3.797	3.875	3.514	3.662
Only Stationary and Poolable RERs (IPS)	2.949	3.449	1.833	3.213
Only Stationary and Poolable RERs (Chang test)	3.462	3.128	2.692	2.655

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