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. However, one weakness of such tests seems to be their failure to inform the researcher as to which exactly cross-section units are stationary. As a consequence, a reservation for PPP analyses based on such tests is that the results may be driven by a small number of real exchange rates in the panel.

In this paper we examine for PPP 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 those procedures to tests that account for cross-sectional dependence. Our results reveal evidence of mean-reversion that is significantly stronger as compared to those obtained by standard stationarity tests, strengthening the case for PPP. Moreover, we provide half-lives estimates for the mean-reverting real exchange rates based on both traditional measures and a new alternative measure. We find that the half-lives are shorter than earlier thought.

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

JEL Classification: C12, C15, C23, F31

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*This is a preliminary and incomplete draft. Please do not quoate without the author's permission. Part of this research was initiated while the first author was at the University of Connecticut. We thank Andrew Bailey for encouragement and helpful discussions. The views are of the authors and do not necessarily reflect those of the Bank of England.

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1 Introduction

Given the central role of Purchasing Power Parity (PPP) in theoretical models of 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 macroeconomics[1]. The literature that considers the time series properties of the real exchange rate and the persistence of deviations from PPP has evolved over time, partly reflecting developments in econometric methodology. Thus, from the Augmented Dickey-Fuller (ADF) tests researchers gradually moved to tests that incorporate structural breaks, fractionally integrated processes, tests where stationarity is the null hypothesis, and so on. The focus of the most recent advances in the relevant research, however, is on nonlinearities and on time series properties of real exchange rates in panel frameworks. Our contribution relates mainly to the last aspect.

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. PPP was challenged by the results of earlier studies focusing on the first years after the Bretton-Woods and using tests with high statistical power to reject the null strengthens the evidence for real exchange rate stationarity, helping to restore confidence in PPP. In addition 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. The failure of such tests to provide information as to which exactly cross-section units are stationary make researchers to have reservations for the evidence either because the test results could be driven by a small num-

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

[2] Taylor and Sarno (1998) emphasize this point.

ber of real exchange rates in the sample and/or because the outcome of the tests is sensitive to the selection of series included in the panel.

This problem, therefore, emerges as possibly the "Achilles heel" of panel-unit-root tests applied to real exchange rates. The existing panel tests no-doubt help to answer a set of questions that motivate economists to do research on PPP. Such questions mostly pertain to its general validity as a long-run international parity condition that constitutes a fundamental building block of international macroeconomics. The inability of the existing panel tests to provide country specific results, however, constitutes a serious handicap when the focus is on some policy related and practical issues. For example, when the degree of real exchange rate persistence is used as an indication of whether the shocks are real or generated in the aggregate demand side a meaningful discussion should be based on specific results for each country/real exchange rate. Such limitations become even more obvious when PPP studies are motivated by the need to obtain a benchmark for policy[3] such as setting of exchange rate parities, gauging the degree of exchange rate misalignment, comparing national income levels, and so on.

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.[4]

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. In addition we introduce a similar procedure that evaluates the poolability of the real exchange rates series in panels -a dimension usually overlooked. 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. 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 some straightforward advantages compared to the standard panel test methodologies. While we

[3] For example, see Engel (2002).

[4] For example, see Deveraux and Engel (2002).

exploit all advantages of the panel structure (such as their enhanced power), 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 use a new methodology that considers the legitimacy of pooling given sets of real exchange rates in a panel. 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 the state-of-the-art panel tests which are free from a number of pitfalls characterizing the main body of the relevant literature (such as correcting for 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. Fifth, in addition to the standard half-life measure, we use an new one. Finally, we consider a number of additional 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 the real exchange rates that are stationary versus those that follow random walks. Moreover, we are able to focus on the half-lives of the mean-reverting real exchange rates. We find that the half-lives are not as lengthy as initially thought, indicating that the "PPP puzzle" may not be so puzzling. This evidence is strong, especially during the post-Bretton Woods era, where earlier studies failed to uncover evidence for PPP.

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 the results of our analysis. Section 5 discusses those results and their implications emphasizing how they differ from existing evidence. Finally, Section 6 concludes.

2 A Review of Some Issues Related to PPP

A stylized fact of the post-Bretton Woods float 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 series. Despite the voluminous literature and the most recent evidence of real exchange rate stationarity the profession's conventional wisdom concerning PPP remains, in general, inconclusive. The studies that consider relatively long time-series, low frequency data, and use new statistical methodologies tend to be more successful in validating PPP.

Leaving aside studies that use cointegration frameworks or variance ratio tests, a 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.[5] Early attempts to utilize panel data sets as a means of increasing the power of unit root tests in PPP studies include Hakkio (1984) and Abuaf and Jorion (1990). Tests for unit roots within heterogeneous panels are currently well established, and the most widely used approaches are those of **?**, and **?**.[6] Until the emergence of nonstationary panel techniques the evidence supporting the existence of PPP had not only been weak (see **?** and **?**) but also lacked robustness. In particular, the results tended to depend on the length of the sample period, the choice of countries and in particular the choice of numeraire currency. 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. In particular, Papell and Theodoridis (2000) 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.

Early studies of PPP using panel unit-root tests reversed the relatively gloomy for PPP picture. Studies like Coakley and Fuertes (1997), **?**, **?**, **?**, **?**, Taylor and Sarno (1998), **?**, and so on, provided increased evidence of real exchange stationarity using panel frameworks focusing on industrial

[5] For surveys see **?**, **?**, and **?**, A. Taylor ( ) and Sarno and Taylor ( ).

[6] Other approaches exist in testing for the presence of unit roots in heterogeneous panels, including those of **?**, **?**, and so on.

countries. Withe the exception of Coakley and Fuertes (1996) and **?** all the above studies rely primarily on the use of the **?** tests -as this paper does as well.

Despite the increased ability to uncover evidence that validates PPP when panel data are used[7] the existing evidence of panel data studies are not necessarily considered conclusive. Another set of evidence based on panel data methodologies exists that is less favorable to PPP (**?**, **?**, **?**, **?**). The fact that a number of studies employing panel tests fail to always rescue the PPP hypothesis makes the issue more contentious. In summary, while the results on balance are supportive of PPP, they are not unanimous by any means.

A critical issue that emerges when panel unit roots are employed is the problem of cross-sectional dependence. O'Connell's (1998) work has been particularly influential in this area by suggesting that 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 Anker (1999), Flores et. al. (1999), Papell and Theodoridis (1998), Taylor and Sarno (1998)- provided more favorable evidence for PPP. Papell (1997), using **?** 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 cleraly 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 and her coauthors in a number of papers. In particular, Chang and Song (2003) discuss a panel unit root test where the use of nonlinear covariates in a Dickey-Fuller unit root regression context makes the text 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 where the nonlinear covariates are uncorrelated even in the presence of cointegration in the series. Our results are supportive for PPP even after incorporating those possibilities.

[7] Infulential papers with such findings inculde those of Abuaf and Jorion (1990), **?** and Taylor and Sarno (1998).

[8] More recently, Banerjee et al. (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.

Many authors, however, have pointed out other -potentially more fundamental- perils of using panel unit-root tests (e.g., Mark 2001, Taylor and Sarno 1998, Sarno and Taylor 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 exists where the panel appears as stationary but most 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/wrongly conclude that the panel is on balance stationary or -in the best case- he will not be able to distinguish which are the cross-sectional units that display stationarity.

While some attempts have been made to circumvent this problem (Taylor and Sarno, 1998), to our knowledge there is no procedure available so far that directly considers stationarity of the individual cross-sectional units in a panel framework. Flores et. al. (1999) attempt to address this problem by allowing different cross-section units to have different speeds of mean-reversion but this is not a direct test.

Another dimension of analyzing PPP issues in panels that has received scant -if any- attention relates to the validity of pooling specific sets of real exchange rate series. Applying a panel test 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 panel are employed. When discretion is exercised in removing or adding cross-section units in the panel the (summary) result can be affected. Rogoff (1996), 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 PPP studies. Rogoff (1996), for example, suggests another potential criticism of the favorable-to-PPP results obtained with panel tests which is their inclusion of high-inflation countries. This is a special case where that specific cross-section units drive the results. Other cases where the results may be driven by a small number of cross-sectional units include .... Our analysis, however, is not only immune to this kind of criticism but also provides a way of getting around this problem.

In particular, since we provide an account of the time series properties of individual real exchange rate this problem disappears.

[I think that we should omit thi paragraph-it is relevant only if we try to do the relative price versus the exchange rate movenets analysis]

Besides the explanations for the failure of PPP that are primarily statistical in nature (i.e., having to do with the imperfections of the existing econometric techniques) a number of theoretical explanations have been posed. Some of the possible reasons that have been put forward for the failure to find evidence for PPP include traditional forms of price stickiness (Dornbusch, 1976) as well as explanations based on trade costs (e.g., Dumas, 1992) and price discrimination (e.g., Chari, Kehoe, and McGratan, 2000). To what extend the two types of explanations /literature are consistent and reinforce each other?

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., **?**, 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 (2003a). 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 **?** 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 stationarity 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 $H_0 : \beta_j = \beta$, $j = 1, \ldots, N$ 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 **?**, is to use an extension of the **?** parameter stability test on the pooled dataset. Other tests for this null hypothesis have been developed by **?** and **?**.

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 non-poolable 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 (2003b).

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 a panel and the methodology for determining the poolability of the series is discussed in the following two subsections.

3.1 Separating stationary from nonstationary series

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

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

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

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

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

$$H_0 : \beta_j = 0, \quad \forall j \tag{3}$$

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 $\Delta\mathbf{y}_j = (\Delta y_{j,1},\ldots,\Delta y_{j,T})'$ on a matrix of deterministic regressors $\boldsymbol{\tau}_T$ and $\mathbf{y}_j = (y_{j,0},\ldots,y_{j,T-1})'$. $\boldsymbol{\tau}_T$ could include just a constant, i.e. $\boldsymbol{\tau}_T = (1,\ldots,1)'$ or a constant and a time trend, i.e. $\boldsymbol{\tau}_T = ((1,1)',(1,2)',\ldots,(1,T)')'$.

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

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

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

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

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

$$\bar{t}_T = 1/N\sum_{i=1}^{N} t_{j,T} \tag{6}$$

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

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

As **?** discuss, this test has a standard normal distribution if $N \to \infty$. $E(t_T)$ 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 **?**.

For further use define the following. Let $\mathbf{Y_i} = (\mathbf{y}_{j_1}, \ldots, \mathbf{y}_{j_M})$, $\mathbf{i} = \{j_1, \ldots, j_M\}$ and $\mathbf{t_i} = (t_{j_1,T}, \ldots, t_{j_M,T})'$. Also define $\mathbf{i}^j = \{j\}$, $\{1, \ldots, N\} \equiv \mathbf{i}^{1,N}$ 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 no consider the case $\beta_j > 0$. Then, $\mathcal{I}_{\mathbf{i}} = (\mathcal{I}_{j_1}, \ldots, \mathcal{I}_{j_M})'$. We wish to estimate $\mathcal{I}_{\mathbf{i}^{1,N}}$. We denote the estimate by $\hat{\mathcal{I}}_{\mathbf{i}^{1,N}}$.

To do so we consider the following procedure.

1. Set $j = 1$ and $\mathbf{i}_j = \{1, \ldots, N\}$.
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 $\hat{\mathcal{I}}_{\mathbf{i}_j} = (0, \ldots, 0)'$. If the test rejects go to step (3).
3. Set $\hat{\mathcal{I}}_{\mathbf{i}^l} = 1$ 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 (2003a).

3.2 Separating poolable from nonpoolable series

To illustrate the methodology, consider the following panel data model

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

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

$$H_0 : \beta_j = \beta, \quad \forall j \tag{9}$$

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

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

This is a Haussman type statistic. If the panel estimator, $\tilde{\beta}$, were efficient then, under the null hypothesis we know from **?** that

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

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

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

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 $N \to \infty$. 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 $T \to \infty$

$$S_{T,j} \xrightarrow{d} \chi^2_k \tag{13}$$

for each unit j.

The poolability test is based on the $S_{T,j}$ statistics. In particular Kapetanios (2003b) suggests that $S^s_T = sup_j S_{T,j}$ be used as a test statistic for the test of the null hypothesis H_0. As before, let $\mathbf{Y_i} = (\mathbf{y}_{j_1}, \ldots, \mathbf{y}_{j_M})$, $\mathbf{i} = \{j_1, \ldots, j_M\}$ and $\mathbf{i}^j = \{j\}$, $\{1, \ldots, N\} \equiv \mathbf{i}^{1,N}$ 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, $\mathcal{I}_{\mathbf{i}} = (\mathcal{I}_{j_1}, \ldots, \mathcal{I}_{j_M})'$. We wish to estimate $\mathcal{I}_{\mathbf{i}^{1,N}}$. We denote the estimate by $\hat{\mathcal{I}}_{\mathbf{i}^{1,N}}$.

To do so we consider the following procedure.

1. Set $j = 1$ and $\mathbf{i}_j = \{1, \ldots, N\}$.
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 $\hat{\mathcal{I}}_{\mathbf{i}_j} = (0, \ldots, 0)'$. If the test rejects go to step (3).
3. Set $\hat{\mathcal{I}}_{\mathbf{i}^l} = 1$ 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 (2003b).

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). In each case the real exchange rate is bilateral. We use the average quarterly nominal exchange rates and the price levels are consumer price indices. All variables are in logs. All data are from the International Monetary Fund's *International Financial Statistics* in CD-ROM. The data are not seasonally adjusted.

Before we discuss the results of our analysis it is worth explaining the choice of the particular data set and the use of the $US and the DM as numeraires. Yen's behavior has been considered as exceptional in the post WWII era. 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.[9] The length of the data was dictated by the availability of the IFS/IMF data that are the universally accepted in this literature. We stop at 1998 because since then a number of countries in our sample joined the European Monetary Union (EMU) and have a common currency.[10]

4 Results

In presenting our results we arrange each table so that the first three columns correspond to three different specifications of the corresponding 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. We assume a typical four-lag structure. 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 results. The results of the standard panel unit root tests (i.e., without applying our methodology) are not provided because since we proceeding with the new methodology to identify the stationary series it implies that the series as a panel were found stationary (as described in section 3).

Tables 1-4 provide the results from applying our procedure to standard Augmented Dickey-Fuller (ADF) tests (first three columns) and the Im et. al. (1997) 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

[9]For a recent analysis of the yen real exchange that uncovers evidenc of stationarity taking into account nonlinear behavior see Chortareas and Kapetanios (2003).

[10]For an analysis that focuses explicitly on the real exchange rates after the launch of the EMU see Chortareas and Kapetanios (2004c).

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 Im et. al.'s (1997) 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 area 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).

In Tables 5-8 we provide the results of three specifications for a univariate version of the Chang (2003) tests as well as three specifications for the multivariate Chang (2003) test. We apply the methodology outlined in section 3 to the last test. Overall the Chang tests seem to reject more easily the null of nonstationarity as compared to the Dickey Fuller and Im et. al. 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 non-stationarity 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.

One potential weakness of panel tests of unit roots (and cointegration) is that linkages (or cointegrating vectors) 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. Banerjee et. al. (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. To correct for this possibility we employ a test introduced by Chang (2003) that takes into account the possibility that cointegrating relationships between the cross-sectional units may exist. 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 (2003) tests with cointegration, however, is that their results may be sensitive to the ordering of the series. Indeed if we run the same 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.

4.1 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 (1996).

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 the real exchange rates as $T = -1/(\log \beta)$. Then the half-life that utilizes the speed of adjustment parameter can be written as[11]

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

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, 1996).[12] Frakel and Rose (1996) for example, in a study covering 150 countries find a half-life of four years. Abuaf and Jorion's (1990) multivariate approach indicates half-lives of 3.3 years, Wei and Parsley find half-lives well in excess of four years, Frakel (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 do not revert to their PPP values and therefore the estimated half-lives for those process are or 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.

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

[12] Studies 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.

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 Im. et. al. (1997) and Chang (2003) 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 Im et. al. (1997) 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. That is we estimate the half-life when all series are included in the panel and then when only the stationary real exchange rates (as emerge from applying our methodology) are included in the panel. 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 (22) that includes all the real exchange rates shows that the traditional measure of half-lives for the four datasets considered 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 Im et. al. 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 merge from the Im et. al 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. The resulting half-lives of PPP deviations, however, remain higher that what would be consistent with the presence of nominal rigidities. We obtain estimates of half-lives however, based on an alternative approach recently suggested by Chortareas and Kapetanios (2004b). It may be debatable of course, whether the currently widely used measure of PPP deviations half-lives are the best, but they are not unique by any means. Half-lives are traditionally measured as the point in time following a shock, at which the instantaneous effect of the shock is half what it was at the time of the impact of the shock. It is therefore, an instantaneous concept. Chortareas and Kapetanios (2004b) propose viewing the cumulation of the effect of the shock as the relevant quantity. In this context, the half-life is defined as the point in time as which half the cumulative effect of the shock has elapsed. This is more in line with the concept of half-life as used in the physics literature, where the concept originated. An additional advantage of this approach is that it avoids uniqueness issues when shock effects are negative for absolute values of the impulse responses.

We provide individual estimates of the half-lives using the Chortareas and Kapetanios (2004b) measure in Tables (18) and (19). Table (21) mirrors the structure of Table (20) which uses the traditional measure. Our results show that the half-lives are considerably shorter. When considering all the exchanges rates for example the half-lives are between 1.69 to 2.62 years (when the AR process are estimated individually) and 1.68 and 2.0 years (when the AR process is estimated as a panel). Again, considering only the stationary real exchange rates bringing those ranges to 1.02 to 1.52 years and 0.96 to 1.61 years respectively. The detailed results showing specific values of half-lives emerging from using different for panel unit root tests are provided in Table (23).

On balance we show that the so-called PPP-puzzle is less pronounced when one focusses only the stationary real exchange rates. Moreover. when an alternative approach for measuring half-lives is used the puzzle is eliminated since the emerging half-lives are consistent with adjustment to nominal shocks.

5 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 both conventional and most recently developed panel unit root tests. We also use an additional methodology to evaluate the legitimacy of pooling particular sets of series together.

Our results show increased evidence of mean-reversion in real exchange rates and therefore strengthen the case for PPP. We are able to identify the stationary real exchange rates in the panels without trading-off any tests power. Our results are robust when tests for cross-sectional dependence are performed.

Moreover we consider the half-lives of PPP deviations and find that the so-called "PPP-puzzle" may have been overstated. First we show that when one focuses on the stationary only real exchange rates within the panel the half-lives become shorter. The PPP-puzzle does remains but it is less pronounced. When an alternative measure of half-lives is used the puzzle is eliminated and the resulting estimates become compatible with the predictions of the relevant theoretical literature.

Further issues remain open, however, pertaining to further explaining and understanding the stylized facts of the empirical literature. Some of the most interesting of those issues relate to the source and nature of the deviations from PPP.[13]

[13] For example, Taylor (2003) argues characteristically that deviations from PPP are "always and everywhere a monetary phenomenon" as Taylor (2003) suggests?

Table 1

DF and Im et. al. Tests, $US, Full sample, Lags 4

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

DF and Im et. al. Tests, $US, Post- Bretton Woods, Lags 4

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

DF and Im et. al. Tests, DM, Full sample, Lags 4

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

Table 4

DF and Im et. al. Tests, DM, Post-Bretton Woods, Lags 4

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
Chang Tests, $UD, Full sample, Lags 4

DF1	DF2	DF3	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
Chang Tests, \$UD, Post Bretton Woods, Lags 4

DF1	DF2	DF3	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
Chang Tests, DM, Full sample, Lags 4

DF1	DF2	DF3	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
Chang Tests, DM, Post-Breton Woods, Lags 4

DF1	DF2	DF3	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

Chang Tests with Cointegration, $UD, Full sample, Lags 4

DF1	DF2	DF3	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

Chang Tests with Cointegration, $UD, Post-Bretton Woods

DF1	DF2	DF3	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

Chang Tests with Cointegration, DM, Full sample, Lags 4

DF1	DF2	DF3	SPSM1	SPSM2	SPSM3
Neth	Fin	Aus	Nor	.	Aus
NZ	Nor	Can			Can
Nor	Por	Jap			Jap
		Por			Lux
					Nor
					Por

Table 12

Chang Tests with Cointegration, DM, Post Bretton Woods, Lags 4

DF1	DF2	DF3	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

Chang Tests with Cointegration (reverse order), $UD, Full sample, Lags 4

DF1	DF2	DF3	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
Chang Tests with Cointegration (reverse order), $UD, Post-Bretton Woods, Lags 4

DF1	DF2	DF3	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

Chang Tests with Cointegration (reverse order), DM, Full Sample, Lags 4

DF1	DF2	DF3	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 15
Chang Tests with Cointegration (reverse order), DM, Post-Bretton Woods, Lags 4

DF1	DF2	DF3	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 Series

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		

Table 18

Individual Half Lifes (HL1: Tradidional Measure; HL2: C&K Measure)

$US Full Sample	HL1	HL2	$US Post-BW	HL1	HL2
Aus	6.154	2.016	Aus	5.583	1.845
Aut	4.161	1.591	Aut	3.112	1.532
Bg	4.011	1.730	Bg	4.289	1.563
Can	74.051	2.385	Can	-2499.75	-2499.75
Cyp	3.352	1.893	Cyp	3.557	1.990
Fin	2.546	1.669	Den	3.386	1.558
Fr	3.282	1.465	Fin	2.668	1.184
Ger	4.649	1.786	Fr	3.186	1.350
Gr	3.338	2.385	Ger	3.244	1.392
Ita	2.952	1.146	Gr	3.400	2.839
Jap	4.167	1.292	Ita	3.069	1.252
Lux	5.003	1.803	Jap	4.238	2.526
Mal	2.302	1.001	Kor	3.297	1.115
Neth	5.631	3.287	Lux	4.341	1.640
NZ	3.128	1.092	Mex	4.191	2.026
Nor	6.571	3.208	Mal	3.016	1.279
Por	4.850	2.529	Neth	1.359	0.833
SAf	1.733	0.962	NZ	3.107	1.098
Sp	3.882	1.447	Nor	2.327	1.402
Swe	4.545	1.809	Por	5.148	2.592
Swi	4.165	1.560	SAf	3.035	1.348
UK	2.103	1.174	Sp	4.041	1.558
			Swe	5.997	4.262
			Swi	2.497	1.300
			UK	2.282	1.284

Table 19

Individual Half Lifes (HL1: Tradidional Measure; HL2: C&K Measure)

DM Full sample	HL1	HL2	DM Post-BW	HL1	HL2
Aus	1.651	0.913	Aus	2.683	1.123
Aut	2.655	3.814	Aut	5.678	4.071
Bg	7.018	5.728	Bg	3.301	1.135
Can	3.441	1.335	Can	3.892	1.499
Cyp	15.676	6.008	Cyp	2.535	1.908
Fin	2.446	2.593	Den	2.636	1.717
Fr	2.016	1.328	Fin	4.398	1.454
Gr	5.123	5.495	Fr	1.216	0.982
Ita	6.210	2.850	Gr	0.987	1.343
Jap	1.642	0.752	Ita	4.176	1.981
Lux	2.823	1.361	Jap	4.354	2.542
Mal	11.647	4.540	Kor	1.520	0.740
Neth	6.302	4.600	Lux	3.604	2.023
NZ	2.399	1.451	Mex	3.359	1.410
Nor	3.745	1.463	Mal	4.801	3.188
Por	2.327	1.043	Neth	4.350	2.604
SAf	1.688	1.110	NZ	1.494	0.915
Sp	1.815	1.120	Nor	3.432	1.257
Swe	8.756	4.989	Por	4.250	1.327
Swi	2.513	1.540	SAf	2.837	1.708
UK	4.108	1.835	Sp	3.023	1.508
US	4.658	1.791	Swe	9.143	5.616
			Swi	3.111	1.778
			UK	3.250	1.348
			US	3.253	1.393

Table 20

Traditional Half-Life Meassure

	\$US Full	\$US post-BW	DM Full	DM post-BW
All RERs	3.93	3.51	4.57	3.49
Only Stationary RERs	2.98	3.07	1.89	3.24
Only Stationary RERs Chang	3.49	3.16	2.91	2.36

Table 21

C&K Half-Live Meassure

	\$US Full	\$US post-BW	DM Full	DM post-BW
All RERs	1.75	1.69	2.62	1.86
Only Stationary RERs	1.27	1.40	1.02	1.37
Only Stationary RERs Chang	1.52	1.45	1.28	1.10

Table 22

Panel Half Lifes: All Series

Dataset	HL-Traditional	HL-CK
$US Full	3.797	1.683
$US post-BW	3.875	1.902
DM Full	3.514	2.006
DM post-BW	3.662	1.736

Table 23

Panel Half Lifes: Only stationary series

Dataset	HL-Traditional	HL-CK
Im et. al. Test		
\$US Full	2.949	1.241
\$US post-BW	3.449	1.611
DM Full	1.833	0.961
DM post-BW	3.213	1.361
Chang Test		
\$US Full	3.462	1.523
\$US post-BW	3.128	1.431
DM Full	2.692	1.224
DM post-BW	2.655	1.263