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## Smooth breaks and non-linear mean reversion: Post-Bretton Woods real exchange rates

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The recent literature on Purchasing Power Parity (PPP) has emphasized the role of two phenomena that may lead to the rejection of the PPP hypothesis: structural breaks and non-linear adjustment induced by transaction costs. These two hypotheses are analyzed separately in the literature. We develop tests for unit roots that account jointly for structural breaks and non-linear adjustment. Structural breaks are modeled by means of a Fourier function that allows for infrequent smooth temporary mean changes and is hence compatible with long-run PPP. Nonlinear adjustment is modeled by means of an ESTAR model. Our tests present good finite sample properties. The tests are applied to a set of 15 OECD countries' RERs and are able to reject the null of a unit root in 14 cases. The breaks are usually associated with the great appreciation and later depreciation of the dollar in the 1980s and the ESTAR adjustment appears to play an important role.

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### 1. Introduction

Purchasing Power Parity (PPP) remains one of the core assumptions of long-run equilibrium in a wide range of open economy macroeconomic models. Its importance has generated hundreds of empirical and theoretical papers.<sup>1</sup> The resiliency of the random walk model for the real exchange rate

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<sup>1</sup> Excellent overviews of the PPP literature can be found in the seminal papers of Rogoff (1996), Sarno and Taylor (2002) and Taylor and Taylor (2004).

(RER) has attracted wide attention because its incompatibility with PPP. To date, the consensus view is that, for very long time spans, PPP appears to hold although the speed of mean reversion of the RER is slow. Although the evidence regarding the recent historical period of floating exchange rates since the break-down of the Bretton-Woods system increasingly supports mean reversion, this evidence is still not as conclusive. This is especially the case when using US-dollar-based bilateral RERs.

The failure to find evidence in favor of PPP in the literature developed during the 1980s and early 1990s led to several new technical developments that attempted to correct the shortcomings of previous studies. Tests of the PPP hypothesis are commonly based on unit root tests on the RER. A RER that reverts to a constant mean is compatible with PPP, whereas a non-stationary RER would violate the hypothesis. The main problem of the initial studies based on standard unit root tests is the widely reported lack of power of these tests for finite samples. This problem is exacerbated in the typical sample periods used for tests based on post-Bretton-Woods data that usually span for 20–30 years. Attempts at circumventing this problem led to four main developments in the PPP literature. The first one is the use of historical datasets that substantially increase the sample period of analysis hence increasing the power of the tests as pioneered by [Lothian and Taylor \(1996\)](#). These tests, however, do not account for the fact that exchange rate regimes have experienced several important changes in the last century. The observed increased volatility of the RER under the floating period (see [Frankel and Rose, 1995](#)) that led the way to the development of sticky price models of the nominal exchange rate, bears the question of whether PPP is a valid explanation of exchange rate determination under floating exchange rate regimes.

The second development is the use of panel techniques such as in, for instance, [Coakley and Fuertes \(1997\)](#) and [Papell \(1997\)](#). Panel unit root tests can increase the power of unit root tests by making use of cross-sectional information. Although there are important merits to this approach, it has also been criticized on several basis. For instance, the existence of cross-sectional correlation that may lead to size distortions was first pointed out in [O'Connell \(1998\)](#). A second criticism from [Sarno and Taylor \(1998\)](#) is that in many of the panel unit root tests the null hypothesis is such that we could reject it if only one of the cross-sectional units is a stationary process.<sup>2</sup> This criticism is also important because it points out that panel methods can give a general picture of the stationarity properties of RERs, but fail to give an answer on a case by case basis. Finally, as pointed out by [Banerjee et al. \(2005\)](#), the potential presence of cross-unit cointegration relations may lead to size distortions that may account for the higher likelihood of rejecting the null of a unit root.

A third important innovation was made possible by the appearance of unit root tests that allow for breaking deterministic components as pioneered by [Perron \(1989\)](#). When RER deviate persistently from their equilibrium value due to long-lived events such as bubbles the mean to which they revert presents a temporary break which, if not accounted for, can also lead to spurious acceptance of the unit root null. PPP tests that allow for one or multiple structural breaks were developed, for instance, in [Hegwood and Papell \(1998\)](#). They apply unit root tests that allow for multiple breaks on a historical dataset of five US-dollar-based RERs and find evidence of mean reversion. However, as these changes appear to be permanent, they emphasize that this is not support for the standard but rather a qualified version of PPP which they term quasi-PPP. For PPP to hold structural breaks in the series have to be temporary, so that the mean toward which the RER reverts at the start and end of the sample is the same. Recognizing this point, [Papell and Prodan \(2006\)](#) test for PPP using a restricted structural change model where long-run PPP is imposed.<sup>3</sup> They use historical data for seven countries' RER against the US-dollar for which no previous evidence of PPP is found.<sup>4</sup> Their results, when using a structural change model where the change is temporary, reject the null of a unit root in only in two cases. Regarding the scarce evidence on post-Bretton-Woods PPP, especially for US-dollar bilateral exchange rates, [Papell \(2002\)](#) argues that an important event that may have driven the rejection of PPP is the "Great Appreciation" of the US-dollar in the early 1980s and its subsequent depreciation. This bubble-

<sup>2</sup> See also [Taylor and Sarno \(1998\)](#) for Monte Carlo evidence.

<sup>3</sup> They also test for a version of PPP allowing for a time trend justified on the basis of Balassa-Samuelsun-type effects.

<sup>4</sup> Recently, [Prodan \(2008\)](#) developed tests for restricted structural change with better size properties that help reconcile contradictions between unit root and structural change tests in historical RER data.

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