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# Equilibrium exchange rate determination and multiple structural changes ☆

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ABSTRACT

The large appreciation and depreciation of the US Dollar in the 1980s stimulated an important debate on the usefulness of unit root tests in the presence of structural breaks. In this paper, we propose a simple model to describe the evolution of the real exchange rate. We then propose a more general smooth transition (STR) function than has hitherto been employed, which is able to capture structural changes along the (long-run) equilibrium path, and show that this is consistent with our economic model. Our framework allows for a gradual adjustment between regimes and allows for under- and/or over-valued exchange rate adjustments. Using monthly and quarterly data for up to twenty OECD countries, we apply our methodology to investigate the univariate time series properties of CPI-based real exchange rates with both the U.S. Dollar and German Mark as the numeraire currencies. The empirical results show that, for more than half of the quarterly series, the evidence in favor of the stationarity of the real exchange rate was clearer in the sub-sample period post-1980.



## 1. Introduction

The time series properties of real and nominal exchange rates have been an enduring research topic during the post Bretton Woods period. The so-called PPP puzzle of Rogoff (1996) suggests that the relatively slow mean reversion of real exchange rates is too slow to be consistent with purchasing power parity (PPP), even when panel unit root methods are used (see MacDonald, (2007) for an overview). Recent work by, for example, Papell (2002) and Sollis (2005) demonstrates that the lack of evidence in favor of PPP might be due to the existence of structural breaks as a result of the dramatic behavior of the US Dollar in the 1980s (the so-called Lothian effect). However, their results show rather weak evidence when the US Dollar is assumed to be the base currency.

In this paper we make a number of contributions to the literature on the time series properties of real exchange rates. First, we propose a simple equilibrium exchange rate model as initially discussed in Dutta and Leon (2002) which allows for deviations from PPP and is consistent with the risk-adjusted real interest parity relationship, as suggested by Clark and MacDonald (1998). The proposed model captures the long-run exchange rate equilibrium and the short run dynamic adjustment to equilibrium. In contrast to other research on real exchange rates which exploits the real interest parity relationship, we use a univariate modeling framework.[1]

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[1] In this paper the idea is to develop unit root tests for structural breaks, which are consistent with the exchange rate behavior suggested by the economic model.

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Second, our estimation is conducted in a non-linear framework and we make an econometric contribution by proposing a novel transition function, and we use simulations to show that our empirical transition function matches the exchange rate behavior suggested by our exchange rate model. Based on our transition function, we propose two structural break tests and report their size and power. Thus, in contrast to a large part of the literature on PPP, whose focus has mainly been empirical (i.e. proposing new tests of PPP), our paper also proposes a novel exchange rate model based on Dutta and Leon (2002). Finally, some empirical applications to different real exchange rate data are provided.

The remainder of the paper is organized as follows. In the next section we overview existing work on the univariate properties of real exchange rate determination and also present a simple equilibrium exchange rate model to motivate our econometric analysis. The empirical specification and simulation results are presented in Sections 3 and 4, respectively. The results of our empirical tests are contained in Section 5. Finally, Section 6 contains a conclusion.

## 2. Literature overview and theoretical modeling

### 2.1. Unit root based analysis

Unit root tests have been the most common method of investigating the PPP hypothesis. The most popular test of the PPP hypothesis utilizes the univariate ADF test, which regresses the real exchange rate on a constant, its lagged level and $p$ lagged first differences,

$$q_t = \alpha + \beta q_{t-1} + \sum_{i=1}^{p} \phi_i \Delta q_{t-i} + \varepsilon_t, \tag{1}$$

where $q_t$ denotes the real exchange rate and $\alpha$ and $\beta$ are assumed to be constant.[2] Indeed, previous studies, by using demeaned values of $q_t$, under the assumption of constant $\alpha$, do not consider possible effects from economic fundamentals which can potentially be captured by shifts in the mean process of the series.

An important strand in the literature on PPP is the papers which use panel data methods to test the hypothesis. For example, Abauf and Jorion (1990) and Jorion and Sweeney (1996), use monthly data, and conduct panel unit root tests on real exchange rates for the G10 countries and produce evidence of rejection of the unit root null at the 10% level. In particular, Jorion and Sweeney (1996) employ six more years of monthly data from 1973 to 1993 for 10 currencies against the US Dollar and reject the unit root hypothesis at the 5% significance level, using no lags of the differenced dependent variable in the ADF regression. For seven European currencies against the Deutschmark, the rejection of a unit root is even stronger, with a $p$-value of 0.002.

Wu (1996) tests annual, quarterly and monthly dollar real exchange rates for a panel of 18 countries from January 1974 to April 1993 and strongly rejects the unit root hypothesis for both CPI (consumer price index) and WPI (wholesale price index) -based rates. In particular, he is able to reject the null at the 1% level in both cases, and estimates an autoregressive parameter of 0.98 for monthly data. However, since Wu (1996) allows for a time trend, which has as the alternative hypothesis trend stationary rather than levels stationarity, it is hard to say that the rejection of the unit root null provides evidence in favor of PPP.

Oh (1996) employs annual real exchange rate data, constructed from the Summers and Heston data set, for the post Bretton Woods period, and shows a rejection of the unit root hypothesis. This result is much stronger than Frankel and Rose's (1996) result obtained with annual data or previous studies with quarterly or monthly data. MacDonald (1996) uses the Levin and Lin panel unit root test and annual data for the post Bretton Woods period and is able to reject a unit root in the real exchange rate at the 5% significance level.

Papell (1997) criticizes regression-based studies on pooled real exchange rates for the free floating periods and suggests considering a heterogeneous intercept in the regression, which is equivalent to including country-specific dummy variables. He shows evidence in favor of PPP and a faster rate of mean reversion when the Deutschmark rather than the US Dollar is used as a base currency. In particular, the estimated half-life is 2 years in the former case and 2.5 years in the latter. Finally, his empirical results show that PPP is more likely to hold in the case of larger than smaller panels, for monthly rather than quarterly data and when the German Mark rather than the US Dollar is used as the base currency. However, O'Connell (1998) points out that the empirical evidence favoring PPP is mainly due to tests being badly over-sized when the unit root null is true and provides convincing Monte Carlo evidence to support this assertion. Specifically, employing a pooled GLS–ADF test, which has the correct size in the presence of cross-sectional dependence, he finds no evidence in favor of PPP using a panel of 63 real exchange rates (and smaller regional subpanels), using quarterly data from 1973:2 to 1995:4.

The above empirical evidence on PPP has led researchers to explore alternative methods to attempt to establish the relationship. For example, the large spike in the US Dollar in the 1980s led Papell, (2002) to suggest incorporating structural change into the estimates. Using panel methods, the test strongly rejects the unit root null for those countries that adhere to the typical pattern of the dollar's rise and fall. Christopher et al. (1999) consider fractional integration and mean shifts in a single currency. In their study, they use both CPI- and WPI-based rates and demonstrate that the unit root hypothesis is robust against both fractional alternatives and structural breaks. This evidence suggests rejection of the unit root during the floating period and structural changes. Bleaney and Leybourne (2003) point out that the rejection of the unit root hypothesis is not necessarily correct because these tests strongly over-reject the null in certain circumstances, particularly when the series have a stochastic

[2] Generally, a time trend is not included in the Eq. (1) because such an inclusion would be theoretically inconsistent with long-run PPP.