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Purchasing power parity and the long memory properties of real exchange rates: Does one size fit all?

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ABSTRACT

This paper examines the time series behavior of monthly bilateral real exchange rates (RER) on a comprehensive sample of 78 industrialized and developing countries, using the US Dollar, the UK Pound and the German Deutsche Mark as *numeraires*. We suggest a three step testing procedure based on recently introduced econometric techniques, in order to assess the mean-reverting properties of the RER and to address the question of whether real exchange rates follow a non linear process or a long memory process. The main results are as follows. Firstly, most of the bilateral real exchange rates under study are not mean-reverting. Secondly, the nonlinear ESTAR type adjustment is far from being prominent. Finally, only few bilateral RER exhibit true long memory mean-reverting properties.

1. Introduction

Most models of international trade and open economy rest on the hypothesis of purchasing power parity (PPP). At the aggregated level, this hypothesis implies that the nominal exchange rate should converge to the ratio of price levels between two countries, i.e. the real exchange rate (RER) should be a mean-reverting process.

The empirical validity of this PPP assumption remains one of the most active and controversial issues in international economics (Taylor, 2006; Taylor and Taylor, 2004). Empirical methodologies and results are mixed. Generally, the usual unit-root tests conclude that PPP does not hold during the post-Bretton Woods period (see Section 2 for a brief survey). Some potential reasons to explain this puzzle are first that countries under study have very heterogeneous exposure to foreign markets, different commercial links with the leading countries (such as the United States, the United Kingdom, or Germany) and have experienced a variety of exchange rate regimes during the last thirty years. Secondly, it may also be that usual testing techniques are inadequate in presence of non-standard dynamics, such as nonlinearity, structural instability, or long memory processes.

This article addresses these empirical difficulties to check PPP during the post-Bretton Woods period in two ways. First, we use a broader set of countries than the set considered in the literature: we thus consider monthly data on 78 CPI-based bilateral real exchange rates of industrialized and developing economies, over the period 1970–2006. For each currency, we consider three bilateral nominal exchange rates, the *numeraire* being alternatively US Dollar, UK Pound and German Mark. It can be seen that the RER behavior does not only depend on the period and the country under study but also on the *numeraire* used in computing the bilateral RER: the PPP hypothesis is more likely to occur for countries commercially linked or geographically close to the countries of which the currency is taken as *numeraire*. Second, we use recent econometric techniques to detect a long-memory process or a short-memory process with structural breaks. Our sequential testing strategy consists of three steps. First, we test for mean-reversion using the FELW estimator of long-memory parameter and drop from the sample each series which does not follow a mean-reverting process. Second, we determine whether the mean-reverting processes are stationary mean-reverting or not. Third, among non-stationary-mean-reverting processes, we discriminate between true long-memory processes and short-memory processes contaminated by abrupt changes in level. Finally, we compute impulse-response functions in order to evaluate half-lives for those true long memory mean-reverting bilateral RER.

The main results are as follows. Firstly, most of the bilateral RER appear to be non mean-reverting processes. Secondly, the nonlinear

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Exponential Smooth Transition Auto-Regressive (ESTAR) type adjustment is far from being prominent and, finally, only few bilateral RER exhibit true long memory mean-reverting properties. For these true long-memory processes, the half-lives are found to lie between 1 month and 6 years.

The remainder of the paper is as follows. In Section 2, the empirical literature on PPP is briefly reviewed. Section 3 considers the econometric methodologies used in the paper. Section 4 reports the empirical results and Section 5 concludes.

2. Controversies as to the PPP hypothesis in the empirical literature: a selected review

The breakdown of the Bretton Woods system at the beginning of the 1970s stimulated a large flow of research about the long-run equilibrium level of the RER. On the theoretical side, most of macroeconomic models assume PPP in the short run (Frenkel, 1976) or, at least, in the long-run (Dornbusch, 1976). However, on the empirical side, the validity of the PPP hypothesis remains one of the most active and controversial issues in international economics (Taylor, 2003, 2006; Taylor and Taylor, 2004).

2.1. The two PPP puzzles

Since the volatility of nominal exchange rates appears to be more pronounced than the volatility of prices, empirical evidence overwhelmingly led to the PPP being rejected as a short run model of exchange rate. In order to test the validity of the PPP hypothesis as a long run relationship, early studies used standard testing methodologies such as the augmented Dickey–Fuller (ADF) test for a unit root in the real exchange rate. In logarithmic form, the RER q_t is defined as:

$$q_t = s_t - p_t + p_t^*, \tag{1}$$

where s_t is the log of the bilateral nominal exchange rate between the domestic and the foreign country, p_t and p_t^* are respectively the log of the domestic and foreign country price levels. As defined in Eq. (1), the RER measures the deviation from PPP: under long-run PPP, the logarithm of the RER must display reversion towards zero (after appropriate scaling).

According to the ADF-test, the RER is supposed to follow a linear autoregressive model that can be reparametrized as:

$$\Delta q_t = \rho q_{t-1} + \sum_{j=1}^{k-1} a_j \Delta q_{t-j} + a_0 + e_t, \tag{2}$$

where $\Delta q_t = q_t - q_{t-1}$ and e_t is a white noise disturbance. Under the null hypothesis H_0: $\rho = 0$, the RER contains a unit-root and displays no mean-reversion towards the PPP equilibrium. Using univariate unit root tests, numerous studies of RER in industrialized countries prove incapable of rejecting the null hypothesis for the post-Bretton Woods period when the US dollar is taken as *numeraire* (see e.g. the numerous references cited in Taylor (2006)).[1] Notably, some other studies find support for PPP when RER is expressed *vis-à-vis* the German Mark (Chowdhuri and Sdogati, 1993; Cheung and Lai, 1998, 2000) or for high inflation countries (e.g. Choudhry et al. (1991) which use multivariate cointegration analysis). The non-rejection of the unit root hypothesis in the RER is known as the first PPP puzzle (see e.g. Taylor et al. (2001)), since it questions one of the most popular intuitions among economists (Rogoff, 1996).

The second PPP puzzle highlighted in the literature reflects the fact that, among the studies which conclude in favor of RER mean-reversion, the empirical measurement of the half-lives of deviations from PPP is around three to five years (Rogoff, 1996). This high degree of persistence is at odds with the implications of sticky-price models of open economies, which imply that the half-life of a shock to the RER should be less than two years.[2]

Confronted by these two puzzles, three different processes are considered in the empirical literature to model the dynamic behavior of RER.

2.2. Linear autoregressive model

The first one is the linear autoregressive model (as described in Eq. (2)). Following Engle and Granger (1987) terminology, if the RER is found to follow a $I(0)$ – or stationary – process instead of a $I(1)$ – or nonstationary – process, it exhibits a *geometrical* reversion towards the long run equilibrium after a shock. In this case, PPP holds at least in the long run. However, the second puzzle is not solved when autoregressive roots are found to be close to one.

2.3. Nonlinearity and structural breaks

The second kind of process considered to model the RER is constituted by various forms of nonlinear models. Most of the literature consider alternatively the band-threshold autoregressive (TAR) model (e.g. Obstfeld and Taylor (1997)), the ESTAR process (e.g. Taylor et al. (2001)), or the Markov regime switching model (e.g. Kanas (2006)).

These nonlinear models belong to the more general class of structural break models, as illustrated by simple examples (see e.g. Park and Shintani (2005) and Cerrato et al. (2010) for some extensions). Following the ADF Eq. (2), nonlinear and structural break models can be represented by:

$$\Delta\tilde{q}_t = \beta\tilde{q}_{t-1}\rho(z_t,\theta)\sum_{j=1}^{k-1} a_j\Delta\tilde{q}_{t-j} + e_t, \tag{3}$$

where $\tilde{q}_t$ is the log of the RER expressed in deviations from the mean, $\rho(z_t,\theta)$ is the transition function, z_t is a transition variable and (β,θ) a set of parameters (assuming $\beta<0$ and $\theta>0$), both influencing the value of persistence. For instance, in the Self-Exciting Threshold Auto-Regressive (SETAR) model, the transition variable is the (demeaned) RER with lag delay $d\geq 1$, i.e. $z_t = \tilde{q}_{t-d}$, and the transition function can be given as $\rho(z_t,\theta) = 1\{\tilde{q}_{t-d}\leq -\theta\} + 1\{\tilde{q}_{t-d}\geq\theta\}$. Conversely, in the ESTAR model, the transition function is given by $\rho(z_t,\theta) = 1 - exp\left(-\theta\tilde{q}_{t-d}^2\right)$.

In these SETAR and ESTAR cases, the mean reversion occurs only when the size of the deviation from the long-run equilibrium exceeds a given threshold. For instance, considering the SETAR case, in the central regime $-\theta<\tilde{q}_{t-d}\leq\theta$, the RER follows an $I(1)$ process since $\rho(z_t,\theta) = 0$, while in the outer regimes ($\tilde{q}_{t-d}\leq -\theta$ or $\tilde{q}_{t-d}\geq\theta$) it follows an $I(0)$ mean-reverting process. In the ESTAR model, the transition between regimes is smooth, with a transition function bounded between 0 and 1. When the RER deviation from the mean is null ($\rho(z_t,\theta) = 0$), the RER follows an $I(1)$ process, and the transition towards the outer regime ($\rho(z_t,\theta)\neq 0$) occurs when the RER deviates from his mean ($\tilde{q}_{t-d}\neq 0$). In the latter case, the RER follows an $I(0)$ process and the speed of transition towards the outer regime increases with the value of θ.Whilst globally mean-reverting, these nonlinear processes follow a near random walk behavior for sufficiently small deviations from PPP. The ESTAR process becomes increasingly mean-reverting with the size of the deviation from the

[1] However, the literature has often pointed out the low power of standard unit-root tests over short time spans of data. Long-span or panel-data studies partly address this criticism.

[2] Some authors have recently discussed the appropriateness of usual measures of half-lives and have suggested some alternative measures for assessing the persistence in real exchange rates (see e.g. Chortareas and Kapetanios (2004), El-Gamal and Ryu (2006)).