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Purchasing power parity in OECD countries: Nonlinear unit root tests revisited

Juan Carlos Cuestas [a,*], Paulo José Regis [b]

[a] University of Sheffield, United Kingdom
[b] Xi'an Jiaotong-Liverpool University, China

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ABSTRACT

The aim of this paper is to provide additional evidence on the purchasing power parity empirical fulfilment in a pool of OECD countries. We apply the Harvey et al. (2008) linearity test and the Kruse (2011) nonlinear unit root test. The results point to the fact that the purchasing power parity theory holds in a greater number of countries than has been reported in previous studies.

1. Introduction

The purchasing power parity (PPP) theory has probably been one of the more controversial topics in international finance given that its empirical validity is still subject to analysis. Following the more general fashion in time series econometrics, compared to the initial papers testing for a unit root using the Augmented Dickey Fuller and Phillips–Perron tests, more recent studies have incorporated panel and nonlinear unit root tests.

The PPP theory has important implications from a theoretical perspective because it is the basic building block of a number of open economy macroeconomic models (Dornbusch, 1980; Obstfeld and Rogoff, 1995, 1996). In addition, its empirical validity can be understood as a measure of economic integration among countries, as well as a way of assessing the degree of misalignment of currencies. In its absolute version, the PPP theory establishes that prices in different countries should be the same when converted into a common currency. This relationship can be expressed mathematically as follows:

$$E_t = \frac{P_t^*}{P_t} \tag{1}$$

where E_t is the nominal exchange rate, defined as the price in foreign currency of a unit of the domestic currency, and P_t and P_t^* are the average prices of the basket of goods of a representative consumer in the home and foreign country. Eq. (1) implies that the real exchange rate[1] should be equal to 1. However, it is well known that PPP does not hold in the short run because prices are relatively inflexible in response to changes in the nominal exchange rate. Thus, if PPP holds at all, it is expected to hold in the long run.

In order to empirically analyse the fulfilment of PPP, unit root testing has become a very popular approach. If the real exchange rate contains a unit root, the shocks should have permanent effects and the variable will never return to its long run equilibrium. However, if the real exchange rate is stationary, shocks tend to die out in the long run and the equilibrium is achieved some time after the shock has occurred.[2]

Soon after the Dickey and Fuller (1979) test was developed, the early studies of the PPP hypothesis were based on short/medium size time series and typically rejected the PPP hypothesis. However, there were concerns of inadequate power of the tests. Many authors moved on to very long-run data to a century or two of annual time series (see Froot and Rogoff, 1995; Taylor, 2002, among others), an approach that has been more favourable to PPP. However, this strategy is likely to suffer from the existence of structural shifts in the data such as changes from fixed to flexible exchange rate regimes (or vice versa) or experienced periods of hyperinflation as well as

* Corresponding author at: Department of Economics, University of Sheffield, 9 Mappin Street, Sheffield, S1 4DT, United Kingdom.
E-mail address: j.cuestas@sheffield.ac.uk (J.C. Cuestas).

[1] Real exchange rate defined as $RER = P_t E / P_t^*$.
[2] Although not within the scope of the present paper, another popular approach has been testing for cointegrating relationships between the logs of the nominal exchange rate, home and foreign prices. We thank an anonymous referee for this point.

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devaluations. This study focuses on monthly exchange rates, mostly for developed countries in a period where the currencies are floating most of the time, with over 400 observations per country. Although the time dimension is large enough to allow for individual countries unit root tests, this is complemented by some well-known panel data unit root tests.

Most studies make use of bilateral real exchange rates (usually relative to the US dollar). Instead, we analyse the effective real exchange rate to avoid potential biases associated with the choice of base country in bilateral rates (most commonly, the US). The effective rate is usually more attractive to economists and policymakers since it is a better measure for understanding trade flows and international competitiveness. Previous studies that have tested the PPP in the context of REER include Corbae and Ouriatis (1991), Cashin and McDermott (2003) and Bahmani-Oskooee et al. (2007).

Bahmani-Oskooee et al. (2007) applied Kapetanios et al.'s (2003) tests, which controls for the possibility of nonlinearities in the data generation process, to a set of OECD countries. Their results are more favourable towards the stationarity of the real exchange rate than in previous studies, which mostly focus on linear unit root tests. However, the authors do not test for the presence of nonlinearities in the data and include a linear time trend, which is not compatible with the absolute or relative version of the PPP theory, since this theory implies mean reversion to a constant.

In this paper we contribute to the empirical analysis of PPP by first using panel data unit root tests in order to explore the cross-section and time series properties of the data jointly (Choi, 2001; Im et al., 2003; Levin et al., 2002; Maddala and Wu, 1999). Second, we apply the recently developed Kruse (2011) unit root test, which is an upgraded version of the Kapetanios et al. (2003) test in order to distinguish which series are stationary. Prior to the Kruse (2011) test, we check the adequacy of the nonlinear behaviour under the alternative hypothesis by testing the hypothesis of linearity vs. nonlinearity by means of the Harvey et al. (2008) test.

The remainder of the paper is organised as follows. In the next section we summarise the methods applied in this empirical research, followed by section three where our results are presented. The last section concludes.

2. Unit root testing

In a preliminary step to the individual country analysis, we apply a group of panel unit root tests, that is, Levin et al. (2002), Im et al. (2003), Maddala and Wu (1999) and Choi (2001). As pointed out by many authors, power may be gained when using panel data tests which may increase the sample size considerably (see Hakkio, 1984; Abuaf and Jorion, 1990, among many others). However, in case of rejection of the null, one needs to look at the individual tests so as to assess for which country the unit root hypothesis is rejected. This is a preliminary analysis, which enables us to gather some information on whether all the series are non-stationary. These results can also be compared with the unit root tests applied to each country, so as to gain robustness in the conclusions. Levin et al. (2002) suppose a common unit root under the null hypothesis against the alternative of stationarity of all individuals, whereas the other tests allow for individual unit roots under the alternative hypothesis.

Alternatively, Im et al. (2003) base their test on the assumption of different autoregressive parameter for every individual. A different approach is followed by Maddala and Wu (1999) and Choi (2001), who combine the different p-values of the individual auxiliary regressions, either for the ADF or Phillips–Perron tests, to obtain the following test

$$-2\sum_{i=1}^{N} \ln p_i \rightarrow \chi^2_{2N} \tag{2}$$

where p_i are the asymptotic p-value of a unit root test for individual *i*. Additionally, Choi (2001) proposes the following test, based on the combination of individual p-values:

$$Z = \frac{1}{\sqrt{N}}\sum_{i=1}^{N} \Phi^{-1}(p_i) \rightarrow N(0,1) \tag{3}$$

where Φ is the standard normal cumulative distribution function.

If the PPP hypothesis does not hold for the pool of countries, it is still possible that it might hold for some of the countries. In order to distinguish the countries for which this hypothesis holds, we apply individual unit root tests which take into account the possibility of nonlinear behaviour of the real exchange rate.

According to Michael et al. (1997) and Taylor et al. (2001), among others, real exchange rates might follow a nonlinear path over time. If that is the case, as stated by many authors such as Kapetanios et al. (2003), traditional (linear unit root tests) may suffer from power problems, i.e. they tend to over accept the null hypothesis. Thus, Kapetanios et al. (2003) propose a unit root test against the alternative of globally stationary exponential smooth transition autoregression (ESTAR).

$$y_t = \beta y_{t-1} + \phi y_{t-1} F(\theta; y_{t-1}) + \varepsilon_t \tag{4}$$

where ε_t is $iid(0,\sigma^2)$ and $F(\theta;y_{t-1})$ is the transition function, which is assumed to be exponential,

$$F(\theta; y_{t-1}) = 1 - exp\left\{-\theta(y_{t-1} - c)^2\right\} \tag{5}$$

with $\theta > 0$. However, Kapetanios et al. (2003) assume that $c = 0$.

In practice, Eq. (5) is written as,

$$\Delta y_t = \alpha y_{t-1} + \gamma y_{t-1}\left(1 - exp\left\{-\theta y^2_{t-1}\right\}\right) + \varepsilon_t. \tag{6}$$

in order to apply the test. This equation implies the existence of two regimes, i.e. an inner or central regime and an outer regime, where the transition between the regimes is smooth. Kapetanios et al. (2003) impose $\alpha = 0$, implying that the variable is a unit root in the central regime. The null hypothesis $H_0 : \theta = 0$ is tested against the alternative $H_1 : \theta > 0$, i.e. we test whether the variable is an I(1) process in the outer regime. Taylor and Peel (2000), among others, justify that an ESTAR function is appropriate to model exchange rates, since effects of the shocks depend on the magnitude of the shock.

However, taking a Taylor linear approximation around $\theta = 0$, the following auxiliary regression can be obtained

$$\Delta y_t = \delta_1 y^3_{t-1} + \varepsilon_t \tag{7}$$

The hypothesis $H_0 : \theta = 0$ and $H_1 : \theta > 0$ in Eq. (6) is equivalent to $H_0 : \delta_1 = 0$ and $H_1 : \delta_1 < 0$. The latter is easier to implement and critical values are available from the authors.

However, the idea of Kapetanios et al. (2003) of imposing the location parameter *c* in the smooth transition function to be equal to zero may be too restrictive for variables where the threshold value may be

Table 1
Panel unit root tests results.

Method	Statistic	Probability
Levin, Lee and Chu	−1.016	0.1549
PP − Fisher Chi-square	99.11	0.0002
ADF − Fisher Chi-square	98.28	0.0002
Im, Pesaran and Shin W-stat	−4.082	0.0000

Note: The order of lags has been determined by the MAIC (Ng and Perron, 2001). Probabilities for Fisher tests are computed using an asymptotic Chi-square distribution. All other tests assume asymptotic normality.