Re-examining Purchasing Power Parity for the Australian Real Exchange Rate

Mübariz Hasanov
Department of Economics,
Hacettepe University
Ankara, Turkey
e-mail: muhas@hacettepe.edu.tr

Abstract

In this paper, we re-examine stationarity of the Australian real exchange rate (RER). For this purpose, we modify the test of Kapetanios et al. [Testing for a unit root in the nonlinear STAR framework. Journal of Econometrics 112 (2003), 359-379] to allow for a nonlinear trend function in the data generating process. Using bootstrap techniques, we show that the null hypothesis of unit root can be rejected, providing evidence in favour of PPP proposition for the Australian RER.

Keywords: Purchasing Power Parity, Nonlinearity, Unit Root

JEL Codes: C12, C22, F31
1. Introduction

Purchasing power parity (PPP) is perhaps one of the most important propositions in international economics literature. According to the PPP proposition, nominal exchange rates move together with differences in relative prices in two countries. While there may be small deviations in relative prices due to transportation costs and trade barriers, it is generally agreed that large deviations in relative prices will be traded away by arbitrageurs, and real exchange rates will tend toward PPP in the long run (Rogoff 1996). PPP proposition is of central importance for policy makers and economists from several perspectives. First, since PPP is an anchor for long-run equilibrium exchange rates, deviations from the PPP level signal misalignment in nominal exchange rate and allow policy makers to take appropriate policy actions. Second, PPP is a vital assumption of many open-economy macroeconomic models. Therefore, the failure to find evidence of PPP would lead one to question open-economy macroeconomic theory. Finally, PPP exchange rates are used in international comparisons of real income across countries. If PPP does not hold, then such comparisons are meaningless.

PPP suggests that real exchange rate follows a stationary process. Therefore, tests of PPP have often been based on examination of stochastic properties of real exchange rate series. Earlier researchers that used conventional unit root tests failed to find stationarity, contradicting to PPP (e.g. Meese and Rogoff 1988, Taylor 1988, Mark 1990). Such a failure was attributed to low power of cointegration tests, and researchers have been searching for alternative frameworks within which to test for unit roots. For example, Frankel and Rose (1996) applied panel unit-root tests to increase the number of observations. However, Taylor et al. (2001) argues that
conclusions drawn from panel unit root tests may be misleading owing to incorrect interpretation of the null hypothesis of joint non-mean reversion of all series under investigation. Another strand of the literature points to possible nonlinearities in real exchange rate dynamics and argues that the PPP puzzle can be resolved once nonlinear adjustment toward equilibrium is properly modelled (e.g. Michael et al., 1997; Taylor et al. 2001). On the other hand, Lundbergh et al. (2003) argued that time series might be described more appropriately by simultaneous structural break and nonlinearities. In fact, Telatar and Hasanov (2009), using the test procedure of Sollis (2004), which allows for both a structural break and asymmetric adjustment in the data generating process, provide empirical evidence in favour of PPP in selected transition countries.

Our aim in this paper is to contribute to the empirical literature on testing validity of the PPP proposition for the Australian real exchange rate (RER). A number of works have been devoted to testing the PPP proposition in the case of Australia. Corbae and Oularis (1990) tested stochastic properties of Australian RER, and found no evidence of the absolute version of PPP. They concluded that a series of permanent, real shocks affected RER during their sample period. Olekalns and Wilkins (1998) extended the work of Corbae and Oularis (1990) by calculating nonparametric measures of persistence and estimating fractionally integrated ARMA models for RER series. They found that shocks to real exchange rate have finite life, and interpret their results as evidence in favour of PPP. Henry et al. (2001) examined possible nonlinearities in the Australian RER series. While they found a strong evidence of a nonlinear dynamics in the data, their results provide a little evidence of PPP. Henry and Olekalns (2002) examined the validity of the PPP hypothesis for the Australian RER series for the post Bretton Woods period. They applied parametric
and non-parametric techniques to the Australian RER series and found no evidence of PPP even after allowing for structural breaks. Darne and Hoarau (2008) applied unit root tests with structural break and found that PPP proposition does not hold in the long run for the Australian RER series. Cuestas and Regis (2008) found some evidence of PPP after allowing for more general specification of the nonlinear deterministic components based on Chebyshev polynomials. Cuestas and Gil-Alana (2009) questions the methodology of Cuestas and Regis (2008), and applied nonlinear unit root tests as well as fractional integration tests in the context of structural changes to the Australian RER series. They found no evidence of mean reversion in the series, contradicting to the PPP hypothesis. Yet, their results indicate a decline in the degree of persistence in Australian RER series after the 1985 currency crisis.

Our approach to test the validity of the PPP proposition is different from previous works. Taking account of the fact that both structural breaks and nonlinearities may characterize real exchange rate dynamics, in this paper we consider a possibility that real exchange rate series may follow a nonlinear stationary process around a deterministic (nonlinear) trend function. For this purpose we generalize the test procedure of Kapetanios et al. (2003), henceforth KSS, to allow for nonlinear trend function. KSS develop unit root test procedure against globally stationary exponential smooth transition (ESTAR) type nonlinearity, which is thought to be relevant for real exchange rate dynamics (see, for example, Michael et al. 1997; Taylor et al. 2001; Kapetanios et al. 2003). Unlike KSS, who consider only a linear trend function, we allow for a polynomial trend function in the data generating process. Using bootstrap critical values, we show that the Australian real exchange rate is stationary around nonlinear trend function.
The rest of the paper is organised as follows. In section 2 we briefly discuss the econometric methodology. In section 3 we present the empirical results and then section 4 concludes.

2. Econometric Methodology

Following Chortareas et al. (2002), we consider following data generating process:

\[ y_t = \mu + \phi(t) + x_t, \quad t = 1, \ldots, T \]  
\[ \Delta x_t = \gamma x_{t-1} \left[ 1 - \exp(-\phi x_{t-1}) \right] + \epsilon_t, \]  

where \(-2 < \gamma < 0\), and \(\epsilon_t \sim iid(0, \sigma^2)\). As shown by KSS, one may test for unit root by testing the null hypothesis \(\theta = 0\) against the alternative hypothesis \(\theta > 0\). Under the null hypothesis \(y_t\) follows a linear unit root process around deterministic trend function \(\phi(t)\), whereas it is nonlinear stationary ESTAR process under the alternative

The above representation of the data generating process has a nice property in that it allows for a deterministic trend function under both the null hypothesis and the alternative hypothesis, without introducing any parameters that are irrelevant under either (Schmidt and Phillips, 1992). Chortareas et al. (2002) assume that the trend function \(\phi(t)\) in Eq. (1) is linear, and propose alternative de-trending methodology for the KSS test following Schmidt and Phillips (1992).

Different specifications for the trend function \(\phi(t)\) have been considered in tests of unit root. For example, Leybourne et al. (1998) and Sollis (2004) use logistic trend function that allows for a smooth break in the trend. Bierens (1997) models nonlinear trend using Chebyshev polynomials. Becker et al. (2006) use trigonometric functions
(via means of Fourier transformations) to model possible gradual breaks in the data generating process. Instead of imposing specific form of nonlinearity, following Ouliaris et al. (1988) and Schmidt and Phillips (1992), in this paper we use time polynomials to model possible nonlinearities in the trend function. Use of time polynomials to model nonlinear trends has advantages over other specifications. First, unlike logistic functions, time polynomials do not impose specific form of nonlinearity in the trend function. In addition, as shown by Lin and Teräsvirta (1994), first and higher order logistic transition functions in time trend can well be approximated by time polynomials. Second, use of trigonometric functions or Chebyshev polynomials might be problematic. As Cuestas and Gil-Alana (2009) argue, Chebyshev polynomial approximation for the nonlinear time trend is problematic because there is no unique way of selection of the order of the polynomials. A similar problem arises in selecting frequency components for trigonometric functions (Becker et al. 2006). However, in the case of time polynomials, one may use conventional statistical significance tests to choose the order of time polynomials, without any burden on estimating various nonlinear models and choosing the appropriate one. Therefore, use of time polynomials allows one to model more general classes of nonlinearities and possible multiple structural breaks in the trend function, and to choose appropriate order of polynomials.

Although Chortareas et al. (2002) use different de-trending methodology following Schmidt and Phillips (1992), in this paper we follow KSS to de-trend the series under investigation. Assuming that the nonlinear trend function can be approximated by a time polynomial, Eq. (1) can be re-written as follows:
\[
y_i = \mu + \sum_{i=1}^{p} \beta_i t^i + x_i
\]  

(3)

The order of time polynomial can be selected by testing significance of additional powers of time trend. Define de-trended series \( x_i = y_i - \hat{\mu} - \sum_{i=1}^{p} \hat{\beta}_i t^i \) where \( \hat{\mu} \) and \( \hat{\beta}_i \) are OLS estimates of \( \mu \) and \( \beta_i, \ i = 1, \ldots, p \). Now, one may test stationarity of de-trended series \( x_i \) following KSS. As KSS argue, testing the null hypothesis \( H_0 : \theta = 0 \) directly is not feasible because the parameter \( \gamma \) is not identified under the null. Therefore, one may follow Luukkonen et al. (1988) and replace the exponential transition function with its first order Taylor approximation, which gives the following auxiliary regression for the de-trended series \( x_i \) :

\[
\Delta x_i = \delta \hat{x}_i^3 + e_i
\]  

(4)

where \( e_i \) comprises original shocks \( \epsilon_i \) as well as the error term resulting from Taylor approximation. The auxiliary regression model (4) suggests that one may obtain \( t \)-statistic for \( \delta = 0 \) against \( \delta < 0 \) as follows:

\[
t_{\text{NTNL}} = \hat{\delta} / \text{s.e.}(\hat{\delta}),
\]  

(5)

where \( \hat{\delta} \) is the OLS estimate and \( \text{s.e.}(\hat{\delta}) \) is the standard error of \( \hat{\delta} \).

To deal with possible serial correlation in error term \( \epsilon_i \) in (2), one may augment the auxiliary regression (4) with lagged values of \( \Delta x_i \) :

\[
\Delta x_i = \delta \hat{x}_{i-1}^3 + \sum_{j=1}^{p} \alpha_j \Delta x_{i-j} + e_i
\]  

(6)

Unlike the case of testing linearity against STAR-type nonlinearity, the \( t_{\text{NTNL}} \) test does not have an asymptotic standard normal distribution (e.g., Chortareas et al.,
2002; Kapetanios et al., 2003). Therefore, we obtain empirical distribution of the test statistic \( t_{NTNL} \) using bootstrap techniques.

3. Empirical Results

In this paper we use quarterly observations of the Australian real Trade Weighted Index (TWI) computed by the Reserve Bank of Australia, which is the most frequently used measure of RER in the empirical literature. The sample covers the period from 1970:Q2 to 2009:Q4. In the first step, we estimate equation (3). The order of time polynomial was selected by testing significance of additional powers of time trend using maximum order of 12. Ordinary least squares estimates of the coefficients of time polynomials are given in Table 1.

(Table 1)

Figure 1 plots real exchange rate series along with estimated nonlinear trend function and deviations from the trend. As can readily be seen from the figure, the estimated nonlinear trend function appears to be a good approximation for the deterministic component of the series and suggests that structural changes were rather gradual.

(Figure 1)

In the next step, using the residuals from equation (3) we estimate equation (6) to compute the test statistics \( t_{NTNL} \). The lag order in equation (6) was selected so as to remove significant autocorrelation in the residuals. For comparison purposes, in
addition to the proposed test we have also performed conventional ADF (Dickey and Fuller, 1979), Phillips-Perron (1988) and KPSS (Kwiatkowski et al., 1992) stationarity tests as well as KSS nonlinear unit root test (2003) and Sollis’s (2004) ST-TAR unit root test that allows for simultaneous smooth structural change and asymmetric adjustment in the data generating process\(^3\). The results of these tests are provided in Table 2.

\[\text{(Table 2)}\]

The results of the ADF, PP, KSS and ST-TAR unit root tests suggest that the null hypothesis of unit root is rejected at conventional significance levels. Similarly, the KPSS test rejects the null hypothesis of stationarity at 1\% significance level, contradicting to the PPP proposition. However, our new proposed test that allows for nonlinear adjustment towards nonlinear trend function rejects the null hypothesis of unit root at 5\% significance level, providing some evidence in favour of PPP for the Australian RER. This finding suggests that a model that allows for more gradual structural breaks and nonlinear adjustment (rather than single structural break and nonlinear models) might be more appropriate for the Australian RER series.

4. Conclusion

In this paper, we tested the validity of PPP for the Australian real exchange rate series. Conventional unit root tests as well as newly developed test procedures that allow for nonlinearity and single gradual structural break fails to reject the null hypothesis of unit root, contradicting to the PPP proposition. However, after allowing
for higher order nonlinearity in the deterministic trend function (which may capture several gradual structural breaks) as well as nonlinear adjustment in the series, we were able to reject the null hypothesis of unit root in the Australian RER series, providing some evidence in favour of the PPP proposition.

Endnotes

1. For a survey of literature on PPP see, for example, Rogoff (1996), Sarno and Taylor (2002), Taylor (2002), and Taylor (2003).
2. See Kapetanios et al. (2003) for further discussions on geometric ergodicity and asymptotic properties of the ESTAR models.
3. In order to see whether the Australian RER series exhibit long memory or not, we also estimated fractional difference parameter following the methodology outlined in Andrews and Guggenberger (2003). Estimated difference parameter $\hat{d} = 1.005$ with standard error = 0.256 suggests that the series under investigation are difference stationary, contradicting to PPP.

References


### Table 1. OLS Estimates of Coefficients of Time Polynomials

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient estimate</th>
<th>Standard error</th>
<th>t-statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>5.081</td>
<td>0.073</td>
<td>69.647</td>
</tr>
<tr>
<td>$t$</td>
<td>-0.064</td>
<td>0.030</td>
<td>-2.136</td>
</tr>
<tr>
<td>$t^2$</td>
<td>0.013</td>
<td>0.004</td>
<td>3.123</td>
</tr>
<tr>
<td>$t^3$</td>
<td>-9.647x10^{-4}</td>
<td>2.663x10^{-4}</td>
<td>-3.623</td>
</tr>
<tr>
<td>$t^4$</td>
<td>3.693x10^{-5}</td>
<td>9.517x10^{-6}</td>
<td>3.881</td>
</tr>
<tr>
<td>$t^5$</td>
<td>-8.290x10^{-7}</td>
<td>2.050x10^{-7}</td>
<td>-4.043</td>
</tr>
<tr>
<td>$t^6$</td>
<td>1.152x10^{-8}</td>
<td>2.770x10^{-9}</td>
<td>4.156</td>
</tr>
<tr>
<td>$t^7$</td>
<td>-1.003x10^{-10}</td>
<td>2.362x10^{-11}</td>
<td>-4.245</td>
</tr>
<tr>
<td>$t^8$</td>
<td>5.311x10^{-13}</td>
<td>1.233x10^{-13}</td>
<td>4.308</td>
</tr>
<tr>
<td>$t^9$</td>
<td>-1.565x10^{-15}</td>
<td>3.597x10^{-16}</td>
<td>-4.351</td>
</tr>
<tr>
<td>$t^{10}$</td>
<td>1.965x10^{-18}</td>
<td>4.490x10^{-19}</td>
<td>4.375</td>
</tr>
</tbody>
</table>

**Notes:**
(a) significant at 1 per cent significance level.
(b) significant at 5 per cent significance level.

### Table 2. Unit Root Test Results

<table>
<thead>
<tr>
<th></th>
<th>ADF</th>
<th>PP</th>
<th>KPSS</th>
<th>KSS</th>
<th>ST-TAR</th>
<th>$t_{NTNL}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test statistics</td>
<td>-1.312</td>
<td>-1.083</td>
<td>0.276</td>
<td>-2.868</td>
<td>-2.987</td>
<td>-3.982</td>
</tr>
<tr>
<td>Critical Values</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1%</td>
<td>-4.020</td>
<td>-4.018</td>
<td>0.216</td>
<td>-3.93</td>
<td>-4.393</td>
<td>-4.458</td>
</tr>
<tr>
<td>5%</td>
<td>-3.440</td>
<td>-3.439</td>
<td>0.146</td>
<td>-3.40</td>
<td>-3.937</td>
<td>-3.775</td>
</tr>
<tr>
<td>10%</td>
<td>-3.144</td>
<td>-3.143</td>
<td>0.119</td>
<td>-3.13</td>
<td>-3.704</td>
<td>-3.419</td>
</tr>
</tbody>
</table>

**Notes:** All test regressions include time trend. The KPSS test differs from other tests in that it assumes that the series under investigation are stationary under the null hypothesis.
(a) The bootstrap critical values for the $t_{NTNL}$ statistics were calculated using 100,000 replications.
(b) rejection of the null hypothesis of stationarity at 1 per cent significance level.
(c) rejection of the null hypothesis of unit root at 5 per cent significance level.
Figure 1. Australian Real Exchange Rate with Estimated Nonlinear Trend Function