International Research Journal of Finance and Economics
ISSN 1450-2887 Issue 98 September, 2012

http://www. internationalresearchjournaloffinanceandeconomics.com

The ADL Test for Threshold Cointegration to Test the Validity of Purchasing Power Parity

Su-ling Tsai
Corresponding Author, Postgraduate Institute of China and Asia-Pacific Studies
National Sun Yat-sen University in Taiwan
E-mail: d966010010@student. nsysu. edu.tw
Tel: +886 921022756

Jia-hsi Weng
Associate Professor Institute of China and Asia-Pacific Studies
National Sun Yat-sen University in Taiwan
E-mail: jhw654@faculty. nsysu. edu.tw

Chi-lin Lin
postgraduate Institute of China and Asia-Pacific Studies
National Sun Yat-sen University in Taiwan

Abstract

This study applies a newly-developed Autoregressive Distributed Lag (ADL) test for threshold cointegration, proposed by Li and Lee (2010) to test the validity of long-run purchasing power parity (PPP) for three countries of Southern Africa (i. e., Botswana , South Africa, Swaziland) over the January 1970 to January 2011. The empirical results indicate that PPP only holds true for one of these countries under study.

Keywords: Purchasing Power Parity; ADL Test; Threshold Cointegration
JEL Classification Codes: C22; F31

I. Introduction

Nonlinear behavior of Purchasing power parity (hereafter, PPP) is well documented in the literature of international finance. PPP states that the exchange rates between currencies are in equilibrium when their purchasing power is the same in each of the two countries. This means that the exchange rate between any two countries should equal the ratio of two currencies' price level of a fixed basket of goods and services. The basic idea behind the PPP hypothesis is that since any international goods market arbitrage should be traded away over time, we should expect the real exchange rate to return to a constant equilibrium value in the long run. Studies on this issue are critical not only for empirical researchers but also for policymakers. According to the records, there is a common sense that short-term PPP is not formed. But to the long-term PPP, it is still not sure whether it is true or not. Some references in the field are McDonald and Taylor (1992), Taylor (1995), Rogoff (1996), Taylor and Sarno (1998), Taylor and Peel (2000), Lothian and Taylor (2000, 2008), Sarno and Taylor (2002), and Taylor and Taylor (2004) who have provided in-depth information on the theoretical and empirical aspects of PPP and the real exchange rate.

As for methodology, recent studies of long-run PPP have mostly utilized conventional unit root tests for real exchange rates and cointegration tests for the relationship between various measures of domestic and foreign prices as well as nominal exchange rates. The conclusions drawn from these studies have primarily been based on linear tests of stationarity and/or cointegration. The power of linear cointegration tests is lower in an asymmetric adjustment process. More to the point, it is very likely that the assumption of symmetric adjustments yield poor results when it comes to equilibrium relationships because conventional cointegration tests do not take asymmetric adjustments into account. Enders and Granger (1998) also show that the standard tests for unit root and cointegration all have lower power in the presence of misspecified dynamics. This is important since the linear relationship is inappropriate if prices are sticky in the downward, but not in the upward direction. Madsen and Yang (1998) have provided evidence that prices are sticky in the downward direction and that such stickiness means that real exchange rate adjustments are asymmetric. Dumas(1992)thinks that the exchange rate should be nonlinear adjustment due to the existence of transaction cost. Taylor and Peel(2000) also point that investors applied technical analysis will lead to the adjustment of real exchange rate into nonlinear state . Michael et al. (1997) indicate that real exchange rate diverges from PPP's phenomenon and reflects on nonlinear adjustment. The reason might be the existence of transaction cost at the market. It means that real exchange rate will existe unit root as the adjustment of diverged PPP in the range of transaction cost. However, it will represent Mean Reversion when it diverges over the transaction cost too much. To sum up, use the nonlinear model to examine PPP, it is more suitable for the exchange rate.

Kilian and Taylor (2003) also suggest that nonlinearity may arise from the heterogeneity of opinion in the foreign exchange market concerning the equilibrium level of the nominal exchange rate: as the nominal rate takes on more extreme values, a great degree of consensus develops concerning the appropriate direction of exchange rate movements, and traders act as accordingly. All these motivate us to use the Autoregressive Distributed Lag (hereafter, ADL) test for threshold (asymmetric) cointegration in our study. The present empirical study contributes significantly to this field of research by using the ADL test for threshold cointegraion, proposed by Li and Lee (2010), to determine whether long-run PPP existed in three countries of southern Africa (i. e., Botswana, South Africa, Swaziland). To utilize the ADL test for threshold cointegration to test the long-run PPP for three countries. Empirical results indicate that PPP holds true for one country (South Africa) under study, and the long-run PPP adjustment process toward its equilibrium is asymmetric.

The plan of this paper is organized as follows. Section II presents the data used in our study. Section III briefly describes the ADL test for threshold cointegration proposed by Li and Lee (2010) and Section IV presents our empirical results. Section V concludes the paper.

II. Data

Our empirical analysis covers the three countries: Botswana , South Africa, Swaziland. Monthly data are employed in our empirical study, and the time span is from January 1970 to January 2011. All datas are taken from the International Monetary Fund's International Financial Statistics CD-ROM. All consumer price indices and nominal exchange rates relative to the USA dollar data. Each of the consumer price index and nominal exchange rate series was transformed into natural logarithms before the econometric analysis.

III. Li and Lee's (2010) ADL Test for Threshold Cointegration

In this study, we employ the ADL test for threshold cointegration technique advanced by Li and Lee (2010) to test for long-run PPP with asymmetric adjustments for three countries of southern Africa. Follow the Li and Lee (2010), we also relax the assumption of a pre-specified cointegrating vector and consider estimating the cointegrating vector. Therefore, the threshold ADL model is appropriate and

threshold cointegration tests are suggested. First the estimated cointegrating vector is given by the following regression:

$$e_t = \alpha_0 + \alpha_1 P_t^* + \alpha_2 P_t + u_t \quad (1)$$

where e_t is the logarithm of the foreign exchange rate in the domestic currency; P_t^* and P_t represent the logarithm of foreign and domestic price levels, respectively, and u_t is the stochastic disturbance term. Two indicators, *Indicator A* with $I_t^a = I(u_{t-1} < u_{t-1}^*(\tau))$ and *Indicator B* with $I_t^b = I(\Delta u_{t-1} < \Delta u_{t-1}^*(\tau))$, are considered. Specifically, the threshold ADL regression model of PPP is described as follows

$$\begin{aligned}\Delta e_t = {} & \beta_0 + \beta_1 e_{t-1} I_t + \beta_2 e_{t-1}(1-I_t) + \beta_3 P_{t-1} I_t + \beta_4 P_{t-1}(1-I_t) + \\ & \beta_5 P_{t-1}^* I_t + \beta_6 P_{t-1}^*(1-I_t) + \beta_7 \Delta P_t + \beta_8 \Delta P_t^* + \beta_9 \Delta e_{t-1} + \beta_{10} \Delta P_{t-1} + \beta_{11} \Delta P_{t-1}^* + \varepsilon_t\end{aligned} \quad (2)$$

where I_t^a can be replaced with I_t^b if *Indicator B* is adopted. Most important, the adjustment speeds toward the long-run equilibrium, as measured by β_i (i = 1, 2, 3, 4, 5, 6) are allowed to vary in the threshold model. Thus, the conventional ADL model is a special case of the threshold ADL model when $\beta_1 = \beta_2$, $\beta_3 = \beta_4$, and $\beta_5 = \beta_6$.

Here, only one lag of Δe_t, ΔP_t and ΔP_t^* is included in the regression following the the parsimony principle. The lag-selection is guided by the partial autocorrelation function (PACF) of Δe_t. Li and Lee (2010) proposed two tests for threshold cointegration. The first - the BO type test, is due to Boswijk (1994), who suggests testing the coefficients of e_{t-1}, P_{t-1}, and P_{t-1}^* in the testing regression. In contrast, the second-the BDM type test of Banerjee et al. (1998) suggesting adding lead of both P_{t-1} and P_{t-1}^* to the regression so that the asymptotic results are valid in the absence of strict exogeneity. The threshold BO and BDM tests are based on testing the following two null hypotheses, respectively:

$H_0 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0$ BO test

$H_0 : \beta_1 = \beta_2 = 0$ BDM test,

Based on their Monte Carlo experiment, Li and Lee (2010) indicate that the BO test performs better than any of other tests in terms of size and power. Given this, we recommend using the BO threshold cointegration test for our empirical research. As there is generally no prescribed rule as to whether to use the *Indicator A* or *Indicator B* in our model, the recommendation is to select the adjustment mechanism using a model selection criterion such as the Akaike Information criteria (AIC) or Schwartz criteria (SC).

IV. Empirical Results and Economic Implications

As we mentioned earlier that there is generally no prescribed rule as to whether to use the *Indicator A* or *Indicator B* in our model, Table 1 and 2 report the results from our threshold ADL test using the *Indicator A* and *Indicator B* functions, respectively.

Table 1: Conditional threshold ADL model of PPP with *Indicator A*

	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}
Botswana	-0.081 (-1.225)	-0.048 (-2.121)	-0.118 (-3.060)	0.031 (1.346)	0.005 (0.187)	0.099 (2.707)	-0.030 (-1.055)	-0.111 (-0.398)	-0.438 (-0.721)	0.111 (2.244)	-0.147 (-0.541)	-0.113 (-0.182)
	$E_t(\tau) = 0.105$, $\tau = 0.748$, *BO stat* : 16.609, *AIC* = -300.690											
South Africa	-0.043 (-0.363)	-0.044 (-1.947)	-0.053 (-1.418)	0.029 (0.902)	0.000 (0.008)	0.027 (0.644)	0.009 (0.206)	-0.190 (-0.564)	-0.826 (-1.101)	0.075 (1.526)	-0.922 (-2.757)	0.084 (0.112)
	$E_t(\tau) = 0.148$, $\tau = 0.839$, *BO stat* : 16.315, *AIC* = -117.853											
Swaziland	0.006 (0.044)	-0.050 (-2.353)	-0.086 (-2.102)	0.040 (1.275)	-0.020 (-0.380)	0.082 (1.812)	-0.039 (-0.778)	0.110 (1.217)	-0.965 (-1.318)	0.084 (1.717)	0.047 (0.523)	-0.471 (-0.651)
	$E_t(\tau) = 0.159$, $\tau = 0.832$, *BO stat* : 14.503, , *AIC* = -139.937											

Note: 1. The critical values for BO statistic are tabulated at Li and Lee's (2010) Table 1 of their paper. The critical values of BO test for 10%, 5%, and 1% are 22. 11, 24. 67, and 30. 09, respectively.

2. ***, **, and * indicates significance at the 0. 01, 0. 05 and 0. 1 levels, respectively.
3. The number in parenthesis indicates the robust t-statistic.

Table 2: Conditional threshold ADL model of PPP with *Indicator B*

	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}
Botswana	-0.019 (-0.283)	-0.044 (-3.266)	-0.015 (-0.712)	0.036 (2.312)	-0.015 (-0.609)	-0.001 (-0.047)	0.013 (0.528)	-0.015 (-0.056)	-0.440 (-0.724)	-0.022 (-0.328)	-0.059 (-0.220)	-0.210 (-0.339)
	$E_t(\tau) = 0.015,\ \tau = 0.780,\ BO\ stat: 17.823,\ AIC = -301.890$											
South Africa	-0.048 (-0.433)	-0.036 (-2.604)	-0.002 (-0.125)	0.020 (0.880)	0.006 (0.164)	-0.022 (-0.782)	0.038 (0.962)	-0.172 (-0.515)	-0.803 (-1.071)	-0.077 (-1.121)	-0.727 (-2.185	-0.218 (-0.291)
	$E_t(\tau) = 0.023,\ \tau = 0.797,\ BO\ stat: 22.331^*,\ AIC = -123.768$											
Swaziland	-0.109 (-0.910)	-0.056 (-3.452)	0.007 (0.475)	0.031 (1.381)	0.015 (0.362)	-0.024 (-1.022)	0.046 (1.079)	0.087 (0.962)	-0.781 (-1.081)	-0.014 (-0.224)	0.082 (0.825)	-0.377 (-0.523)
	$E_t(\tau) = -0.003,\ \tau = 0.460,\ BO\ stat: 19.217,\ AIC = -144.598$											

Note: 1. The critical values for BO statistic are tabulated at Li and Lee's (2010) Table 1 of their paper. The critical values of BO test for 10%, 5%, and 1% are 20. 90, 23. 43, and 28. 66, respectively.
2. ***, **, and * indicates significance at the 0. 01, 0. 05 and 0. 1 levels, respectively.
3. The number in parenthesis indicates the robust t-statistic.

The recommendation is to select the adjustment mechanism using a model selection criterion such as the Akaike Information criteria (AIC) or Schwartz criteria (SC). Here, we use the AIC in our study. When we use the AIC model selection criterion and the results are reported in Table 3.

Table 3: Use the AIC model and threshold ADL model of PPP with *Indicator B*

	β_0	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}
Botswana	-0.019 (-0.283)	-0.044 (-3.266)	-0.015 (-0.712)	0.036 (2.312)	-0.015 (-0.609)	-0.001 (-0.047)	0.013 (0.528)	-0.015 (-0.056)	-0.440 (-0.724)	-0.022 (-0.328)	-0.059 (-0.220)	-0.210 (-0.339)
	$E_t(\tau) = 0.015,\ \tau = 0.780,\ BO\ stat: 17.823,\ AIC = -301.890$											
South Africa	-0.048 (-0.433)	-0.036 (-2.604)	-0.002 (-0.125)	0.020 (0.880)	0.006 (0.164)	-0.022 (-0.782)	0.038 (0.962)	-0.172 (-0.515)	-0.803 (-1.071)	-0.077 (-1.121)	-0.727 (-2.185	-0.218 (-0.291)
	$E_t(\tau) = 0.023,\ \tau = 0.797,\ BO\ stat: 22.331^*,\ AIC = -123.768$											
Swaziland	-0.109 (-0.910)	-0.056 (-3.452)	0.007 (0.475)	0.031 (1.381)	0.015 (0.362)	-0.024 (-1.022)	0.046 (1.079)	0.087 (0.962)	-0.781 (-1.081)	-0.014 (-0.224)	0.082 (0.825)	-0.377 (-0.523)
	$E_t(\tau) = -0.003,\ \tau = 0.460,\ BO\ stat: 19.217,\ AIC = -144.598$											

Note: 1. The critical values for BO statistic are tabulated at Li and Lee's (2010) Table 1 of their paper. The critical values of BO test for 10%, 5%, and 1% are 20. 90, 23. 43, and 28. 66, respectively.
2. ***, **, and * indicates significance at the 0. 01, 0. 05 and 0. 1 levels, respectively.
3. The number in parenthesis indicates the robust t-statistic.

Based on the results from Tables 3, we find that the null hypothesis is rejected in favor of the alternative hypothesis for only one countries (South Africa). Apparently, the ADL test for threshold cointegration employed in our study provided evidence favoring the long-run validity of PPP for one of these countries under study, and the long-run PPP adjustment process toward its equilibrium is asymmetric, as indicated by the significant coefficients of β_i (i = 1, 2, 3, 4, 5, 6) for each country (see Tables 1 and 2) . Our results have important policy implications for these countries under study.

The major policy implication that emerges from this study is that that PPP can be used to determine the equilibrium exchange rate for only one of these three countries, namely South Africa. The government of South Africa can use PPP to predict exchange rate that determine whether a currency is over or undervalued and experiencing difference between domestic and foreign inflation rates. Nevertheless, reaping unbounded gains from arbitrage in traded goods is not possible in South Africa.

V. Conclusions

The documents do not reach agreement on the issue whether long-term PPP exist or not. The main reason lies on the difference of exchange rate system, different varieties of the prices, and alterative datas. They will all influence the equilibrium of long-term PPP. This paper employs the ADL test for threshold cointegration recently introduced in the literature by Li and Lee. (2010). The Monte Carlo simulations of Li and Lee (2010) show that the test does not suffer from low power and have good size properties. We apply this ADL test for threshold cointegration to test the validity of long-run PPP for three countries of southern Africa over the January 1970 to January 2011. The empirical results indicate that PPP only holds true for South Africa . As concerns major policy, our study implies that PPP can be used to determine the equilibrium exchange rate for South Africa.

References

[1] Dumas, B. (1992) Dynamic Equilibrium and the Real Exchange Rate in Spatially Separated World , *Review of Financial Studies,*5, 153-80.

[2] Enders, W. and Granger, C. W. F. (1998) Unit-root tests and asymmetric adjustment with an example using the term structure of interest rates, *Journal of Business Economics & Statistics*, 16, 304-311.

[3] Juvenal, L. and Taylor, M. P. (2008) Threshold adjustment of deviations from the law of one price, *Studies in Nonlinear Dynamics and Econometrics,* 12(3), 1-44.

[4] Kilian, L. and Taylor, M. P. (2003) Why is it so difficult to beat the random walk forecast of exchange rates? *Journal of International Economics*, 60(1), 85-107.

[5] Li, J. and Lee, J. (2010) ADL test for threshold cointegration, *Journal of Time Series Analysis*, 31, 241-254.

[6] Lothian, J. R. and Taylor, M. P. (2000) Purchasing power parity over two centuries: strengthening the case for real exchange rate stability reply to Cuddington and Liang, *Journal of International Money and Finance*, 19(5), 759-764.

[7] Lothian, J. R. and Taylor, M. P. (2008) Real exchange rates over the past two centuries: how important is the Harrod-Balassa-Samuelson effect? *Economic Journal,* 118(532), 1742-1763.

[8] MacDonald, R. and Taylor, M. P. (1992) Exchange rate economics: A survey, *Staff Papers- ., Monetary Fund,* 39(1), 1-57.

[9] Michael, P., Nobay, A. R. and Peel, D. A. (1997) Transaction cost and nonlinear adjustment in real exchange rate: An empirical investigation , *Journal of Political Economy,*, 105, 862-79.

[10] Rogoff, K. (1996) The purchasing power parity puzzle, *Journal of Economic Literature*, 34, 647-668.

[11] Sarno, L. and Taylor, M. P. (2002) Purchasing power parity and the real exchange rate, *IMF Staff Papers*, 49, 65-105.

[12] Taylor, A. M. and Taylor, M. P. (2004) The purchasing power parity debate, *Journal of Economic Perspectives,* 18(4), 135-158.

[13] Taylor, M. P. (1995) The economics of exchange-rates, *Journal of Economic Literature,* 33(1), 13-47.

[14] Taylor, M. P and D. A. Peel (2000) Nonlinear Adjustment, Long-Run Equilibrium and Exchange Rate Fundamentals, *Journal of International Money and Finance*, 19, 1, 33-53.

[15] Taylor, M. P. and Sarno, L. (1998) The Behavior of real exchange rates during the post-Bretton Woods period, *Journal of International Economics*, 46(2), 281-312.

[16] Chang, T., Lee, C. -H. and Chou, P. -I (2010) Purchasing power parity in G-7 countries: Further evidence based on ADL tests for threshold cointegration, *Economics Bulletin*, 31(2), 1172-1182.

[17] Wu, J. and Chen, S. (2001) Nominal exchange rate prediction: Evidence from a nonlinear approach, *Journal of International Money and Finance,* 20, 521-532.