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Purchasing power parity in G-7 countries: Further evidence based on ADL test for threshold cointegration

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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 G-7 countries over the January 1994 to April 2010. The empirical results indicate that PPP only holds true for Canada and France two countries. Our results have important policy implications for the G-7 countries under study.

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1. Introduction

Over the past several decades, empirical studies have devoted increasing interest to testing the validity of purchasing power parity (hereafter, PPP) hypothesis as it has important implications in the international macroeconomics. PPP states that 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. In particular, a non-stationary real exchange rate indicates that there is no long-run relationship between nominal exchange rate, domestic and foreign prices, thereby invalidating the purchasing power parity. As such, PPP can not be used to determine the equilibrium exchange rate and invalid PPP also disqualifies the monetary approach to exchange rate determination, which requires PPP to hold true. Some references in the field are McDonald and Taylor (1992), Taylor (1995), Rogoff (1996), Taylor and Sarno (1998), 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.

While some empirical evidence of long-run PPP for both developed countries and less-developed countries seems convincing, unfortunately thus far none has been proven to be conclusive. 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. Since ample evidence in support of asymmetric reactions in key economic variables has been widely acknowledged in recent years, there is no reason to assume that the long-run PPP adjustment process toward equilibrium is always symmetric. As shown by Madsen and Yang (1998) and Ramsey and Rothman (1996), for example, economic variables such as inflation rates, etc. follow an asymmetric adjustment process. Besides, as pointed out by Balke and Fomby (1997), 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. Other reasons for the asymmetric adjustment are the presence of transactions costs that inhibit international goods arbitrage and official intervention in the foreign exchange market may be such that nominal exchange rate movements are asymmetric (see, Taylor, 2004; Juvenal and Taylor, 2008; Wu and Chen, 2001). 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 in our study Autoregressive Distributed Lag (hereafter, ADL) test for threshold (asymmetric) cointegration.

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 exists in G-7 countries. The major advantage of this approach is that it allows us to simultaneously investigate nonlinearity and cointegration. With this, the current research hopes to fill the existing gap in the literature. To the best of our knowledge, this study is the first of its kind to utilize the ADL test for threshold cointegration to test the long-run PPP in G-7 countries. The empirical results indicate that PPP only holds true for Canada and France two countries studied. Our results have important policy implications for the G-7 countries under study.

The plan of this paper is organized as follows. Section 2 presents the data used in our study. Section 3 briefly describes the ADL test for threshold cointegration proposed by Li and Lee (2010) and Section 4 presents our empirical results. Section 5 concludes the paper.

2. Data

Our empirical analysis covers the G-7 countries: Canada, France, Germany, Italy, Japan, UK, and USA. Monthly data are employed in this study, and the time span is from January 1994 to April 2010. All consumer price indices, CPI (based on 2005 = 100) and nominal exchange rates relative to the USA dollar data are taken from the International Monetary Fund's International Financial Statistics CD-ROM. Each of the consumer price indices and real exchange rate series was transformed into natural logarithms before the econometric analysis. Testing for PPP against the USA is based on the argument that internal foreign exchange markets are mostly dollar

dominated. A summary of the statistics is given in Table 1. Our Jarque-Bera test results indicate that for all 6 country pairs, the bilateral real exchange rate data sets are approximately non-normal. The Japan/USD with values varying from 4.164 to 4.879 and a standard deviation of 0.151 is the most volatile currency, whereas the UK/USD with values varying from -0.731 to -0.330 and a standard deviation of 0.102 is the less volatile currency. Figure 1 plot the real exchange rates series for these six country pairs. We do not find any significant upward or downward trend in the real exchange rate series. From these figures, for most of the series, there seem to exhibit some nonlinear adjustment patterns.

3. 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 the G-7 countries. 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:

$$e_t = \alpha_0 + \alpha_1 P_t^* + \alpha_2 P_t + u_t \tag{1}$$

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

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

where I_t 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:

$$H_0 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = 0 \quad \text{BO test}$$
$$H_0 : \beta_1 = \beta_2 = 0 \quad \text{BDM test,}$$

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).

4. Empirical Results

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, 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, the ADL model with the *Indicator A* is favored in all of the cases with the exception of Canada and Japan.

This means that for France, Germany, Italy and the UK, we use ADL model with *Indicator A function* and Canada and Japan, we use ADL model with *Indicator B function.* Table 2 and 3 report the results from our ADL test for threshold cointegration using the *Indicator A* and *Indicator B functions,* respectively. Based on the results from Tables 2 and 3, we find that the null hypothesis is rejected in favor of the alternative hypothesis for only two cases, Canada and France. Apparently, the ADL test for threshold cointegration employed in our study provided weak evidence favoring the long-run validity of PPP for these G-7 countries under study, with the exception of Canada and France. Our result is not consistent with those of Kapetanios et al. (2003) and Chang et al. (2010), both studies also found that the real exchange rates of Canada failed to reject the null of a unit root irrespective of whether linear or nonlinear tests were employed

The major policy implication that emerges from this study is that that PPP can be used to determine the equilibrium exchange rate for only two of the G-7 countries, namely Canada and France. The governments of these two countries 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 these two countries.

5. Conclusions

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 G-7 countries over the January 1994 to April 2010. The empirical results indicate that PPP only holds true for Canada and France two countries studied.

Our results have important policy implications for these G-7 countries under study. As concerns major policy, our study implies that PPP can be used to determine the equilibrium exchange rate for only Canada and France two countries under study.

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Table 1. Summary statistics (USD Base)

	Canada	France	Germany	Italy	Japan	UK
Mean	0.267	1.691	0.465	7.409	4.614	-0.505
Median	0.273	1.665	0.442	7.385	4.640	-0.490
Maximum	0.463	2.020	0.793	7.729	4.879	-0.330
Minimum	0.004	1.451	0.214	7.131	4.164	-0.731
Std. Dev.	0.118	0.142	0.144	0.137	0.151	0.102
Skewness	-0.326	0.717	0.570	0.568	-0.782	-0.477
Kurtosis	2.233	2.664	2.608	2.761	3.141	2.368
Jarque-Bera	8.278**	17.712***	11.872***	10.996***	20.161***	10.683***

Note: 1. The sample period is from January 1994 to April 2010.

2. ln(real exchange rate)=ln(nominal exchange rate)+ln(foreign price level)-ln(domestic price level); the US as the base country.

3. ** and *** indicate significance at the 5% and 1% level, respectively.

Table 2. 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}
France	6.532	-0.170	-0.202	-3.378	2.016	-3.377	2.032	-0.274	-0.885	0.084	0.387	0.424
	(4.95)	(-3.72)	(-5.02)	(-4.92)	(4.87)	(-4.85)	(4.77)	(-0.30)	(-1.33)	(1.19)	(0.42)	(0.61)
	$E_t^*(\tau)$ = -0.029			$\tau = 0.372$			*BO stat* : **26.906****			*AIC* = **-373.5**		
Germany	1.654	-0.123	-0.040	-0.819	0.471	-0.681	0.326	-0.860	-1.106	0.106	0.657	0.652
	(1.74)	(-1.69)	(-1.78)	(-1.72)	(1.71)	(-1.43)	(1.19)	(-1.17)	(-1.57)	(1.46)	(0.88)	(0.96)
	$E_t^*(\tau)$ = -0.085			$\tau = 0.301$			*BO stat* : 11.115			*AIC* = **-352.257**		
Italy	1.084	-0.119	-0.176	0.273	-0.319	-1.929	1.991	-0.646	-1.202	0.107	0.203	1.016
	(3.44)	(-3.41)	(-1.91)	(1.37)	(-1.66)	(-1.72)	(1.63)	(-0.52)	(-1.83)	(1.46)	(0.17)	(1.53)
	$E_t^*(\tau) = 0.077$			$\tau = 0.816$			*BO stat* : 16.079			*AIC* = **-369.958**		
UK	0.316	-0.178	-0.157	-0.087	-0.004	0.787	-0.871	0.668	-1.507	-0.034	-1.217	0.152
	(2.35)	(-3.01)	(-2.51)	(-0.33)	(-0.01)	(2.02)	(-2.14)	(1.25)	(-2.60)	(-0.46)	(-2.49)	(0.23)
	$E_t^*(\tau) = 0.004$			$\tau = 0.617$			*BO stat* : 19.118			*AIC* = **-399.596**		

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 3. 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}
Canada	0.587	-0.049	-0.008	-0.436	0.312	-0.382	0.252	0.220	-1.352	0.354	0.925	-0.297
	(3.15)	(-2.49)	(-0.35)	(-2.07)	(1.75)	(-1.83)	(1.43)	(0.39)	(-2.39)	(3.19)	(1.72)	(-0.56)
	$\Delta E_t^*(\tau) = 0.005$			$\tau = 0.577$			*BO stat* : **30.202*****			*AIC* = **-503.206**		
Japan	0.884	-0.103	-0.020	-0.187	0.098	-0.122	-0.051	-0.395	-0.020	-0.178	-0.509	1.822
	(0.73)	(-1.96)	(-0.72)	(-0.70)	(2.08)	(-0.47)	(-2.08)	(-0.52)	(-0.03)	(-1.77)	(-0.64)	(2.35)
	$\Delta E_t^*(\tau)$ = -0.026			$\tau = 0.189$			*BO stat* : 18.842			*AIC* = **-293.088**		

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.

Figure 1. The tendency of real exchange rates given natural logarithms for G-7 countries—The USA base (1994M1-2010M4)