Testing for purchasing power parity for ASEAN-5 using asymmetric cointegration tests

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ARTICLE INFO

ABSTRACT

This paper tries to examine if purchasing power parity exists in Indonesia, Malaysia, Philippines, Singapore, and Thailand. To this end, we conduct a nonlinear asymmetric cointegration approach on testing for the existence of purchasing power parity (PPP) in ASEAN-5 countries using the threshold cointegration tests (TAR and MTAR). Based on Monthly data from 1996 to 2016, results of the threshold cointegration tests revealed evidence of long run PPP with asymmetric adjustment in Philippines and Thailand. However, PPP does not hold in Indonesia, Malaysia and Singapore, and the adjustment process in these countries is symmetric.

1. Introduction

The purchasing power parity theory, one of the oldest theories in the field of international finance states that the exchange rate between two countries should be equal to the ratio of the aggregate price levels between the two countries. Despite substantial empirical studies on the theory of PPP, research on the purchasing power parity is still being carried out because of its importance in policy implications in international trade and finance. Among the importance of PPP, is that it can be used to predict exchange rate to determine whether a currency is over-valued or under-valued. PPP is also used in measuring and comparing national income levels among countries. It is a tool used for forecasting general economic circumstances of countries (Beirne, 2010).

Because of its importance, considerable effort has been put into testing the validity of the long-run purchasing power parity. Countless researchers have utilized conventional linear unit root tests in real exchange rates, and cointegration between various measures of domestic and foreign prices and nominal exchange rates in the study of the long-run purchasing power parity (Su et al., 2010). The conclusions drawn from these studies are based on linear tests of unit roots and/ or cointegration. There is no reason to continue assuming that the long run

PPP adjustment process towards equilibrium is symmetric since a lot of evidence supporting asymmetric reactions in key economic variables have been acknowledged (Lu et al., 2011). As shown by Bahmani-Oskooee et al. (2016), economic variables such as the exchange rate may follow an asymmetric adjustment process. The power of linear cointegration test is low in an asymmetric adjustment process. Enders and Granger (1998) showed that the standard tests of stationarity and cointegration have low power in the presence of misspecified dynamics (Lu et al. 2011).

Due to the importance of the purchasing power parity, many empirical analyses have been conducted using different methods in determining the validity of PPP theory for different countries. In an effort to finding more powerful tests, a number of researchers have considered tests of nonlinearity or asymmetry in testing economic variables. These researchers include Baum et al. (2001) who modelled the dynamics of adjustments to long run PPP over the post- Bretton Wood era in a nonlinear framework for a set of U.S. trading partners from the period of August, 1973 to December, 1995 using the exponential smooth transition autoregressive (ESTAR) model. They found support for a nonlinear dynamic structure with a very slow convergence to long run purchasing power parity in the post-Bretton Woods era. Furthermore, Chen et al. (2013) found out that cointegration adjustment between exchange rate and oil prices in Philippines from the period of 1970Q1-2011Q4 appear to be asymmetric with the use of the momentum threshold autoregressive (MTAR) model. But they got a contrary result when they applied the threshold

autoregressive (TAR) model. Moreover, Haughton and Iglesias (2012) analysed asymmetric interest rates and the monetary transmission mechanism in the volatility on interest rates and the monetary transmission mechanism in the countries of Caribbean single market and economy (CSME) using monthly data from the period 1995 to 2010. The results of TAR and MTAR models showed asymmetric cointegration for Guyana, Jamaica and St. Lucia (but not for Barbados, Haiti, Trinidad and Tobago) for both lending and deposit rates. In addition, Khim and Liew (2004) in a paper titled "Nonlinear Adjustment of ASEAN-5 Real Exchange Rates; Symmetrical or Asymmetrical?" examined whether the nonlinear adjustment dynamics of exchange rate to the equilibrium level is symmetrical or asymmetrical using quarterly data from 1973Q1 to 1996Q4. They found out that the U.S. Dollar based real exchange rates of Indonesia, Philippines, Singapore and Thailand exhibit LSTAR-type nonlinearity, implying that the real exchange rates of these countries have asymmetric response towards appreciation and depreciation. In examining the stationarity of property of 11 Asian real exchange rates, Liew et al. (2004) found stationarity in most of the 11 Asian countries from the period of 1968Q1 to 2001Q2 when they applied the KSS (Kapetanios et al., 2003) nonlinear unit root test. Finally, Tiwari and Shahbaz (2014), examined the PPP hypothesis for India with her five major trading partners over the period of 1991M1-2009M2 using the DF-GLS unit root test and the threshold autoregressive (TAR) model as well as the momentum-TAR (M-TAR) models for the empirical analysis. Their analysis revealed that PPP hypothesis does not hold for all the major trading partners of India, indicating that intermediate goods face high barriers to trade in these sampled countries.

To this end, the main aim this paper is to investigate if there exist a long run validity of purchasing power parity and asymmetric adjustment in ASEAN-5 using the threshold cointegration test of Enders and Siklos (2001) on a set of monthly data from January, 1996 to March, 2016. Based on the results of the threshold cointegration tests, there exists a long run PPP with asymmetric adjustment in Philippines and Thailand. However, PPP does not hold in Indonesia, Malaysia and Singapore, and the adjustment process in these countries is symmetric.

2. Econometric methodology

2.1. Threshold cointegration tests (TAR and MTAR)

Following Su et al. (2010), we apply threshold cointegration technique advanced by Enders and Siklos (2001) to test for the long run PPP with asymmetric adjustment in ASEAN-5. The test is based on a two-stage process. First, we estimate a long run equilibrium relationship of the form:

$$e_t = \alpha_0 + \beta_1 p_t^* + \beta_2 p_t + \mu_t \qquad (1)$$

where e_t is the logarithm of nominal exchange rate, p_t^* and p_t represent the logarithm of foreign and domestic price levels respectively and μ_t is the stochastic disturbance term. The second stage focuses on the OLS estimates of ρ_1 and ρ_2 in the following regression:

$$\mu_t = I_t \rho_1 \mu_{t-1} + (1 - I_t)\rho_2 \mu_{t-1} + \sum_{i=1}^{t} \gamma_i \mu_{t-1} + \varepsilon_t \qquad (2)$$

where ε_t is a white-noise disturbance and the residuals, μ_t, in Eq. 1 are extracted to Eq. 2 to be further estimated. I_t is the Heaviside indicator function such that:

$$I_t = \begin{cases} 1 & if \quad \mu_{t-1} \geq \tau \\ 0 & if \quad \mu_{t-1} \geq \tau \end{cases}$$

where τ is the threshold value. A necessary condition for $\{\mu_t\}$ to be stationary is: $-2 < (\rho_1, \rho_2) < 0$. If the variance of ε_t is sufficiently large, it is also possible for one value of ρ_j to be between –2 and 0 and for the other value to equal zero. Although there is no convergence in the regime with the unit-root (i.e., the regime in which $\rho_j = 0$), large realization of ε_t will switch the system into the convergent regime. Enders and Granger (1998) and Enders and Siklos (2000) both pointed out in either case, under the null hypothesis of no convergence, the F-statistic for the null hypothesis $\rho_1 = \rho_2 = 0$ has a nonstandard distribution. The critical values for this non-standard F-statistic are tabulated in their paper. Enders and Granger (1998) also showed that if the sequence is stationary, the least squares estimates of ρ_1 and ρ_2 have an asymptotic multivariate normal distribution.

Model using Eq. 2 is known as the threshold auto regression model (TAR), where the test for threshold behavior of the equilibrium error is termed threshold cointegration test. Assuming the system is converged, $\mu_t = 0$ can be considered as the long-run equilibrium value of the sequence. If μ_t is above its long-run equilibrium, the adjustment is $\rho_1 \mu_{t-1}$ and if μ_t is below its long-run equilibrium, the adjustment is $\rho_2 \mu_{t-1}$. The equilibrium error therefore behaves like a threshold autoregression. The null hypothesis of $\rho_1 = \rho_2 = 0$ tests for the cointegration relationship and the rejection of this null imply that existence of cointegration between variables. In revealing of $\rho_1 = \rho_2 = 0$ hypothesis, it is valuable to further test for symmetric adjustment (i.e. $\rho_1 = \rho_2$) by using a standard F-test. When adjustment is symmetric as $\rho_1 = \rho_2$, Eq. 2 converges the prevalent augmented DF test (Said and Dickey, 1984). Rejecting both the null hypotheses of $\rho_1 = \rho_2 = 0$ and $\rho_1 = \rho_2$ imply the existence of threshold cointegration and the asymmetric adjustment.

According to Enders and Granger (1998), this model is especially valuable when adjustment is asymmetric such that the series exhibits more 'momentum' in one direction than the other. Instead of estimating Eq. 2 with the Heaviside indicator depending on the level of μ_{t-1}, the decay could also

be allowed to depend on the previous period's change in μ_{t-1}. The Heaviside indicator could then be specified as:

$$I_t = \begin{cases} 1 & if \quad \mu_{t-1} \geq \tau \\ 0 & if \quad \mu_{t-1} < \tau \end{cases}$$

where τ is the threshold value. This model is termed as momentum-threshold auto regression model (M-TAR). The TAR model can capture 'deep' cycle process if, for example, positive deviations are more prolonged than negative deviations. The M-TAR model allows the autoregressive decay to depend on μ_{t-1}. As such, the M-TAR representation can capture 'sharp' movements in a sequence.

In the most general case, the value of τ is unknown, it needs to be estimated along with the values of ρ_1 and ρ_2. By demeaning the $\{\mu_{t-1}\}$ sequence, the Enders and Granger (1998) test procedure employs the sample mean of the sequence as the threshold estimate of τ. However, the sample mean is a biased threshold estimator in the presence of asymmetric adjustments. For instance, if autoregressive decay is more sluggish for positive deviations of μ_{t-1} from τ than for negative deviations, the sample means estimator will be biased upwards. A consistent estimate of the threshold τ can be obtained by using Chan (1993) method of searching over possible threshold values to minimize the residual sum of squares from the fitted model. Enders and Siklos (2001) applied Chan's methodology to a Monte Carlo study to obtain the F-statistic for the null hypothesis of $\rho_1 = \rho_2 = 0$ when the threshold τ is estimated using Chan's procedure. The critical values of this non-standard F-statistic for testing the null hypothesis of $\rho_1 = \rho_2 = 0$ are also tabulated in their paper. As there is generally no presumption as to whether to use TAR or M-TAR model, the recommendation is to select the adjustment mechanism by a model selection criterion such as the Akaike information criterion (AIC) or Schwartz Bayesian information criterion (SBC).

3. Results

We applied the threshold cointegration tests to test for the PPP hypothesis. Prior to the TAR and MTAR cointegration tests, time series unit-root tests were conducted to check for the stationarity of variables. The time series unit-root tests include the ADF and PP. Below are the results of the analyses.

Table 1 presents the results of time series unit root tests. The table shows results for Augmented Dickey-Fuller (ADF) (Said and Dickey, 1984) and Phillips-Perron (PP) (Phillips and Perron, 1988) unit root tests for the individual Asian countries (Indonesia, Philippines, Malaysia, Singapore and Thailand). The results provide evidence for unit root in the log of nominal exchange rate (lxrate) and the log of respective price levels i.e. the log of consumer price index for the Asian countries and also the log of the consumer price index for US (Lcpi and Lcpi_us)

when we applied the ADF and the PP test. But after first differenced (ΔLxrate, ΔLcpi and ΔLcpi_us), these variables become stationary confirming that they are integrated of order one. Therefore, we fail to reject the null hypothesis of a unit root. Meaning that our variables of interest are not stationary at levels but stationary at first differenced.

Table 1: Time series unit root tests

Country	ADF	PP
Indonesia		
Lxrate	0.9587	1.1988
ΔLxrate	-5.9819***	-11.5332***
Lcpi	-1.0656	-1.1106
ΔLcpi	-12.4589***	-20.8158***
Cpi_us	-1.2089	-1.4259
ΔCpi_us	-10.0725***	-7.9067***
Philippines		
Lxrate	1.4500	1.1180
ΔLxrate	-13.6470** *	-14.0349***
Lcpi	0.7967	0.6154
ΔLcpi	-13.6470***	-13.5051***
Cpi_us	-1.2089	-1.4259
ΔCpi_us	-10.0725***	-7.9067***
Malaysia		
Lxrate	0.6087	0.5097
ΔLxrate	-14.7519 ***	-14.8259***
Lcpi	0.0857	-0.0899
ΔLcpi	-14.1464***	-14.1508***
Cpi_us	-1.2089	-1.4259
ΔCpi_us	-10.0725***	-7.9067***
Singapore		
Lxrate	-0.3430	-0.3316
ΔLxrate	-15.9426***	-15.9513***
Lcpi	1.1870	-1.1332
ΔLcpi	-14.7413***	-14.7568***
Cpi_us	-1.2089	-1.4259
ΔCpi_us	-10.0725***	-7.9067***
Thailand		
Lxrate	0.4380	0.5130
ΔLxrate	-11.9127***	-11.8658***
Lcpi	0.0079	0.0862
ΔLcpi	-14.7413***	-14.7568***
Cpi_us	-1.2089	-1.4259
ΔCpi_us	-10.0725***	-7.9067***

Note: *** denotes the significance at 1% level.

Furthermore, Table 2 presents the results of the threshold autoregressive (TAR) model and the momentum threshold autoregressive (MTAR) model for the case where $\tau = 0$. The results failed to reject the null hypotheses of no cointegration and symmetry for all the five countries (Indonesia, Philippines, Malaysia, Singapore and Thailand) with the use of the MTAR. This implies that PPP is not valid in these countries and the adjustment process is symmetric when $\tau = 0$. The results are the same for the TAR model except for the presence of asymmetric adjustment in Thailand.

However, in Table 3 where we find the results of the TAR and MTAR models in which we have consistent estimates for τ, the results for all the countries considered in our sample failed to reject the null of no cointegration and symmetry for Indonesia, Philippines, Malaysia and Singapore, implying that PPP does not exist in these countries. The result is opposite for Thailand. For Thailand, the null hypotheses of no cointegration and symmetry are rejected, indicating the presence of cointegration and asymmetry adjustment. The result of Thailand

clearly shows that PPP is valid in Thailand and the adjustment process is asymmetrical. Furthermore, looking at the result of the MTAR model, we fail to reject the null hypotheses of no cointegration and symmetry for Indonesia, Malaysia, Singapore and Thailand indicating that PPP does not hold and the adjustment process is symmetric. The result here is different for Philippines, where we reject the null hypotheses of no cointegration and symmetry indicating that PPP holds and the adjustment process towards equilibrium is asymmetric.

Table 2: Results of the TAR and MTAR when $\tau = 0$

Country	TAR	MTAR
Indonesia		
τ	0	0
ρ_1	-0.1086**	-0.1070**
ρ_2	-0.0742*	-0.0751*
ϕ_μ	4.7272 (7.0845)	4.7038 (7.6044)
$\rho_1 = \rho_2$	0.3638 (2.2884)	0.3188 (3.7895)
Philippines		
τ	0	0
ρ_1	-0.0133	-0.0142
ρ_2	-0.0307***	-0.0415***
ϕ_μ	4.8924 (5.8040)	5.7603 (6.1306)
$\rho_1 = \rho_2$	0.8654 (2.9144)	2.5360 (3.8532)
Malaysia		
τ	0	0
ρ_1	-0.1683*	-0.2307**
ρ_2	-0.1262	-0.0727
ϕ_μ	2.0100 (7.0309)	3.0651 (7.6423)
$\rho_1 = \rho_2$	0.1589 (2.3300)	2.2342 (3.8703)
Singapore		
τ	0	0
ρ_1	-0.0307	-0.0518
ρ_2	-0.0743	-0.0580
ϕ_μ	1.1535 (7.0825)	0.9578 (7.5244)
$\rho_1 = \rho_2$	0.3823 (2.2638)	0.0077 (3.8363)
Thailand		
τ	0	0
ρ_1	-0.0859	-0.2194**
ρ_2	-0.3302***	-0.1556*
ϕ_μ	6.3208 (7.0803)	3.5700 (7.6549)
$\rho_1 = \rho_2$	5.7209(2.2492)**	0.3763 (3.9649)

Note: ρ_1 and ρ_2 determine the speed of adjustment for positive and negative deviations respectively. ϕ_μ denotes the F-statistic for the null of no cointegration, and $\rho_1 = \rho_2$, the statistic for the test of symmetry. *, **and *** indicate significance at 10%, 5% and 1% levels respectively

4. Conclusion

This paper investigates whether there is a long-run purchasing power parity (PPP) with asymmetric adjustment for a group of ASEAN-5 countries for the period of 1996-2016 using the Enders and Siklos (2001) threshold cointegration (TAR and MTAR) tests. Unit-root tests were applied prior to the cointegration tests in checking the fulfilment of the data for cointegration tests. The unit-root tests revealed that all variables (exchange rate, consumer price index for each ASEAN5 and U.S.) are not stationary at levels but stationary at first difference, i.e. all variables are integrated of order 1. Furthermore, we conducted the asymmetric cointegration test for the TAR and MTAR models when $\tau = 0$. The results of these tests failed to reject the null hypothesis of no cointegration for all the countries (Indonesia, Philippines, Malaysia, Singapore and Thailand), but the null of symmetry was rejected only for Thailand (which means that all

other countries have symmetric adjustment except for Thailand which is asymmetric). However, we found support for cointegration and asymmetric adjustments when we obtained estimates for τ. With values for τ, we conducted the asymmetric cointegration test where the null hypotheses of no cointegration and symmetry were reject for Thailand in the case of the TAR model and for Philippines with the MTAR model. Based on the results of the threshold cointegration tests, there is evidence of long run PPP with asymmetric adjustment in Philippines and Thailand. However, PPP does not hold in Indonesia, Malaysia and Singapore, and the adjustment process in these countries is symmetric. This may due to the price fluctuations in Indonesia, Malaysia and Singapore that make the local prices deviate from the price in U.S.

Table 3: Results of the TAR and MTAR with value for τ

Country	TAR	MTAR
Indonesia		
τ	0.268492	0.268492
ρ_1	-0.1272**	-0.2144*
ρ_2	-0.0711**	-0.0845***
ϕ_μ	5.0040 (7.1971)	5.1379 (7.5358)
$\rho_1 = \rho_2$	0.8963 (2.2212)	1.1539 (3.6956)
Philippines		
τ	0.029818	-0.002209
ρ_1	-0.0176	-0.0132
ρ_2	-0.0284***	-0.0719***
ϕ_μ	4.6062 (5.7273)	8.6749 (6.1271)**
$\rho_1 = \rho_2$	0.3182 (2.8302)	8.1465(3.6956)**
Malaysia		
τ	-0.012681	0.001190
ρ_1	-0.1929**	-0.2401**
ρ_2	-0.1022	-0.0839
ϕ_μ	2.3037 (7.2099)	3.0059 (7.6392)
$\rho_1 = \rho_2$	0.7367 (2.2990)	2.1249 (3.8052)
Singapore		
τ	-0.023151	0.000842
ρ_1	-0.0216	-0.1275*
ρ_2	-0.0921*	-0.0291
ϕ_μ	1.4632 (7.0423)	1.7789 (7.3981)
$\rho_1 = \rho_2$	0.9966 (2.4322)	1.6227 (3.8363)
Thailand		
τ	0.019283	0.010440
ρ_1	-0.0578	-0.2839**
ρ_2	-0.3433***	-0.1554**
ϕ_μ	7.5141 (7.1681)**	4.0032 (7.6196)
$\rho_1 = \rho_2$	8.0394(2.2957)**	1.2178 (3.7836)

Note: ρ_1 and ρ_2 determine the speed of adjustment for positive and negative deviations respectively. ϕ_μ denotes the F-statistic for the null of no cointegration, and $\rho_1 = \rho_2$ the statistic for the test of symmetry. *, **and *** indicate significance at 10%, 5% and 1% levels respectively.

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