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PURCHASING POWER PARITY THEORY: A CROSS-SECTIONAL DEPENDENCE PANEL DATA ANALYSIS OF SIXTEEN DEVELOPED COUNTRIES

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ABSTRACT

This paper examined the purchasing power parity (PPP) theory for a group of sixteen developed countries using powerful statistical panel data methods that account for cross-sectional dependence. The paper utilized the Pesaran panel unit root test, the cointegration test of Westerlund, the Augmented Mean Group (AMG) estimator, the Common Correlated Effect Mean Group (CCEMG) estimator, and the panel data Granger non-causality test of Dumitricus and Hurlin to analyze the causal relationships among the variables involved in the study. The tests showed that the PPP theory occurs in this group of countries. Furthermore, outcomes of the long-run estimation revealed both depreciation and appreciation of the nominal exchange rates. Apart from providing important policy implications on the results obtained, this paper made another significant contribution by extending the linear AMG and CCEMG estimators into nonlinear estimators and further used them in examining the long-run PPP theory.

Keywords: Augmented mean group, common correlated effect mean group, pesaran, purchasing power parity, westerlund.

INTRODUCTION

Panel data have become increasingly useful in all areas of empirical research. A set of panel data is seen as data containing observations on cross-sectional units over several periods. Because of their usefulness, panel data methods are applied in almost all spheres of human endeavor. Here, we are concerned with applying panel data in econometrics, particularly PPP theory. The theory of PPP tells us that between two currencies (of different countries), the nominal exchange rate should be equivalent to the ratio of total levels of price. The unit of currency in one nation will have equal potential to buy products and services in another nation or the other country (Choji & Sek, 2017). In other words, PPPs are price relatives showing the ratio of prices in national currencies of the same good or service in various countries (Taylor & Taylor, 2004).

Several works on the PPP theory have been carried out for over a decade because of how critical this theory is in international trade and finance. Other than that, the PPP theory is vital because it can help us ascertain the general economic circumstances of a nation. Numerous research has been done concerning the PPP theory in developed countries, yet, more needs to be done due to the evolution of more powerful statistical methods.

Among the numerous works done on PPP in developed countries, it includes the work of Carnovale (2001). The author re-evaluated the PPP theory by utilizing the Christiano and Fitzgerald filter to a long span of data for ten developed countries. They had strong confirmation for the PPP, while more conventional methods are unable to find support for the theory. However, Hegwood and Papell (2002) did not find proof for the occurrence of the PPP in six developed nations (U.S., U.K., Sweden, Belgium, France, and Germany) with a time span varying by country. They concluded that standard tests of the unit root are not adequate in examining the real exchange rate behavior, not due to low power but due to the restrictive nature of the tests that do not show the true behavior of the data. The behavior includes permanent and temporary diversions from equilibrium in the long run. On the other hand, Jenkins and Snaith (2008) employed the Pedroni test of cointegration. It considers each panel member's heterogeneous slope coefficients and short-run dynamic differences to examine the PPP on monthly data from 1918:01 to 1995:06 of eleven developed countries. They discovered proof to back the PPP when they utilized tradable products in their price levels. Their finding indicates that the failure to support the PPP in past research could be due to the addition of products that are not tradable in the general price list.

Furthermore, Gengenbach et al. (2008) applied several panel tests of unit root that consider dependence on cross-sections of monthly data from 1986-2000 for 14 developed nations. Results of the various tests provide evidence for the PPP in some countries. Jiang et al. (2015) discovered that the theory of PPP occurred in thirty-four the Organisation for Economic Co-operation and Development (OECD) nations from Jan. 1994 – Aug. 2013. It was done by employing a recent panel test of stationarity with a combination of smooth shifts and sharp breaks, a unique way to test for a unit root in a panel by Bahmani-Oskooee et al. (2014). Nevertheless, Al-Zyoud (2015) did not find support for PPP when he used monthly data from the period of 1995:01-2008:08 to examine the movement in long-run between Canadian and the U.S. dollar rates of exchange by utilizing the cointegration test of Engle-Granger. The analysis showed that absolute PPP occurs, implying no long-run association between Canadian and U.S. dollar exchange rates.

Similarly, Emirmahmutoglu and Omay (2014) reexamined the PPP hypothesis in 15 EU countries using a nonlinear heterogeneous panel test of a unit root. The null hypothesis allows for symmetric or asymmetric exponential smooth transition autoregressive, which they proposed. While the results of the linear and symmetric nonlinear heterogeneous panel unit root tests are against the PPP hypothesis, the asymmetric nonlinear heterogeneous panel test they proposed supported the PPP hypothesis. Recently, Papell and Prodan (2020) discovered support for the PPP when they used data with low-frequency averages in measuring long-run covariability and variability for 16 developed countries from 1870 to 2013. Finally, Doganlar et al. (2020) utilized the Fourier Quantile test of unit root for Turkey together with its main partners of the trade from 1993:1-2018:8, supporting the long-run PPP validity.

Most of the literature above approved the theory of PPP in developed countries, especially the studies that applied panel data methods. The studies considered the above-used tests of unit root or/and cointegration tests to check if the PPP theory occurs. However, none of these studies went a step further to examine the long-run relationships and what that means for the groups of countries involved. In examining the long-run relationship, this work utilizes the AMG estimator by Eberhardt and Teal (2010) and the CCEMG estimator by Pesaran (2006). This is because these powerful methods that considered dependence on cross-sections in panel data have not been used in this area of research. In addition, the study extends the linear panel AMG and CCEMG estimators to nonlinear AMG and CCEMG based on a nonlinear model of Shin et al. (2014) since the real exchange rate is believed to follow an asymmetric adjustment process (Bahmani-Oskooee et al., 2015).

Furthermore, since most studies on PPP did not provide policy implications on the results found, this work offers policy implications on the results found. It is not only in regards to whether PPP is valid but also based on the impact of the aggregate prices on the nominal exchange rates, as advised by Carnovale (2001). This is because PPP encompasses the key variables involved in monetary policy (exchange rates and price levels). Moreover, in past studies concerning the PPP theory, no study has examined the causal relationships between the variables. Thus, we examine the causal relationships of the variables involved by utilizing the panel test of Granger non-causality of Dumitrescu and Hurlin (2012), which accounts for cross-sectional dependence in panel data. Finally, it is worth noting that all the methods employed in this study account for dependence in cross-sections since that is the main issue affecting panel data studies. The study results supported the theory of PPP in the 16 developed countries considered.

METHODOLOGY AND DATA

Data Description

The data were obtained from the Thomson Reuters DataStream, a group of 16 developed countries from January 2003 to August 2016.

The data set is monthly and consists of the nominal exchange rates (EXRATE), consumer price indices (CPI) for the domestic countries, and the consumer price indices (CPIUS) for the U.S. since the dollar was used as the base currency. All the variables were transformed into their log forms and denoted by LEXRATE, LCPI, and LCPIUS. Moreover, the 16 developed countries involved are Norway, Australia, New Zealand, Belgium, Switzerland, Canada, Finland, the United Kingdom, France, Sweden, Germany, Greece, Ireland, Iceland, Spain, and Denmark.

Panel Unit Roots Tests Allow for Cross-sectional Dependence

Pesaran (2007) recommends a way of accounting for cross-sectional dependence in unit root tests. The method depends on augmenting the Augmented Dickey-Fuller (ADF) regression using lagged cross-sectional mean and its first difference to account for cross-sectional dependence, which may arise through a single-factor model. This is known as the Cross-sectional Augmented Dickey-Fuller (CADF) test, with the CADF regression as:

$$\Delta y_{it} = \alpha_i + \rho_i^* y_{i,t-1} + d_0 \bar{y}_{t-1} + d_1 \Delta \bar{y}_t + \varepsilon_{it}, \quad (1)$$

where $\bar{y}_t$ is the average at time t of all N observations. If a serial correlation exists in the error term, the regression should be augmented as in the univariate case. However, lagged first differences of y_{it} and $\bar{y}_t$ must be included to get:

$$\Delta y_{it} = \alpha_i + \rho_i^* y_{i,t-1} + d_0 \bar{y}_{t-1} + \sum_{j=0}^{p} d_{j+1} \Delta \bar{y}_{t-j} + \sum_{k=1}^{p} c_{k+1} \Delta y_{i,t-k} + \varepsilon_{it}. \quad (2)$$

After this CADF regression has been run for each unit i in the panel, Pesaran's method averages the t-statistics on the lagged value (called CADFi) to get the CIPS statistic (Baltagi, 2005):

$$CIPS = \frac{1}{N} \sum_{i=1}^{N} CADF_{i.} \quad (3)$$

This test which assumes cross-sectional dependence has the null hypothesis of unit root against the alternative hypothesis of stationarity. If the null is rejected, PPP exists.

Westerlund Tests of Cointegration

Following Mehmet et al. (2014), the panel test of cointegration proposed by Westerlund (2007) comprises four tests in error correction, which incorporate 2 Panel and 2 Group statistics. These tests in the model of error correction are thus given by:

$$\Delta y_{it} = \delta_i^{'} d_t + \alpha_i (y_{i,t-1} - \beta_i^{'} x_{i,t-1}) + \sum_{j=1}^{\rho_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{\rho_i} \gamma_{ij} \Delta x_{it-j} + e_{it} \cdot \tag{4}$$

From above, $d_t, \delta_i^{'}, \alpha_i$ reveal deterministic structure, vector parameters, and parameter of error correction, correspondingly. These can be estimated with the model of error correction $(y_{i,t-1} - \beta_i^{'} X_{i,t-1})$. Equation (4) could be parameterized and expressed consequently:

$$\Delta y_{it} = \delta_i^{'} d_t + \alpha_i y_{i,t-1} - \lambda_i^{'} x_{i,t-1} + \sum_{j=1}^{\rho_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{\rho_i} \gamma_{ij} \Delta x_{it-j} + e_{it} \cdot \tag{5}$$

Equation (5) would firstly be estimated using ordinary least squares (OLS) for individual panels to produce the statistic of group mean as in:

$$\Delta y_{it} = \hat{\delta}_i^{'} d_t + \hat{\alpha}_i y_{i,t-1} - \hat{\lambda}_i^{'} x_{i,t-1} + \sum_{j=1}^{\rho_i} \hat{\alpha}_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{\rho_i} \hat{\gamma}_{ij} \Delta x_{it-j} + \hat{e}_{it} \cdot \tag{6}$$

Furthermore, we estimate the parameter of the error correction,. At last, the two group statistics are obtained; thus:

$$G_t = \frac{1}{N} \sum_{i=1}^{N} \frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)}, \quad G_\alpha = \frac{1}{N} \sum_{i=1}^{N} \frac{T \hat{\alpha}_i}{\hat{\alpha}_i(1)} \cdot \tag{7}$$

In the same way, there are three stages of panel statistics. Stage one is similar to stage one of group statistics.

$$\Delta \tilde{y}_{it} = \Delta y_{it} - \hat{\delta}_i^{'} d_t + \hat{\lambda}_i^{'} x_{i,t-1} + \sum_{j=1}^{\rho_i} \hat{\alpha}_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{\rho_i} \hat{\gamma}_{ij} \Delta x_{it-j} \tag{8}$$

$$\Delta \tilde{y}_{it-1} = \Delta y_{it-1} - \tilde{\delta}_i^{'} d_t + \tilde{\lambda}_i^{'} x_{i,t-1} + \sum_{j=1}^{\rho_i} \tilde{\alpha}_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{\rho_i} \tilde{\gamma}_{ij} \Delta x_{it-j} \tag{9}$$

Stage two is the estimation of standard error. The panel statistics are obtained in the final stage; thus:

$$p_t = \frac{\hat{\alpha}}{SE(\hat{\alpha})} \text{ and } p_\alpha = T\hat{\alpha} . \tag{10}$$

Westerlund's (2007) test comprises 2 Panel and 2 Group statistics. We perform tests for the null of no cointegration versus the alternative that cointegration exists. Suppose that the null of no cointegration is not accepted for most tests. At that point, there is a long-run relationship between the variables suggesting the occurrence of long-run PPP. In any case, suppose we do not reject the null of no cointegration for most tests. There does not exist any long-run relationship among variables showing that the theory of PPP does not occur in the long run.

CCEMG and AMG

Following Eberhardt (2010), suppose the model:

$$y_{it} = \beta_i x_{it} + \omega_{it}, \tag{11}$$

where,

$$\omega_{it} = \alpha_{1i} + \lambda_i f_t + \varepsilon_{it} \tag{12}$$

$$x_{it} = \alpha_{2i} + \lambda_i f_t + \gamma_i g_t + e_{it}, \tag{13}$$

for $i = 1,...,N$ and $t = 1,...,T$.

Here, x_{it} (LCPI and LCPIUS, respectively) and y_{it} (nominal exchange rates, LEXRATE) are observables, β_i is the observable coefficient for each country on the regressors, ω_{it} consists of unobservables, and ε_{it} is the error term. The unobservables in Equation (12) contains α_{1i} ,the group fixed effects that capture time-invariant heterogeneity over groups. It also contains a common factor that is unobserved f_t with factor loading that is heterogeneous λ_i ,demonstrating heterogeneity that is time-variant and dependent on cross-section. The factors g_t and f_t are unlimited over time to linear evolution. They can be nonstationary and nonlinear, with clear indications for cointegration. Additional issues arise since the regressors are driven by the same common factors as the observables: the existence of f_t in Equations (12) and (13) brings about endogeneity in the estimation equation. Note that ε_{it} and e_{it} are assumed as white noise.

Pesaran's (2006) CCEMG estimator permits actual setup as in Equations (11), (12), and (13). The empirical framework allows dependence on the cross-section, time-variant unobservables with heterogeneous impact over panel members, and issues of identification (β_i is not identified if the regressor consists of f_t). The CCEMG estimator takes care of this issue using an easy but robust augmentation of the group-specific regression equation. Aside from the regressors x_{it} and an intercept, the Equation puts the average of the cross-section from the dependent and independent variables, $\overline{y}_t$ and $\overline{x}_t$,as additional regressors.

The addition of $\bar{y}_t$ and $\bar{x}_t$ can make justifications for the unobserved common factor f_t .We estimate the relationship for individual members of the panel separately, in which the heterogeneous impact (λ_i)is given by the construction. Thus, in practice, averages of cross-sections $\bar{y}_t$ and $\bar{x}_t$ in the model that were observed are computed and then added as explanatory variables in individual N regression equations. Consequently, the coefficients estimated $\hat{\beta}_i$ are averaged over individuals of the panel, where varying weights could be used. Following the presentation of the CCEMG estimator as given in Durusu-Ciftci et al. (2016), Equation (11) can be written as:

$$y_{it} = \beta_i x_{it} + \delta_1 \bar{y}_t + \delta_2 \bar{x}_t + \omega_{it}, \tag{14}$$

$i = 1,...,N; \quad t = 1,...,T$.

Here, δ_1 and δ_2 give the elasticity estimates of y_{it} with respect to the averages of the cross-section of the dependent variable and the regressors observed appropriately. Subsequently, LCPI and LCPIUS are incorporated in x for the linear CCEMG while ω_{it} is the error term. In extending this to a nonlinear framework, we introduce nonlinear variables into the model by decomposing independent variables into their positive and negative parts, as done by Shin et al. (2014). Three cases are considered. Case 1 is where the domestic price is decomposed into its positive and negative parts. Here, LCPI_POS, LCPI_NEG, and LCPIUS are contained in x .Subsequently, Case 2 is where the domestic price is decomposed, in which LCPI, LCPIUS_POS, and LCPIUS_NEG are contained in x .Case 3 is where domestic and foreign prices are decomposed into positive and negative parts, respectively. Here, LCPI_POS, LCPI_NEG, LCPIUS_POS and LCPIUS_NEG are contained in x .In this way, each coefficient β_i in a framework of the panel was estimated, and the CCEMG estimator is simply the average of computed individual CCE estimators given:

$$\hat{\beta}_{CCEMG} = \sum_{i=1}^{N} CCE_i / N . \tag{15}$$

The AMG was formulated by Eberhardt and Teal (2010) as a substitute for Pesaran's (2006) CCEMG estimator. Following Durusu-Ciftci et al. (2016), the AMG estimator accounts for time-series data properties and variations in the impact of observables and unobservables across sectional groups of the panel. This method of estimation is made possible through the D_t year dummy coefficients in the pooled regression of the first difference, through which the coefficient of the year dummy is collected and labeled as $\hat{\mu}_t^{\circ}$ in stage (i). In stage (ii), this variable is added in each of the N country regression. Therefore, the estimates of the AMG are obtained by means of each country's estimates.

$$\begin{aligned} &\text{AMG – Stage (i);}\ \Delta y_{it} = \beta' \Delta x_{it} + \sum_{t=2}^{T} c_t \Delta D_t + e_{it} \\ &\qquad \Rightarrow \hat{c}_t = \hat{\mu}_t^{\circ} \\ &\text{AMG – Stage (ii);}\ y_{it} = \theta_i + \beta' x_{it} + c_i t + d_i \hat{\mu}_t^{\circ} + v_{it}\ , \end{aligned} \tag{16}$$

where θ_i is a constant, e_{it} and v_{it} are error terms of stages (i) and (ii) of Equation (16) sequentially. In the same way, LCPI and LCPIUS are incorporated in x for the linear AMG. In extending this into the nonlinear framework, we consider three cases. Case 1 is where the domestic price is decomposed into its positive and negative parts. Here, LCPI_POS, LCPI_NEG, and LCPIUS are contained in x. Case 2 is where the domestic price is decomposed, and LCPI, LCPIUS_POS, and LCPIUS_NEG are contained in x. Meanwhile, Case 3 decomposes both the domestic and foreign prices into their positive and negative parts, respectively. Here, LCPI_POS, LCPI_NEG, LCPIUS_POS, and LCPIUS_NEG are contained in x.The group-specific cross-sectional AMG that averages over the panel could be given as follows:

$$\hat{\beta}_{AMG} = N^{-1} \sum_i \hat{\beta}_i\ . \tag{17}$$

Dumitrescu and Hurlin Panel Granger Non-causality Test

Following Furuoka (2015), the heterogeneous panel Granger non-causality test of Dumitrescu and Hurlin (2012) is based on two variables model. The general presentation of the model is thus;

$$y_{it} = \alpha_i + \sum_{k=1}^{k} \gamma_i^{(k)} y_{i,t-k} + \sum_{k=1}^{k} \beta_i^{(k)} x_{i,t-k} + \varepsilon_{it}\ , \quad i = 1,...,N : t = 1,...,T \tag{18}$$

where y and x are the two variables observed for N individuals on T periods (the pair of variables involved in our case are LEXRATE and LCPI, LEXRATE and LCPIUS, and finally, LCPI and LCPIUS). Moreover, k is the lag length, and α is the intercept. Meanwhile, β and γ are the slope coefficients, which are allowed to differ across individuals. There are sources of heterogeneity that could be derived from the intercept and the slope coefficients in the panel. Therefore, the panel non-causality test of Dumitrescu–Hurlin is based on the heterogeneous panel assumption. The approach of the heterogeneous non-causality in the panel is based on the average of cross-sectional individual Wald statistics. Under the assumption that Wald statistics, W_i are independently and identically distributed across individuals, the standardized statistic *Z*bar-statistic follows a standard normal distribution. Suppose we have enough evidence to reject the null hypothesis of homogeneous non-causality. In that case, we can accept the heterogeneous causality alternative for some (not necessarily all) individuals in the panel.

RESULTS

Firstly, the test for dependence on cross-section was carried out on each of the variables (LCPIUS, LCPI, and LEXRATE). Table 1 presents the outcomes of tests for cross-sectional dependence. The tests considered are the Breush-Pagan Lagrange Multiplier test, the Pesaran-Scaled Lagrange Multiplier test, the Bias-corrected Scaled Lagrange Multiplier test, and the Pesaran cross-sectional dependence test. For all the variables, LEXRATE, LCPI, and LCPIUS, the null hypotheses of no cross-sectional dependence are rejected. Therefore, the data exhibit dependence on cross-sections.

Table 1

Cross-sectional Dependence Tests

Test	LEXRATE	LCPI	LCPIUS
Breush-Pagan LM	9886.14***	17560.48***	19680.00***
Pesaran Scaled LM	630.40***	1125.78***	1262.59***
Bias-corrected Scaled LM	630.35***	1125.73***	1262.54***
Pesaran CD	84.83***	132.15***	140.29***

where *** indicates significance at a 1 percent level.

Furthermore, Table 2 demonstrates the result of a second-generation (Pesaran) panel test of unit root that accounts for dependence on the cross-section for every one of the variables at first difference and levels (ΔLEXRATE, LEXRATE, ΔLCPI, LCPI, ΔLCPIUS, and LCPIUS). Generally, results show that all the variables are not stationary at levels, but at the first difference, all the variables are integrated in order 1. This is because there is proof of cross-sectional dependence in the data. The cointegration test of Westerlund (2007) was conducted since it considers cross-sectional dependence with the bootstrap.

Table 2

Panel Unit Root Tests

Variables/Tests	Pesaran	Remark
LEXRATE	-0.56	I(1)
ΔLEXRATE	-19.43***	
LCPI	-1.45	I(1)
ΔLCPI	-17.33***	
LCPIUS	-0.66	I(1)
ΔLCPIUS	-19.56***	

where *** indicates significance at a 1 percent level.

Moreover, Table 3 provides the outcome of Westerlund (2007) for the null hypothesis of no cointegration. Outcomes of the test clearly show that all four statistics (G_t, G_a, P_t, and P_a) reject the null hypothesis at a 5 percent significance level for the p-value. Therefore, we say there is a long-run association between the nominal exchange rate and the aggregate price levels. In a similar way, under the Robust p-value, where a bootstrap was considered, all three statistics (majority) reject the null of no cointegration. Therefore, it further confirms the existence of cointegration. Hence, long-run PPP in these 16 developed nations. Some of the numerous studies that also found support for the PPP in developed countries just like this study include the work of Carnovale (2001), Jenkins and Snaith (2008), Gengenbach et al. (2008), Jiang et al. (2015) and Doganlar et al. (2020).

Table 3

Westerlund Test of Cointegration

Statistic	Value	Z-value	p-value	Robust p-value
$_Gt$	-2.62	-4.74	0.00	0.00
G_a	-9.79	-2.90	0.00	0.06
P_t	-10.29	-4.92	0.00	0.00
P_a	-10.09	-6.20	0.00	0.00

We further estimate the long-run relationship with linear and nonlinear (our extension of the linear to nonlinear) AMG and CCEMG to account for cross-sectional dependence. Starting with AMG, Table 4 displays the results of AMG. The table presents the coefficient of the linear AMG and nonlinear AMG (Case 1, Case 2, and Case 3). The outcome of the linear AMG indicates that the coefficient of the local price (LCPI) is not significant. It indicates that the local price does not have any significant effect on the nominal exchange rate. However, the foreign price coefficient is significantly positive at 10 percent, showing that the foreign price significantly impacts the nominal exchange rates. It is seen that a 1 percent increase in the oversea price brings about a 0.73 percent rate of nominal exchange appreciation.

However, for the nonlinear Case 1, none of the coefficients is significant. On the other hand, for nonlinear Case 2, the coefficient of the local price is significant and causes depreciation in the rate of the nominal exchange. To be more specific, a 1 percent increment in the price of the domestic nation results in a 0.94 percent depreciation of the nominal exchange rate. In addition, the positive part of the oversea country price is significant. However, the negative part is not. Therefore, a 1 percent increase in the positive part of the foreign price results in an appreciation of 0.88 percent of the nominal exchange rates. Moreover, considering the nonlinear Case 3, only the negative parts of the local and oversea prices are significant. Note that a 1 percent increase in the negative part of the local price results in 0.0003 percent (0.00 percent from the table due to approximation to two decimal places) appreciation of the nominal exchange rates. Meanwhile, a 1 percent increase in the negative part of the foreign price causes 0.003 percent (0.00 percent from the table due to approximation to two decimal places) depreciation in the nominal exchange rates.

Table 4

Cross-sectional Dependence Tests

Variable	Linear	Nonlinear Case 1	Nonlinear Case 2	Nonlinear Case 3
LCPI	0.44	-	0.94**	-
LCPI_POS	-	-0.00	-	0.00
LCPI_NEG	-	-0.00	-	-0.00**
LCPIUS	-0.73*	0.24	-	-
LCPI_POS	-	-	-0.88**	-0.05
LCPI_NEG	-	-	0.00	0.00**

where ** and * give significance levels at 5 percent and 1 percent correspondingly.

Furthermore, Table 5 displays the results of both the linear and the three cases of the nonlinear CCEMG. For the linear CCEMG, the coefficient of the domestic price is significant, showing that the domestic price has a significant effect on the rate of nominal exchange. Here, it is seen that a 1 percent increment in the local price results in a depreciation of 1.53 percent in the rate of nominal exchange. Next is the nonlinear CCEMG Case 1, where none of the coefficients is significant. Further, for nonlinear Case 2, only the coefficient of the local price is significant. Nevertheless, none of the decomposed parts is significant. Here, a 1 percent increment in the local price makes the rate of nominal exchange depreciate by 1.54 percent. Finally, for the nonlinear Case 3, only the negative part of the local price is significant at 10 percent, making the nominal exchange rate appreciate. Specifically, a 1 percent increase in the negative part of the domestic price results in an appreciation of 0.0003 percent (0.00 percent from the table due to approximation to two decimal places) in the nominal exchange rates.

Table 5

Long-Run Estimates: Linear and Nonlinear CCEMG

Variable	Linear	Nonlinear Case 1	Nonlinear Case 2	Nonlinear Case 3
LCPI	1.53***	-	1.54***	-
LCPI_POS	-	-0.00	-	0.00
LCPI_	-	-0.00	-	-0.00*
NEG	0.19	-0.48	-	-
LCPIUS	-	-	0.44	-0.39
LCPI_POS	-	-	-0.00	0.00
LCPI_				
NEG				

where *** and * give significance levels at 1 percent and 10 percent levels.

From these results, it is obvious that the AMG estimator performed better than the CCEMG estimator. Therefore, we focus on the results of the AMG estimator. Since we introduced asymmetry into the AMG, we tested to see if there was actually a presence of asymmetry using the Wald test. The test results rejected the null hypothesis of symmetry at a 5 percent significance level (with χ^2=5.66 and prob> χ^2= 0.0174), revealing the presence of asymmetry.

To examine the direction of causality, we employed the Granger non-causality tests of Dumitrescu and Hurlin, which accounts for cross-sectional dependence in panel data. Table 6 displays the W-statistic and Zbar-statistic of the Granger non-causality test. The results reveal that

LCPI Granger causes LEXRATE at a 10 percent level of significance, and LEXRATE Granger causes LCPI at a 1 percent significance level. A bidirectional relationship exists between LCPIUS and LEXRATE at a 1 percent significance level. Nonetheless, LCPIUS Granger causes LCPI but not the other way around. This has confirmed that the variables are indeed associated.

Table 6

Dumitrescu and Hurlin Granger Non-Causality Tests

Null hypothesis	W-statistic	Zbar-statistic
LCPI does not homogeneously cause LEXRATE	2.94*	1.78*
LEXRATE does not homogeneously cause LCPI	4.35***	4.53***
LCPIUS does not homogeneously cause LEXRATE	4.23***	4.30***
LEXRATE does not homogeneously cause LCPIUS	14.00***	23.35***
LCPIUS does not homogeneously cause LCPI	12.99***	21.37***
LCPI does not homogeneously cause LCPIUS	2.86	1.62

where *** and * give significance levels at 1 percent and 10 percent, respectively.

CONCLUSION

This study examined the PPP theory for 16 developed countries by utilizing the panel unit root test of Pesaran (2007), the cointegration test of Westerlund (2007), and both linear and nonlinear (AMG and CCEMG) estimators. Apart from using the existing linear AMG and CCEMG to examine the long-run relationships, the paper also extended these linear estimators (AMG and CCEMG) to nonlinear estimators in examining the PPP theory. The test results for unit root revealed that all the variables are integrated into order one, which allowed us to run cointegration tests. The results of the cointegration tests revealed evidence of a long-run relationship between the nominal exchange rates and levels of price, indicating the occurrence of the PPP theory. When investigating the linear and the nonlinear long-run estimates, the long-run estimates showed both appreciation and depreciation of the nominal exchange rates. Consequently, appreciation of the nominal exchange rates will cause the export to be more expensive and imports to be cheaper, reducing inflation. Depreciation, on the other hand, makes exports cheaper and imports more expensive. Thereby, it will cause inflation to increase in this group of countries. In addition, it is impossible for the 16 developed countries to make so many profits in traded goods from arbitrage since the prices of goods are supposed to be the same.

Furthermore, this paper has made some contributions to the PPP theory literature by applying the AMG estimator by Eberhardt and Teal (2010) and the CCEMG estimator of Pesaran (2006) to analyze the long-run estimates. This work applied both the AMG and the CCEMG in examining the long-run estimates since these estimators account for cross-sectional dependence in the panel data. In addition, the study extended the linear AMG and CCEMG to nonlinear AMG and CCEMG for three different nonlinear cases (Case 1, Case 2, and Case 3 are as explained earlier). Here, the extended nonlinear estimates performed better than the linear estimates with evidence of asymmetry. The nonlinear tests showed explicitly how each part (positive or negative) of the domestic or foreign prices affected the nominal exchange rates and the magnitudes of the effects. However, the linear models cannot show such effects. Therefore, the nonlinear models demonstrated more information that the linear models could not capture.

Secondly, this study applied Dumitrescu and Hurlin's (2012). Granger non-causality test to assess the causal relationships among the variables. In past studies concerning the PPP theory, no study has examined the causal relationships between the variables involved in the PPP theory. However, in this study, we examine the causal relationships of the variables involved using the panel Granger non-causality test by Dumitrescu and Hurlin (2012), which considers the dependence on cross-sections in panel data. This has confirmed that there are indeed several forms of relationships among the variable.

Lastly, this study has made another contribution in providing policy implications for the result obtained, especially on the impact of the domestic and foreign prices on the nominal exchange rates, which has not been done in most studies investigating the PPP theory.

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