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PANEL DATA LINEAR METHODS IN INVESTIGATING THE LONG-RUN PURCHASING POWER PARITY THEORY FOR A GROUP OF DEVELOPED COUNTRIES

[1]NIRI MARTHA CHOJI, [2] TERWASE P. AJAI, [3]SILAS A. IHEDIOHA, [4]PAMSON B. CHUN

[1,2,3,4] Department of Mathematics, Plateau State University, Bokkos, Nigeria.
Corresponding Author's email: marthaniri@plasu.edu.ng

ABSTRACT

The purchasing power parity (PPP) theory says that the nominal exchange rates between two nations ought to be equivalent to the ratio of the total price levels between the two countries. This study utilized the Pedroni test of cointegration to check if cointegration holds, further, the study used the dynamic ordinary least square (DOLS) and fully modified ordinary least square (FMOLS) in investigating the relationships between the nominal exchange rates and the domestic and foreign prices in order to say what that means for the countries involved. The paper found support for the PPP, and also, it was discovered that the domestic prices cause depreciation while the foreign prices cause appreciation on the nominal exchange rates. Consequently, depreciation of the nominal exchange rates will cause exports to be cheaper, imports more expensive and hence cause inflation to increase. Appreciation of the nominal exchange rates on the other hand will cause export to be more expensive, imports cheaper and hence reduce inflation in the 16 developed countries.

Keywords: Appreciation; Depreciation; DOLS; FMOLS; PPP.

INTRODUCTION

The purchasing power parity (PPP) theory is a very important theory that has received attention for several decades now. It says that the nominal rates of exchange between two nations or countries ought to be equivalent to the ratio of the total level of prices between the two countries, so that the unit of currency in one country will have commensurate ability to buy products and services from another country. The theory seeks to encourage that the prices of baskets of goods should be the same between countries. However, that is not the case for some countries due to transportation costs and other barriers to trade, but in the long-run though, the theory may still hold after arbitrage must have been taken advantage of. Early research examined the PPP theory using time series methods, however, due to the development of more powerful panel data methods, increased research is being carried out on the purchasing power parity theory. Since panel data possess both cross-sectional as well as time series dimensions, it is a rich source of data. Instead of utilizing time series methods, this paper applies the more robust approach of panel data because of the advantages it has over the time series methods. Some of the advantages of using panel data methods are the ability to control for heterogeneity in individuals, the ability to give more information, more efficiency, panel data sets often have a lot of observations etc. This study uses several panel data linear approaches to examine the PPP theory for a group of 16 developed countries. Some researchers found evidence to support the PPP, but some did not find support for the theory in several countries. Here, studies done in developed countries on the PPP will be investigated since the focus of this paper is on a group of 16 developed countries.

Among the research done in developed countries include the paper titled "A Nonlinear Panel Unit Root Test Under Cross Section Dependence" where Cerrato *et al.* (2007) proposed a nonlinear panel test of unit root that is heterogeneous for testing the H_0 of unit root processes versus the H_a that allows for a proportion of unit root to be generated by globally stationary ESTAR processes and a remaining non-zero proportion to be generated by unit root processes. The suggested test takes the issue of cross-sectional dependence into consideration. The application of the test on quarterly data from 1973Q1-1998Q2 of bilateral real exchange rates of 20 major OECD nations showed proof of nonlinear mean reversion in the real exchange rate and thus, the PPP hypothesis. Further, Carlsson *et al*. (2007), found support for the weak form of PPP against the strong form of PPP in G7 (Canada, France, Italy, Germany, the United Kingdom, Japan and the United States) nations from January, 1973 – December, 1998 using the maximum likelihood (ML) panel cointegration method of Larsson et al. (2001) which is robust in several dimensions in testing the strong form of PPP.

Moreover, Holmes *et al*. (2012) found proof to support the PPP (stationarity) in 21 OECD nations from 1972:Q1 to 2008:Q2 by utilizing the Hadri and Rao (2008) panel test of stationarity which makes allowance for structural breaks, and deals with cross-sectional dependence by bootstrapping. Also, Wallace (2013), applied the approach of Im *et al* (2008) cointegration test to examine the purchasing power parity using instrumental variables that are stationary on the updated version of the Taylor data set (Rev Econ Stat 84(1): 139-150, 2002) for 21 developed countries. They discovered confirmation to help the legitimacy of PPP by utilizing Taylor's set of data. In the same way, Robertson *et al.* (2014), found proof in favour of the PPP hypothesis when they inspected the long-run association between the prices in U.S. and Mexico (a sample of highly disaggregated price data) from the period 1982:01 to 2010:02 utilizing cointegration method of Pedroni (1999) that accounts for heterogeneous relationship across products. Moreover, Kavkler et al. (2016), examined the PPP hypothesis by analysing data set on monthly real exchange rates for 11 members of the Eurozone using the U.S. dollar and Yen as base currencies. They utilised the nonlinear test of unit root which depends on the ESTAR model suggested by Kapetanios *et al.* (2003). The results for the tests of unit root for the U.S. Dollar based real exchange rate (1998-2012) and that of Yen (1996-2012) showed that the PPP does not occur for Eurozone nations. In addition, Lau (2009) developed a panel test of unit root which gives researchers the opportunity to test individual series for unit root while accounting for panel cross-sectional dependence. An application of the test to data on four Developed Countries from 1950-1995 provides evidence for the PPP theory in three out of the four countries.

Recently, Papell and Prodan (2020) found 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) utilised the Fourier Quantile test of unit root for Turkey together with its main partners of trade from 1993:1-2018:8. They found evidence to support the long-run PPP validity.

It is a known fact that a lot of research have been done on PPP in developed countries. However, most of the methods used to examine the PPP are the unit root methods or the cointegration methods or a combination of both (unit root tests and the traditional cointegration methods). Several researchers used different tests of unit root or/and cointegration to analyse the PPP theory, but most of these studies did go further to examine the long-run relationships between the nominal exchange rates and the aggregate levels of price in order to provide policy implications for the countries involved. Most of the studies that applied various methods of cointegration did not go further to examine the long-run relationships, however, Robertson *et al*. (2014) who went ahead to estimate the long-run relationships with the DOLS and the FMOLS, fail to examine the long-run relationships in terms of the impacts of the prices on the nominal exchange rates, and also failed to provide policy implication as to what that means for the countries under study. Furthermore, since all past studies failed to examine the long-run relationships in terms of the impacts of the prices on the nominal exchange rates, and to provide policy implication on the results found, this paper contributes to the area of research on PPP by examining the long-run relationships between the nominal exchange rates and the aggregate levels of price to provide policy implications on the results found (not only in regards to whether PPP is valid or not valid, but also based on the impacts or interactions between the nominal exchange rates and the aggregate prices as Carnovale (2001) advised since the PPP encompass key variables (the exchange rates and price levels) involved in monetary policy).

This paper found support for the PPP by the use of Pedroni test of cointegration in the 16 developed countries considered and, also, there are evidence of both appreciation and depreciation of the nominal exchange rates in this group of Countries.

DATA AND METHODOLOGY

Data Description

In this work, data used was collected from DataStream, Thomson Reuters on a group of Developed Countries. The data set is monthly and consist of the nominal exchange rates (EXRATE), consumer price indices (CPI) for the domestic countries and the consumer price indices (CPIUS) for the US since the United States Dollar was used as the base currency. All the variables were transformed into their log forms and denoted by LEXRATE, LCPI and LCPIUS. The group of 16 developed countries, starts from January 2003-August 2016. The countries included in the sample are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, New Zealand, Norway, Spain, Sweden, Switzerland and the United Kingdom.

Table 1 shows the summary of descriptive statistics for the 16 developed countries. The table displays statistics (Mean, Median, Maximum, Minimum, Standard deviation, Sum and Number of Observations) for LEXRATE, LCPI and LCPIUS. Although we have the same number of observations (2624) for all the variables (LEXRATE, LCPI and LCPIUS), other statistics such as the sum, standard deviation, minimum, maximum, median and mean vary across variables. Considering the sum (total), the LCPI has the highest sum of 15928.9, followed by LCPIUS with the sum of 14089.9 and then LEXRATE with the lowest sum of 4484.9. Furthermore, the standard deviation which is a measure of dispersion measures the spread of the data. The lower the standard deviation, the better. The variable with the highest value of standard deviation is the LEXRATE with 1.8940, followed by LCPI with the standard deviation of 1.8316 and LCPIUS with the lowest value of standard deviation (0.0838). In addition, the mean and median are referred to as measures of central tendencies, they are used to represent the centre of the data or how the data are arranged in the centre. We decided to use both the mean and the median here because the mean is affected by extreme observations more than the median. Here, the LCPI has the highest mean value of 6.0704 with the median of 5.3810, followed by the LCPIUS with the mean of 5.3696 and median of 5.3814 and the LEXRATE which has the smallest mean value of 1.7092 with a median of 1.5735. Comparing these values of mean and median, we can see that the LCPI, followed by LEXRATE have higher means than medians since they are affected by extreme observations as seen from their maximum and minimum values. In this case, the medians are better measures of central tendency than the mean because they are less affected by extreme observations. However, the LCPIUS has a lower mean than the median because the values are not extreme (see maximum and minimum values).

Table 1: Summary of Descriptive Statistics

Statistic	LEXRATE	LCPI	LCPIUS
Mean	1.7092	6.0704	5.3696
Median	1.5735	5.3810	5.3814
Maximum	5.7735	10.5438	5.4819
Minimum	-0.7281	4.2032	5.2073
Std. Dev.	1.8940	1.8316	0.0838
Sum	4484.9	15928.9	14089.9
No. of Obs.	2624	2624	2624

Pedroni Tests of Cointegration

Pedroni (2004) presented various tests which account for considerable heterogeneity for the H_0 of no cointegration in the panel. The tests are divided into sets of Group and Panel stats. The Group statistics consider a type of the averaging for test statistics of cointegration in the time series over cross-sections as in (Phillips & Ouliaris, 1990) statistic:

$$\tilde{z}_\rho = \sum_{i=1}^{N} \frac{\sum_{t=1}^{T} (\hat{e}_{it-1} \Delta \hat{e}_{it} - \hat{\lambda}_i)}{\sum_{t=1}^{T} \hat{e}_{it-1}^2} \quad [1]$$

where, $\hat{e}_{it}$ is gotten from $\hat{e}_{it} = \rho \hat{e}_{it-1} + v_{it}$, and $\hat{\lambda}_i = \frac{1}{2}(\hat{\sigma}_i^2 - \hat{s}_i^2)$, with $\hat{\sigma}_i^2$ and $\hat{s}_i^2$ are specific long-run and contemporaneous residual variances of $\hat{e}_{it}$. In case of the Panel statistics, we define several panel variance ratios for the Panel statistics. Let $\hat{\Omega}_i$ be an estimate which is consistent, the long-run variance-covariance matrix. Define $\hat{L}_i$ to be the lower triangular Cholesky composition of $\hat{\Omega}_i$ such that, in the scalar, $\hat{L}_{22i} = \hat{\sigma}_\varepsilon$ and $\hat{L}_{11i} = \hat{\sigma}_\mu^2 - \hat{\sigma}_{\mu\varepsilon}^2 / \hat{\sigma}_\varepsilon^2$ is a long-run conditional variance. One of these statistics is considered here,

$$z_{t_{\hat{\rho}NT}} = \frac{\sum_{i=1}^{N} \sum_{t=2}^{T} \hat{L}_{11i}^{-2} (\hat{e}_{it-1} \Delta \hat{e}_{it} - \hat{\lambda}_i)}{\sqrt{\tilde{\sigma}_{NT}^2 (\sum_{i=1}^{N} \sum_{t=2}^{T} \hat{L}_{11i}^{-2} \hat{e}_{it-1}^2)}} \quad [2]$$

where, $\tilde{\sigma}_{NT} = \frac{1}{2} \sum_{i=1}^{N} (\hat{\sigma}_i^2 / \hat{L}_{11i}^2)$ (Baltagi, 2005).

The Pedroni (2004) test comprises of 4 Panel and 3 Group stats with the null of no cointegration versus the alternative of cointegration. Supposing the H_0 of no cointegration is rejected for a large portion of the tests, at that point there is long-run relationship amongst the variables, inferring that long-run purchasing power parity is supported. Nonetheless, if we do not reject the null for a large portion of the tests, there exist no cointegration thus, no long-run relationship amongst the variables implying that purchasing power parity theory does not occur.

FMOLS and DOLS

Following Pedroni (2001) consider the following regression equation

$$s_{it} = \alpha_i + \beta_i p_{it} + \mu_{it} \qquad [3]$$

where, s_{it} (LEXRATE) is a log of the nominal exchange rate, p_{it} (LCPI/LCPIUS) is the log of the ratio of the aggregate price (domestic and foreign prices) based on CPI between the nations, s_{it} and p_{it} have cointegration with slopes β_i, which may or may not be similar over *i*. α_i is the slope, μ_{it} is the white noise and the subscript *it* shows the panel data dimension of the data.

Let $\xi_{it} = (\Delta p_{it}, \hat{\mu}_{it})'$ be a stationary vector with differences in price and estimated residuals from the cointegrating regression and let $\Omega_i \equiv \lim_{T\to\infty} E[T^{-1}(\sum_{t=1}^{T}\xi_{it})(\sum_{t=1}^{T}\xi'_{it})]$ be the covariance in long-run for this vector process. This covariance matrix in long-run is normally estimated by utilizing any of the several HAC estimators, like the Newey-West estimator. It could be broken as $\Omega_i = \Omega_i^0 + \Gamma_i + \Gamma_i'$, where Ω_i^0 is the contemporaneous covariance and Γ_i is a weighted sum of autocovariances.

By utilizing this notation, it is seen based on Pedroni (1996, 2000) that, the expression for the between-dimension, group-mean panel FMOLS estimator is given as

$$\hat{\beta}^*_{GFM} = N^{-1}\sum_{i=1}^{N}\left(\sum_{t=1}^{T}(p_{it}-\overline{p}_i)^2\right)^{-1} \times \left(\sum_{t=1}^{T}(p_{it}-\overline{p}_i)s^*_{it} - T\hat{\gamma}_i\right)$$

where,

$$s^*_{it} = (s_{it}-\overline{s}_i) - \frac{\hat{\Omega}_{21i}}{\hat{\Omega}_{22i}}\Delta p_{it}, \qquad \hat{\gamma}_i \equiv \hat{\Gamma}_{21i} + \hat{\Omega}^0_{21i} - \frac{\hat{\Omega}_{21i}}{\hat{\Omega}_{22i}}(\hat{\Gamma}_{22i} + \hat{\Omega}^0_{22i}).$$

Since the statement following the sum over the individual is similar to the usual FMOLS estimator for time series, it is seen that the between dimension estimator is simply formed as

$$\hat{\beta}^*_{GFM} = N^{-1}\sum_{i=1}^{N}\hat{\beta}^*_{FM,i},$$

where $\hat{\beta}^*_{FM,i}$ is the usual FMOLS estimator, used on the *ith* panel member. In the same way, the t-statistic associated with the between-dimension estimator is formed as

$$t_{\hat{\beta}^*_{GFM}} = N^{-1/2}\sum_{i=1}^{N} t_{\hat{\beta}^*_{FM,i}}$$

where, $t_{\hat{\beta}^*_{FM,i}} = (\hat{\beta}^*_{FM,i} - \beta_0)\left(\hat{\Omega}^{-1}_{11i}\sum_{t=1}^{T}(p_{it}-\overline{p}_i)^2\right)^{1/2}$.

In the same way, a between-dimension, group-mean panel DOLS estimator is built thus; Firstly, we start with the augmentation of the cointegrating regression with lead and lagged differences of the regressor in order regulate for the endogenous effect of feedback.

This assumes a part that is equivalent to the nonparametric correction term for s_{it}^* in terms of Δp_{it} in the FMOLS method. Therefore, the DOLS regression is

$$s_{it} = \alpha_i + \beta_i p_{it} + \sum_{k=-k_i}^{k_i} \gamma_{ik} \Delta p_{it} + \mu_{it}^*. \qquad [4]$$

From this regression, the group-mean panel DOLS estimator is constructed as

$$\hat{\beta}_{GD}^* = \left[N^{-1} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} z_{it} z_{it}^{'} \right)^{-1} \left(\sum_{t=1}^{T} z_{it} \tilde{s}_{it} \right) \right]_1$$

where, z_{it} is the $2(k+1)\times 1$ vector of regressors $z_{it} = (p_{it} - \bar{p}_i, \Delta p_{it-k}, ..., \Delta p_{it+k})$, $\tilde{s}_{it} = s_{it} - \bar{s}_i$, and the subscript 1, outside the brackets shows that we only take the first element of the vector to get the pooled coefficient of the slope.

Once more, since the phrase after the sum over i is similar to the usual DOLS estimator in time series, the between-dimension estimator is easily formed as

$$\hat{\beta}_{GD}^* = N^{-1} \sum_{i=1}^{N} \hat{\beta}_{D,i}^*,$$

where $\hat{\beta}_{D,i}^*$ is the usual DOLS estimator, used for the ith member of the panel. In the same way, if $\sigma_i^2 = \lim_{T\to\infty} E[T^{-1}(\sum_{t=1}^{T} \hat{\mu}_{it}^*)^2]$ is the long-run variance of residuals from the DOLS regression (estimated through the HAC methods), then the t-statistic associated with the between-dimension estimator is constructed as

$$t_{\hat{\beta}_{GD}^*} = N^{-1/2} \sum_{i=1}^{N} t_{\hat{\beta}_{D,i}^*}$$

where, $t_{\hat{\beta}_{D,i}^*} = (\hat{\beta}_{D,i}^* - \beta_0) \left(\hat{\sigma}_i^{-2} \sum_{t=1}^{T} (p_{it} - \bar{p}_i)^2 \right)^{1/2}$.

RESULTS AND DISCUSSION

Firstly, the study conducted unit root tests to check the stationarity of all the variables involved. Table 2. shows results of the ADF-fisher, Breitung, and LLC panel unit root tests for every one of the variables at levels and first difference (LEXRATE and ΔLEXRATE, LCPI and ΔLCPI, LCPIUS and ΔLCPIUS). The unit root tests were conducted using the *Eviews* statistical software for each of the variables at levels and at first difference. Generally, most of the panel tests of unit root show that all variables are not stationary at levels but rather at first differenced, implying that all the variables are integrated of order 1. Since every one of the variables is integrated with order 1, we, therefore, go ahead with the cointegration tests. Table 3. Presents the results of Pedroni (2004) panel test of cointegration. Results show that the H_0 of no cointegration is rejected for all the seven (7) statistics of Pedroni indicating the presence of cointegration between the variables. Therefore, we can say that there exists a long-run association between the nominal exchange rate and the aggregate price levels in the 16 developed nations. This shows the occurrence of long-run PPP in this group of countries.

Because the results gave evidence of cointegration/long-run relationship, we hereby say that the purchasing power theory is evident in these 16 developed nations. Since we have proof of long-run association and hence, the occurrence of PPP for thi set of countries, we now estimate the long-run relationship using the DOLS and FMOLS estimators in order to examine the long-run relationships between the nominal exchange rates, and both the local and foreign prices.

Table 2: Panel Unit Root Tests

Variables/ Tests	ADF-Fisher	Breitung	LLC	Rk
LEXRATE	51.9133**	0.3708	-8.0885	I(1)
ΔLEXRATE	1451.26***	-39.3973***	-58.6359***	
LCPI	29.0299	3.4875	-5.5977***	I(1)
ΔLCPI	631.735***	-10.9496***	-22.6604***	
LCPIUS	31.5088	2.4055	-7.9635***	I(1)
ΔLCPIUS	849.185***	-26.1111***	-36.7525***	

Where *** and ** show levels of significance at 1% and 5% appropriately.

Table 3: Pedroni (2004) Test of Cointegration

Test Statistic	Panel Statistic	Group Statistic
V-statistic	4.8953***	
Rho-statistic	-3.4942***	-2.3353***
PP-statistic	-2.9854***	-2.4438***
Adf-statistic	-2.8844***	-2.3889***

Where *** shows significance level at 1%

Table 4 presents the DOLS, FMOLS, linear long-run estimates. Looking at the coefficients of the DOLS, the coefficient of LCPI is positive and significant showing that the domestic price causes a depreciation of the nominal exchange rate. That is, one percent increase in the domestic price leads to 1.40% depreciation in the nominal exchange rate. Furthermore, the coefficient of the foreign price (LCPIUS) is negative and significant indicating that the foreign price causes an appreciation of the nominal exchange rate. 1% increase in the foreign price leads to about 1.52% appreciation in the nominal rate of exchange. Moreover, for the coefficients of the FMOLS, the slope of LCPI is positive and significant showing that the domestic price causes a depreciation in the nominal rate of exchange. That is, 1% increase in the domestic price leads to 1.42% depreciation of the nominal exchange rate. Further, the coefficient of the foreign price (LCPIUS) is negative and significant indicating that the foreign price causes an appreciation in the nominal rate of exchange. 1% increment in the foreign price brings about 1.52% appreciation in the rate of nominal exchange. The results of DOLS and FMOLS are consistent with each other.

Table 4: Long-Run Estimates: Linear DOLS and FMOLS

Variable	Coef. of DOLS	Coef. of FMOLS
LCPI	1.4007***	1.4211***
LCPIUS	-1.5161***	-1.5165***

Where *** gives level of significance at 1%.

CONCLUSION

This paper examined the PPP theory for 16 developed countries, we performed panel tests of unit root and found that the variables were integrated of order one and therefore, the test of cointegration was conducted. Since most studies on PPP do not tell us what it means if PPP holds, in addition, previous studies on PPP did not examine the long-run relationships between the nominal exchange rates and the aggregate price levels in order to provide policy implication. Results of this study showed that cointegration exists implying that the PPP theory was valid in the long-run which led us to estimate the long-run relationships with linear long-run estimators. The long-run estimates revealed both depreciation and appreciation of the nominal exchange rates for these group of countries. Consequently, appreciation of the nominal exchange rates will cause export to be more expensive, imports cheaper and hence reduce inflation. Depreciation of the nominal exchange rates on the other hand, will cause exports to be cheaper, imports more expensive and hence cause inflation to increase in the 16 developed countries. Finally, since the PPP theory is valid in the16 developed countries, it is not possible to make so much profits in traded goods from arbitrage since the prices of goods are supposed to be the same.

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