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1. Introduction

The importance of the purchasing power parity as theoretical proposition as well as policy consideration can hardly be overemphasised. Theoretically speaking, the purchasing power parity (PPP) forms one of the most important building blocks in the models of exchange rate determination. Therefore, the validity of these exchange rate models largely hinges upon that of PPP itself. Policymakers have traditionally been interested in understanding whether a currency is significantly misaligned as compared to its PPP value. The knowledge of the exchange rate misalignment would help them formulate appropriate policies in removing those misalignments so as to enhance competitiveness of the exports and reduce inflationary pressures due to high import prices. In terms of the empirical investigation, PPP receives much attention of the researchers and the literature has developed alongside modern econometric techniques. In most of the cases, however, they failed to assert conclusively the validity of the PPP empirically.

There is a voluminous literature on the Purchasing Power Parity (PPP)[1]. Researchers have extensively investigated the empirical validity of PPP. As the field of econometrics has developed, so has the empirical literature on PPP, often applying newly developed tests. Beginning with simple regressions in 1970s, studies on PPP now employ more complex approaches to look into data for evidence on PPP. Researchers have examined alternative approaches towards achieving this goal including unit root testing of real exchange rates, cointegration procedure and long span studies.

Tests for PPP have recently been designed using panel data rather than pure time-series data. The impetus behind this development has been to overcome the poor power problem of unit root tests while restricting data sets to the recent float only. Hakkio (1984) is considered as the first attempt in this line of research. Hakkio tests the null of nonstationarity forming a panel of four exchange rates. On the other hand, Abuaf and Jorion (1990) use 10 real exchange rates and tests the joint null of non-stationarity. The paper claimed evidence in favour of PPP by marginally rejecting the null. It has left considerable influence on later researchers using panel data to test for PPP. The studies that used panel data usually employed multivariate unit root tests in order to have enhanced power to detect non-stationarity. MacDonald (1996), Flood and Taylor (1996), Frankel and Rose (1996), Coakley and Fuertes (1997) and Li (1999) are few examples that use panel data approach. Most of the studies in this approach report results in favour of PPP. For example, Frankel and Rose (1996) were able to reject the random walk null in a large sample of 150 countries over the period of 1948–1992. The recent studies that use panel data to test for PPP include, among

[1] Some of the comprehensive surveys on PPP are Rogoff (1996), Sarno and Taylor (2002), Taylor (2003) and Taylor and Taylor (2004).

others, Pedroni (2001), Breitung and Candelon (2005) and Coakley, Kellard and Snaith (2005) and Drine and Rault (2007).

The objective of the paper is to investigate whether PPP holds for a set of OECD countries. More specifically, the objective is to test for the symmetry and proportionality in the panel of our interest. In this study, we test for PPP by applying the methodology that is used in Coakley *et al*. (2005) and Coakley and Snaith (2006). Following their approach, the Mean-Group (MG) procedure is applied in our case in order to reach at the estimates from the data that are indistinguishable from $I(1)$ process. We test for symmetry and proportionality hypotheses in two separate panels that differ in terms of the price index. One panel uses the consumer price index (CPI) and the other the producers' price index (PPI). Given that the regressors as well as the residuals are found to be non-stationary process, the study applies the MG panel regression approach that avoids the spurious regression problem of Granger and Newbold (1974) by averaging the long run estimates of individual time series regressions.

The contribution of this study is twofold. First, it adds to the existing empirical literature by looking into the most recent data set of an OECD panel limited to the post-Bretton Woods period only. One of the features of this panel is that it excludes those countries which have recently adopted the common European currency, namely, the Euro. Instead, the study includes some of the newer members of the organisation, for example, Czech Republic and Slovak Republic. The second contribution of the study comes from its methodology and estimation framework. The study applies the MG procedure of Pesaran and Smith (1995). Despite its methodological simplicity and ability to deal with non-stationary data, the MG estimation procedure is relatively less used in the PPP empirical literature. The current study adds to the literature that applies the MG procedure to investigate long run relationship among variables of interest in the area of PPP.

The paper is organised as follows. Section 2 outlines the estimation framework, while section 3 presents results and findings of our analysis and estimation. Section 4 concludes the paper by analysing the objectives vis-à-vis the findings of the paper.

2. Estimation Framework

2.1 The Mean Group (MG) Regression

We apply the MG Regression[2] to the data to find evidence for long run PPP in our panel. The MG approach will enable us to run non-stationary panel regression. We test the symmetry and proportionality hypotheses in the panel where, for symmetry we test $\hat{\beta}_1 = -\hat{\beta}_2$ in the regression

$$s_{it} = \alpha_i + \beta_{1i} p_{it} + \beta_{2i} p^*_{it} + u_{it} \qquad (1)$$

[2] For detailed discussion on the MG procedure and its application to testing for PPP, see Coakley *et al.* (1995) and Coakley and Snaith (2006).

and for proportionality, we test $\hat{\beta}_1 = -\hat{\beta}_2 = 1$ in the regression:

$$s_{it} = \alpha_i + \beta_i\left(p_{it} - p_{it}^{*}\right) + u_{it} \tag{2}$$

To examine the validity of PPP using the MG estimator, we run regressions of exchange rate and the price indices of each country which yield 15 estimates of coefficients. Taking our 15 individual coefficients and standard errors we compute the MG panel coefficients and standard errors, respectively, using the following formulae:

$$\hat{\beta}^{MG} \equiv \overline{\beta} = \frac{\sum_{k=1}^{N}\hat{\beta}_k}{N} \tag{3}$$

$$se(\hat{\beta}^{MG}) \equiv \frac{\sigma(\hat{\beta}_k)}{\sqrt{N}} = \sqrt{\sum_{k=1}^{N}\frac{\left(\hat{\beta}_k - \overline{\beta}\right)^2}{(N-1)}} \Big/ \sqrt{N} \tag{4}$$

The theoretical foundation of the MG approach in non-stationary panel estimation was laid by Phillips and Moon (1999) and Kao (1999). They established the fact that the MG technique can overcome the problem of non-sense regression by averaging the coefficients across groups. Phillips and Moon (1999) develop a regression limit theory for non-stationary panel data. They show that for large size of both time series and cross-section observations, there exists a long-run average relationship among variables. Coakley, Fuertes and Smith (2001) investigate the small sample properties of the MG estimators using Monte-Carlo simulations.

2.2 The General Relative PPP

Coakley *et al*. (2005) propose a novel idea of testing the relative PPP. They generalise the concept of long run PPP in terms of elasticity of nominal exchange rate with respect to relative national price. For PPP to hold, this approach requires that the elasticity be unity but does not restrict the residuals to be stationary in the panel regression[3] based on equation (2).Under the framework of the general relative PPP (RPPP), they show that it is "economically meaningful" test regardless of the time series properties of the residuals in the log-transformed panel regression. The null hypothesis in this framework would be H_0: $\beta \equiv E(\beta_i) = 1$ against the alternative of $\beta \equiv E(\beta_i) \neq 1$. In effect, the test that whether the relative price elasticity is unity is equivalent to testing the relative PPP. However, the proposed test is more general in nature as it does not restrict the residuals to be stationary as in early tests of relative PPP. In their paper, Coakley *et al.* (2005) find strong evidence in favour of long-run PPP for all MG estimators. More specifically, they find that the long run elasticity of relative prices is close to unity.

2.3 Cross-Sectional Dependence

O'Connell (1998) warns that panel data may suffer from cross-sectional dependence (CSD). It is highly likely that the use of common numéraire currency as well foreign price index will induce CSD. Therefore, another estimator is used which is designed to take CSD into account. This estimator is known as the CMG (Pesaran, 2004a). The

[3] This method of testing for PPP within the framework of general RPPP is applied in this paper in conjunction with the MG procedure.

idea of the previous MG estimator remains the same; we only augment the underlying regression equations. This new estimator, CMG, would seize the unobserved common variables or shocks that may induce the cross-sectional dependence. Coakley, Fuertes and Smith (2005) investigate the properties of CMG in the presence of CSD and find that they can produce unbiased estimates of the long run parameters even in the presence of non-stationary disturbance terms. We use the following equation as the unrestricted model to test for symmetry

$$s_{it} = \alpha_i + \beta_{1i} p_{it} + \beta_{2i} p^*_{it} + \gamma_i \bar{s}_t + \delta_i \bar{d}_t + u_{it} \tag{5}$$

where, $\bar{s}_t$ and $\bar{d}_t$ are cross-sectional average of exchange rates and price differential respectively. A problem with this formulation is that it contradicts the essence of the original unrestricted model by incorporating the price differential. So, we simplify this equation and get the following equation which restores the unrestricted nature of the symmetry testing

$$s_{it} = \alpha_i + \beta_{1i} p_{it} + \eta_i p^*_{it} + \gamma_i \bar{s}_t + \delta_i \bar{p}_t + u_{it} \tag{6}$$

Now, $\beta_2 = \eta + \delta$.

Similarly we augment the restricted model as follows

$$s_{it} = \alpha_i + \beta_i d_{it} + \gamma_i \bar{s}_t + \delta_i \bar{d}_t + u_{it} \tag{7}$$

In addition to using a different estimator that accounts for CSD, we also conduct some diagnostic tests for CSD in the residuals. The tests we use are the Breusch and Pagan [BP] (1980) test and the Pesaran (2004b) test known as the PCD. We can use the BP test statistic to test the null hypothesis of no correlation in the residuals. For this, the Lagrange Multiplier test statistic is obtained using the following formula,

$$CD_{lm} = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2 \tag{8}$$

where $\hat{\rho}_{ij}$ is the sample pair-wise correlation of the residuals. BP show that under the null, the test statistic is asymptotically distributed as chi-squared with N $(N–1)$ degrees of freedom. However, one important condition is that we must have sufficiently large T and small N. Another test which is due to Pesaran (2004b) called PCD is conducted using the following formula.

$$PCD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \right) \tag{9}$$

The PCD statistic asymptotically converges to the standard normal distribution under the null of zero correlation.

3. Results and Findings

3.1 Data

We use OECD data for the purpose of testing for PPP. There are three variables of interest in our estimation: nominal exchange rate and two price indices, one for the domestic country and the other for the foreign country (USA). Two panels have been developed for the purpose of estimation, one using the Consumer Price Index (CPI) and the other Producer Price Index (PPI). For the CPI panel we choose Canada, Czech Republic, Denmark, Hungary, Iceland, Japan, South Korea, Mexico, Norway, Poland, Slovak Republic, Sweden, Switzerland, Turkey, and the UK, i.e. 15 cross-section

units altogether. This panel excludes those European countries which are now part of the Euro area. The composition of the PPI panel is little different. Due to the unavailability of data, we have to drop Iceland from the PPI panel making the number of cross-section units to be 14. The data are of monthly frequency and span the period 1991:01 to 2005:12 yielding 180 observations for each country (except for the Slovak Republic for which data are available for a shorter period) yielding around a total of 2700 observations. Exchange rates and price indices are both obtained from the OECD statistical database.

We have chosen to look into the OECD panel for two reasons. First, the OECD, as an organisation for economic cooperation among member countries which are industrialised, forms a block within which the trade and other barriers may be minimal. There is high probability that the PPP will hold among these nations (Froot and Rogoff, 1995). Second, Coakley and Snaith (2006) investigate the validity of PPP using a European panel using exchange rate data prior to the introduction of common European currency, i.e. the Euro. We apply the same methodology (i.e. non-stationary panel regression) to a different set of data, namely, OECD data, for the period up to 2005.

3.2 Results and Findings

Table 1 shows the unit root test results for both CPI and PPI panels. We conduct the ADF test at a lag chosen by the Schwarz-Bayesian Information Criterion (BIC). For the CPI panel, one is unable to reject the null of unit root at 5% level of significance in all but one exchange rate series. On the other hand, we get mixed results for the price indices series with around 40% cases of rejection of the null. The ADF tests on the price differential reject the null only in 4 out of 15 cases. The last two columns of the Table 1 present the unit root tests results for the PPI panel. As in the CPI panel, we are unable to reject the null of unit root in all but one case in the PPI panel. For the price differential series, the unit root null is rejected only in 4 cases out of 15. The overall finding of the ADF test for unit root is that our data are mostly non-stationary and indistinguishable from $I(1)$ process.

Table 2 shows the results of the AEG (Augmented Engle–Granger) test for cointegration. The appropriate number of lags is chosen on the basis of the BIC criteria. On the basis of the critical values for the AEG test given in Enders (2004, pp 441), we are unable to reject the null of unit root in all the residuals at 5% level of significance for both CPI and PPI panels in the unrestricted as well as the restricted models. This finding is in line with the extant literature that deals with testing for PPP. This indicates to the fact that shocks have permanent effect on exchange rates and price indices movements. It then appears that testing for PPP in any pair of country would be tantamount to running spurious or non-sense regression. The results of this and the previous section justify our choice of the non-stationary panel regression framework to test for symmetry and proportionality.

Regressions are run using individual sets of exchange rates and price indices for all 15 countries according to unrestricted model of equation (1). Then, using MG procedure as explained above, we reach at the MG estimates. The result is reported in Table 3. The PPP theory suggests that the signs of the coefficients of the domestic and foreign prices be positive and negative, respectively. In our case, the signs of the MG

Table 1: The ADF Test Results

Country	S	CPI panel		PPI Panel	
		P	p−p*	p	p−p*
1. USA	------	-0.447 (3)	------	2.130(3)	------
2. Canada	-1.216 (2)	- 0.600 (1)	-2.169 (1)	-1.253 (2)	-0.374 (1)
3. Czech Rep.	-1.216 (2)	-4.398 (1)*	-3.577 (2)*	-2.273 (2)	-2.928 (2)*
4. Denmark	- 1.625 (2)	-0.334 (3)	-1.218 (1)	0.728 (2)	0.288 (3)
5. Hungary	- 2.418 (2)	- 4.700 (2)*	-4.538 (2)*	-1.397 (2)	-3.163 (2)*
6. Iceland	-1.633 (3)	0.296 (2)	-0.255 (2)	------	-----
7. Japan	-2.831 (2)	-2.860 (4)	1.790 (4)	-2.059 (2)	0.811 (1)
8. Korea	-1.772 (3)	-2.670 (4)	-2.199 (2)	-0.633 (2)	-1.501 (2)
9. Mexico	-1.518 (2)	-1.869 (2)	-1.849 (3)	0.104 (2)	-1.886 (2)
10. Norway	-1.603 (3)	-0.881 (1)	-1.210 (1)	0.315 (1)	-0.830 (1)
11. Poland	-4.390 (3)*	-6.440 (3)*	-4.891 (4)*	-3.557 (2)*	-3.409 (2)*
12. Slovak Rep.	-1.267 (2)	-2.079 (1)	-2.350 (2)	0.146 (1)	-2.498 (3)
13. Sweden	-1.943 (3)	-2.387 (3)	0.417 (1)	-1.084 (2)	-0.154 (2)
14. Switzerland	-1.824 (2)	-4.618 (4)*	2.168 (4)	-0.853 (1)	1.292 (1)
15. Turkey	-2.882 (2)	-3.942 (2)*	-3.791 (2)*	2.031 (3)	-3.064 (2)*
16. UK	-2.255 (3)	-3.053 (1)*	0.027 (1)	-2.171 (2)	-0.143 (1)

ADF(): denotes the number of lags as selected by the Schwarz-Bayesian information criterion.
(*) Reject the null hypothesis of a unit root at the 5% significance level.

Table 2: The Cointegration Test Results

Country	CPI Panel		PPI Panel	
	Unrestricted	Restricted	Unrestricted	Restricted
1. USA	------	------	------	------
2. Canada	-0.948 (2)	0.313 (2)	-2.874(2)	-2.818(1)
3. Czech Rep.	-1.950 (2)	-1.158 (2)	-2.300(2)	-1.361(2)
4. Denmark	-1.851 (2)	-1.582 (2)	-2.198(2)	-1.6889(2)
5. Hungary	-1.935 (2)	-0.708 (2)	-1.821(2)	-1.748(1)
6. Iceland	-1.287 (3)	-1.185 (3)	------	------
7. Japan	-2.608 (2)	-2.775 (2)	-2.718(2)	-2.715(2)
8. Korea	-2.205 (3)	-1.902 (3)	-3.217(3)	-2.571(3)
9. Mexico	-2.681 (2)	-2.576 (2)	-2.527(2)	-2.533(2)
10. Norway	-2.342 (2)	-1.544 (3)	-3.267(1)	-1.557(2)
11. Poland	-2.146 (3)	-1.649 (3)	-2.430(2)	-1.581(2)
12. Slovak Rep.	-1.957 (2)	-0.746 (2)	-2.062(1)	-0.900(2)
13. Sweden	-1.744 (3)	-1.928 (2)	-1.927(2)	-1.611 (2)
14. Switzerland	-1.871 (2)	-1.818 (2)	-2.505(2)	-1.874(2)
15. Turkey	-3.671 (2)	-2.314 (2)	-3.276(2)	-2.101(2)
16. UK	-2.306 (3)	-2.436 (3)	-2.427(2)	-2.439(2)

ADF(): denotes the number of lags as selected by the Schwarz-Bayesian information criterion.

estimates are all in line with expectations based on the theory. The table also includes the *p*-values of the Kolmogorov-Smirnov (K-S) test for normality. Given high *p*-values in all cases, we accept the null that the beta series are all normally distributed. As a result, we can use the student's *t*-distribution with (N–1) degrees of freedom on the MG estimates to test the symmetry hypothesis.

Next, we proceed to test that the difference between coefficients of the domestic and foreign price variables are zero. Table 3 presents the calculated value of the joint test. We cannot reject the null at 5% level of significance for the MG as well CMG estimators across both the CPI and PPI panels. This indicates to an unequivocal acceptance of the symmetry hypothesis.

Along with the joint test statistics for the symmetry hypothesis, there are also the results of the Breusch-Pagan (BP) test and the Pesaran's (PCD) test. These tests are applied to see whether the CMG estimator has effectively dealt with the CSD problem mentioned earlier. As for the PCD test in the CPI panel, we reject the null of zero pair-wise correlation in residuals for the MG procedure but accept the null for the CMG procedure. For the PPI panel, although we reject the null for both MG and CMG procedures, one can see that the remaining correlations among the residuals have significantly decreased when the CMG technique is applied. The last observation also applies to the results of the BP tests. While one cannot accept the null of no correlation in the residuals based on the calculated BP test statistics, the extent of CSD problem is significantly lower under the CMG as against the MG procedure.

The proportionality tests results are reported in Table 4. As in the unrestricted model, we test the distribution of the MG and CMG estimates for normality. The results of the K-S tests show that the MG and CMG estimates are normally distributed. So inferences that assume normality of observations can be applied to test the proportionality hypothesis.

The test for proportionality is based on the regression of the symmetry-restricted model. We see whether the slope coefficient of the price differential equals unity. This would mean that there is a one-for-one linear relationship between the nominal exchange rate and the price differential between the domestic and foreign country. This is also equivalent to testing whether the elasticity of the price differential is unity under the framework of the general relative purchasing power parity (RPPP) as proposed in Coakley *et. al.* (2005).

The signs of the MG and CMG estimates are all in line with economic theory on PPP. The table reports *t*-statistics for both the tests that the coefficient equals zero and unity, although the proportionality test requires the latter only. The test that the estimates are statistically significant will help us to see whether the price differential has any effect on the changes in the exchange rate movements.

Table 4 gives mixed results for the tests of proportionality hypothesis. As for the CPI panel, we reject the null of proportionality for the MG estimate, but can not reject the null when the CMG estimator is used. In other words, PPP holds when cross-sectional dependence is accounted for, but does not hold otherwise. This goes contrary to what O'Connell (1998) predicted by saying that it would be more difficult to gain support in favour of PPP once CSD was removed. As far as CSD is concerned, it significantly

Table 3: The Symmetry Test Results

	CPI Panel		PPI Panel	
	MG	**CMG**	**MG**	**CMG**
$\hat{\beta}_1$	1.203	1.175	1.089	0.502
$se(\hat{\beta}_1)$	0.619	0.538	0.202	0.561
$\hat{\beta}_2$	–2.033	–1.403	–1.765	–0.884
$se(\hat{\beta}_2)$	0.725	0.499	0.232	0.189
$\hat{\beta}_1$ KS p-values	0.726	0.682	0.159	0.531
$\hat{\beta}_2$ KS p-values	0.999	0.874	0.867	0.759
Joint test $(\hat{\beta}_{1i,}\hat{\beta}_{2i})$	–1.846*	–0.616*	–1.783*	–0.908*
PCD Statistic	45.141	–0.932	22.448	4.682
BP Statistic	5639.054	1728.453	3398.942	1311.985
Avg (Corr)	2.463	-0.051	1.228	0.256
Abs Avg (Corr)	2.889	0.829	1.674	0.600

Notes: (*) indicates non-rejection at 5% level of significance

Table 4: The Proportionality Test Results

	CPI Panel		PPI Panel	
	MG	**CMG**	**MG**	**CMG**
$\hat{\beta}$	0.128	0.399	0.855	0.621
$se(\hat{\beta})$	0.240	0.290	0.132	0.174
t-statistic (β=0)	0.531*	1.377*	6.490	3.567
t-statistic (β=1)	–3.630	–2.073*	–1.099*	–2.181
$\hat{\beta}_1$ KS p-values	0.820	0.972	0.892	0.815
PCD Statistic	59.033	–1.482	21.302	8.766
BP Statistic	6328.056	2093.138	3790.00	1766.797
Avg (Corr)	3.221	-0.081	1.165	0.479
Abs Avg (Corr)	3.502	0.603	1.818	0.822

Notes: (*) indicates non-rejection at 5% level of significance

goes down (by approximately 66%) with CMG procedure as compared to the MG one according to both the BP and PCD test statistics. This is also supported by the size of the remaining average correlation and absolute average correlation in the residuals. Hence, we feel inclined to accept the results of CMG procedure as opposed to MG procedure.

For the PPI panel, our findings are reversed, however. Now we see that we accept the null of proportionality in case of MG estimate but only *marginally* reject the null for CMG estimate. However, the CMG procedure has produced positive slope estimate and also has been able to reduce CSD considerably, as apparent from the BP and the PCD statistics (also from the remaining average and absolute average correlation), given this results one is inclined to see here support for weak RPPP based on $1 > \beta > 0$.

4. Concluding Remarks

The current paper applies non-stationary panel regression approach. The motivation of using this approach comes from the fact that the regressors are non-stationary process and do not cointegrate. Individual regressions between variables in such circumstances would result in nonsense or spurious regression. The Mean-Group (MG) panel regression of Pesaran and Smith (1995) is then applied which is presumably capable of estimating long run relationship among variables in the presence of non-stationary regressors that do not cointegrate.

The study aimed at testing for the validity of PPP within the framework of the general relative PPP as proposed in Coakley *et al.* (2005). Two separate panels are formed, namely, CPI and PPI panels. The unit root test results given in Table 1 and the cointegration test results presented in Table 2 show that the data are mostly non-stationary and indistinguishable from *I* (I) process. Given the non-stationary nature of our data, we use the MG estimators. Two variants of MG estimators are applied to test for PPP through the null of symmetry and proportionality. One is the MG estimator that does not take into account the problem of the cross-sectional dependence (CSD) among residuals which is potentially induced by the use of common base currency and price index. The other one is specially designed to account for CSD and hence gives better estimates.

The estimation results show comprehensive acceptance of the symmetry null in both the panels. As for the proportionality test, the CMG estimate of the CPI panel can not reject the null whereas the MG estimate does. On the other hand, in the PPI panel, the MG estimate accepts the null while the CMG estimate only *marginally* rejects it. Given this mixed results, and positive slope coefficients of the symmetry-restricted model of PPP, we are inclined to accept the weak RPPP in our sample as a whole.

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