

Investigating Purchasing Power Parity using three Panel Data Techniques: Evidence from 20 OECD Countries

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Abstract

Using panel data techniques, this paper examines whether purchasing power parity (PPP) is empirically observed. We focus not on a time series analysis of each country pair, but on the variation of PPP using the entire 20-country data set. The results of this paper are summarized as follows. In terms of absolute PPP, the consumer price index (CPI) and the wholesale price index (WPI) identically reject the null hypothesis that PPP holds. In terms of relative PPP, the PPP hypothesis is accepted using the WPI, but rejected using the CPI, which is consistent with the results of time series analyses. Thus, relative PPP is empirically observed using panel data analysis in relatively short-run data, even when rejected by time series analysis in longer run data. This result is identical to those of previous studies on PPP.

Keywords: absolute PPP; relative PPP; panel data analysis

JEL classification: F31; F41

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I. Introduction

Purchasing power parity (PPP) is one of the most important theories in international economics. PPP has been empirically examined in numerous papers, mostly using time series analysis, covering time periods from the floating exchange rate regime after the Breton-Woods era (1970s) to the present, and periods of up to 100-200 years¹. According to these studies, time series analysis results in the consensus that PPP cannot be empirically rejected in the long run. There are several limitations, however, in the use of time series analysis. The first is that there are countries for which long-run data are unavailable. This is particularly true for countries that have experienced high growth starting from a low level of initial wealth, as well as for once wealthy countries that have declined in relative economic wealth (Froot et al. (1995)). A second limitation arises from the issue of stationarity and the weakness of the power of a test in small sample sizes, which is associated with short-run data series (Phillips et al. (1988); Engel (2000)²). Since co-integration of variables can only be examined with sufficiently large observations, short-run time series are problematic. Thus to examine stationarity and co-integration in time series data, we need data spanning a century (Hakkio et al. (1991); Hatanaka (1994)). Using the observation of Hakkio et al. (1991), all we can do now is “wait”.

To address the above limitations of time series analysis, recent studies have achieved success in testing for PPP by using panel data techniques. This allows for testing for the stationarity of the real exchange, while avoiding time-series limitations. Quah (1994) and Levin et al. (1992) have shown that the power of the stationarity test rises when using panel data. Studies such as those of MacDonald (1996), Oh (1996), and Wu (1996) used panel data methods and concluded that the real exchange rate rejects a random walk.

In this paper, we focus not on a time series analysis of each country pair, but on the variation of PPP in the entire 20-country data set. We examine whether PPP is empirically observed using panel data methods. This approach was selected because previous research has shown that results vary greatly depending on the choice of panel data model. Using the entire data set is consistent with the result that would be obtained from long-run time series analysis and other panel analysis.

¹ See Kim (1990), Papell (1994), Froot et al. (1995), and Lothian and Taylor (1996), which concluded that PPP is empirically supported in long-run time series. Using data from 1973-1988 to examine PPP in Europe, Mark (1990) rejected the null hypothesis of PPP (a random walk) only for the Belgium/Germany comparison.

² Engel (2000) concludes that we can only say that PPP tends to move to the mean in the long run, but we don't know whether PPP is empirically valid.

This paper contains four sections. In the next section, we describe the economic and econometric models used. We explain the PPP hypothesis in Section II.A and the method of econometric analysis in II.B. Three panel data methods are used: the dummy variable model (DVM), the error components model (ECM), and Swamy's (1970) random coefficients model (RCM). In Section III, we report our empirical results. Conclusions are presented in Section IV.

II. Models

A. Purchasing Power Parity (PPP)

The purchasing power parity (PPP) hypothesis is based on the Law of One Price (LOP), which claims that in the absence of trade barriers, transportation costs, and imperfect competition, an identical good has the same price in each country when measured in the same currency unit³. The LOP for good i is

$$P_i = EP_i^*$$

where P_i (P_i^*) is the domestic (foreign) price of the i -th good measured in domestic (foreign) currency and E is the nominal exchange rate (domestic currency to foreign currency). The LOP can be extended to a price index by taking a weighted average of the price of each good. Therefore, absolute PPP is

$$P = EP^* \text{ or } E = \frac{P}{P^*}$$

where P (P^*) is the domestic (foreign) price level.

Absolute PPP has some limitations. First, the basket of goods used to measure the price index in each country should be identical. Second, the choice of relative weights for each good must also be identical in each country. Then, if there are no trade barriers, transportation costs, or imperfect competition, and the baskets of goods and their relative weights are identical in both countries, the rate of change in the exchange rate should equal the rate of change in the price level ratio. Suppose that the production market condition above is a constant, C . This means that

$$E = C \frac{P}{P^*}$$

³ The very strong conditions given above are necessary to realize the LOP. Engel (1993) finds that in the USA and Canada, the relative price of similar goods between the two countries varies more than the prices of quite different goods. Engel et al. (1996) indicate that for about 14 goods in 23 cities in the USA and Canada, the LOP is less likely to hold in two border cities than in more distant cities. They find that the border has the same effect as a distance of 2,500 to 23,000 miles in the variation of relative prices.

i.e.

$$C = \frac{EP^*}{P}.$$

This is defined as the real exchange rate. Absolute PPP holds when $C = 1$. Relative PPP is obtained by log-differentiating $E = CP/P^*$ at time t ,

$$\frac{\dot{E}}{E} = \frac{\dot{P}}{P} - \frac{\dot{P}^*}{P^*}.$$

Thus, Relative PPP might be valid, even if absolute PPP is not.

B. Econometric Analysis

This paper uses panel data methods for analysis, whereas most previous empirical research on PPP used time series or cross sectional analyses. Advantages of using panel data include the following. (1) Panel data methods allow for greater degrees of freedom, which is particularly important when the sample size is too small to meaningfully use either cross-sectional or time-series techniques. (2) Cross-sectional analysis ignores dynamic effects and both cross-sectional and time-series techniques are restricted to two-country comparisons, which may lead to difficulties when comparing economies of different sizes. The panel data approach, on the other hand, suffers from the limitation that the results may vary greatly depending on the model used. Although this paper uses the DVM, ECM, and Swamy's RCM models, there were no cases satisfying assumptions for all models. Therefore, the estimated results in ECM and Swamy's RCM are reported when the parameter lies at right angles to the explanatory variables after first using DVM estimates as a benchmark⁴.

Estimated models used in our panel analyses are

$$y_{it} = \beta_{1it} + \sum_{k=2}^K \beta_{kit} x_{kit} + u_{it}. \quad (1)$$

Although this is a general model that contains both intercept and slope variables, we do not allow for a time-varying slope coefficient in this paper.

III. Model Estimation

A. Data Sets

We use annual data from 1973 to 1994, obtained from the International Monetary Fund (IMF) publication, *International Financial Statistics*. Data from

⁴ Swamy's RCM is usually replaced by a seemingly unrelated regression (SUR) if the assumption of orthogonality is not satisfied. Here, orthogonality was accepted in all cases.

twenty countries converted into natural logarithms are used, including nominal exchange rates (relative to the U.S. dollar) (rf or rh), the Consumer Price Index (CPI, 64), and the Wholesale Price Index (WPI, 63 or 63a). The twenty countries are Japan, Germany, France, Canada, the United Kingdom, Australia, Austria, Belgium, Denmark, Finland, Greece, Ireland, Luxembourg, the Netherlands, New Zealand, Norway, Spain, Sweden, and Switzerland. The WPI is obtained for only 16 of these countries: Italy, France, Luxembourg, and Norway are excluded.

B. Estimating Models

We briefly outline the estimating models here. Note that (2) and (5) are estimated equations for DVM, (3) and (6) for ECM, and (4) and (7) for Swamy's RCM.

First, for absolute PPP

$$e_{it} = \beta_1 + \beta_2(p - p^*)_{it} + \sum_{i=1}^{N-1} \mu_i D_i + \sum_{t=1}^{T-1} \lambda_t D_t + u_{it} \quad (2)$$

$$e_{it} = \beta_1 + \beta_2(p - p^*)_{it} + \sum_{i=1}^N \mu_i d_i + \sum_{t=1}^T \lambda_t d_t + u_{it} \quad (3)$$

$$e_{it} = \beta_1 + \beta_2(p - p^*)_{it} + \sum_{i=1}^N \mu_{1i} d_i + \sum_{i=1}^N \mu_{2i} (p - p^*)_i + u_{it} \quad (4)$$

where i is a country, t represents time, e is the natural log of a nominal exchange rate to the US dollar, p (p^*) is the natural log of the price level in the i -th country's currency (the USA), D_i (D_t) is a country-specific (time-specific) "fixed effects" dummy variable, d_i (d_t) is a "random effects" variable, and u_{it} is the stationary disturbance term.

For relative PPP,

$$\Delta e_{it} = \beta_1 + \beta_2(\Delta p - \Delta p^*) + \sum_{i=1}^{N-1} \mu_i D_i + \sum_{t=1}^{T-1} \lambda_t D_t + u_{it} \quad (5)$$

$$\Delta e_{it} = \beta_1 + \beta_2(\Delta p - \Delta p^*) + \sum_{i=1}^N \mu_i d_i + \sum_{t=1}^T \lambda_t d_t + u_{it} \quad (6)$$

$$\Delta e_{it} = \beta_1 + \beta_2(\Delta p - \Delta p^*) + \sum_{i=1}^N \mu_{1i} d_i + \sum_{i=1}^N \mu_{2i} (\Delta p - \Delta p^*) + u_{it} \quad (7)$$

where Δ is a lag operator of difference 1.

A noteworthy parameter is β_2 . If β_2 is not statistically different from 1, it

means that PPP is empirically valid⁵.

C. Estimated Results

Tables 1 through 4 are divided into three, such that they show the results of DVM (OLS) as a benchmark at the top, ECM in the middle, and Swamy's RCM at the bottom. The estimated values that included both the country and the time effect are shown in whole, and those that included only one of the countries or the time effect are shown for country or for time, respectively. Note that m and z are the Hausman (1978) Test statistic and Pudney's (1978) Test statistic, respectively. DVM (OLS) indicates a standard error modified HC3 of MacKinnon et al. (1985) when there exists heteroskedasticity. G6 indicates the model using only the major six developed countries.

First, in Table 1, we report only the results of the models selected by the criteria of m and z , where the null hypothesis of $\beta_2 = 1$ is (almost) accepted. However, the estimated value includes a time effect in the ECM for industrialized countries that differs enormously from one, in addition to having a contrary sign. Moreover, in Table 2, there is possibility that the estimated value includes a time effect in the ECM is zero, whereas the other models are acceptable the null. Thus, in absolute PPP, the CPI and WPI show the same tendency to reject the null hypothesis that absolute PPP is valid.

Next, we examine relative PPP. Table 3 shows estimates of models examining relative PPP based on the CPI. Although it significantly differs from 1 in two cases, the null hypothesis of $\beta_2 = 1$ could be accepted in all other cases. This result is consistent with Frankel et al. (1995), who studied the 150 member countries of the IMF (1948-1992). In addition, Table 4 based on the WPI accepts the null hypothesis in all cases selected by m and z . Thus, it seems that the WPI is more consistent with the PPP hypothesis than the CPI is with the relative PPP. Our results are consistent with those of time series analysis⁶, and show that similar results can be obtained using panel data covering a shorter time span⁷.

⁵ According to Frankel et al. (1995), these equations are insufficient to explain PPP, because they depend on the assumptions that the deviation factor from PPP and the explanatory variables are uncorrelated ($E[x_{it}u_{it}] = 0$) and contain no autocorrelation on the disturbance term

($\forall i, \forall j, i \neq j, E[u_{it}u_{it}'] = 0$). We estimate these models due to ease of comparison and estimation.

⁶ For example, see Kim (1990).

⁷ For this, Wu (1996) describes that notwithstanding the choice of price index, relative PPP is observed in panel analysis.

IV. Conclusions

The results of the paper may be summarized as follows. (1) In terms of absolute PPP, the consumer price index (CPI) and the wholesale price index (WPI) identically reject the null hypothesis that absolute PPP holds. (2) In terms of relative PPP, the PPP hypothesis is accepted using the WPI, but rejected using the CPI, which is consistent with the results of time series analyses. Thus, even if long-run time series data are not used, relative PPP can be shown to exist using panel analysis with relatively short-run data.

References

- Engel, Charles (1993), "Real Exchange Rates and Relative Prices: An Empirical Investigation", *Journal of Monetary Economics* 32: 35-50.
- Engel, Charles (2000), "Long-Run PPP may Not Hold After All", *Journal of International Economics* 57: 243-273.
- Engel, Charles and Rogers, John H. (1996), "How wide is the Border?", *American Economic Review* 86: 1112-1125.
- Frankel, Jeffrey A. and Rose, Andrew K. (1995), "A Panel Project on Purchasing Power Parity: Mean Reversion within and between Countries", *NBER Working Paper* 5006.
- Froot, Kenneth A. and Rogoff, Kenneth (1995), "Perspectives on PPP and Long-Run Real Exchange Rates", *Handbook of International Economics vol. 3*, Grossman, Gene M. and Rogoff, Kenneth, eds: 1647-1688.
- Hakkio, Craig S. and Rush, Mark (1991), "Cointegration: How Short is The Long Run?", *Journal of International Money and Finance* 10: 571-581.
- Hatanaka, Michio (1994), "Cho-ki teki Keizai Kankei no Econometrics", *Economic Studies Quarterly* 45: 403-418 (in Japanese).
- Hausman, J. A. (1978), "Specification Tests in Econometrics", *Econometrica* 46: 1013-1029.
- Kim, Yoonbai (1990), "Purchasing Power Parity in the Long Run: A Cointegration Approach", *Journal of Money, Credit and Banking* 22: 491-503.
- Levin, Andrew and Lin, Chienfu (1992), "Unit Root Tests in Panel Data: Asymptotic and Finite Sample Properties", *University of California at San Diego Discussion Paper* 92-23.
- Lothian, James R. and Taylor, Mark P. (1996), "Real Exchange Rate Behavior: The Recent Float from the Perspective of the Past Two Centuries", *Journal of Political Economy* 104: 488-509.

- MacDonald, Ronald (1996), "Panel Unit Root Tests and Real Exchange Rates", *Economics Letters* 50: 7-11.
- MacKinnon, J. G. and White, H. (1985), "Some Heteroskedasticity Consistent Covariance Matrix Estimators with Improved Finite Sample Properties", *Journal of Econometrics* 29: 305-325.
- Mark, Nelson C. (1990), "Real and Nominal Exchange Rates in the Long Run: An Empirical Investigation", *Journal of International Economics* 28: 115-136.
- Oh, Keunyeob (1996), "Purchasing Power Parity and Unit Root Tests Using Panel Data", *Journal of International Money and Finance* 35: 405-418.
- Papel, David H. (1994), "Exchange Rates and Prices: An Empirical Analysis", *International Economic Review* 35: 397-410.
- Phillips, Peter C. B. and Perron, Pierre (1988), "Testing for a Unit Root in Time Series Regression", *Biometrika* 75: 335-346.
- Pudney, S. E. (1978), "The Estimation and Testing of Some Error Components Models", *London School of Economics*, mimeo.
- Quah, Danny (1994), "Exploiting Cross-Sectional Variation for Unit Root Inference in Dynamic Data", *Economics Letters* 44: 9-19.
- Swamy, P.A.V.B. (1970), "Efficient Inference in a Random Coefficient Regression Model", *Econometrica* 38: 311-323.
- Wu, Yangru (1996), "Are Real Exchange Rates Nonstationary? Evidence from a Panel-Data Test", *Journal of Money, Credit and Banking* 28: 54-63.

Table.1 Absolute PPP based on CPI

	$\hat{\beta}$	sample	R^2	
Dummy Variable Model				
	0.9971			
whole	(0.02142)	440	0.9981	
	0.996			
country	(0.02487)	440	0.994	
	-0.3981			
time	(0.3239)	440	-0.0424	
	1.0198			
industrial countries	(0.06741)	132	0.9984	
	1.0156			
country	(0.06699)	132	0.9968	
	-1.1293			
time	(1.0951)	132	-0.1876	
Error Components Model				
	0.3012			m
whole	(0.2702)	440	0.0006	263351.4***
	0.9953			
country	(0.03242)	440	0.6821	1.6045
	0.619			
time	(0.2281)	440	0.0143	1.09E-05
	0.797			
industrial countries	(0.3684)	132	0.0273	3063.406***
	1.0152			
country	(0.07545)	132	0.5788	961595.5***
	-2.0299***			
time	(0.5233)	132	0.0968	3.47E-04
Swamy Random Coefficients Model				
	1.0788			z
	(0.2117)			1.7473

Note) Dummy Variable Model indicate standard error modified by MacKinnon and White (1985)'s HC3 when there exist heteroskedasticity.

Standard error in parenthesis

Three asterisks(***) indicate statistically significant at the 1 percent level.

Base country:USA

Terms:1973-1994

Table.2 Absolute PPP based on WPI

	β_2	sample	R ²	
Dummy Variable Model				
	0.9776			
whole	(0.03169)	352	0.9945	
	0.9537			
country	(0.0358)	352	0.9908	
	0.4966			
time	(0.3025)	352	-0.0288	
Error Components Model				
	0.8908			m
whole	(0.2031)	352	0.0494	561.8418***
	0.9533			
country	(0.03596)	352	0.6666	0.258
	0.239			
time	(0.1973)	352	0.0013	8.11E-07
Swamy Random Coefficients Model				
	0.9989			z
	(0.06144)	352		4.7857

Note) Standard error in parenthesis

Three asterisks (***) indicate statistically significant at the 1 percent level.

Base country:USA

Terms:1973-1994

Table.3 Relative PPP based on CPI

	β_2	sample	R ²	
Dummy Variable Model				
	0.994			
whole	(0.02301)	420	0.9653	
	0.9989			
country	(0.02714)	420	0.8844	
	1.0129			
time	(0.01762)	420	0.9107	
	1.0249			
industrial countries	(0.07794)	126	0.9329	
	1.0288			
country	(0.08412)	126	0.8596	
	0.9993			
time	(0.05031)	126	0.8172	
Error Components Model				
	1.0028			m
whole	(0.0279)	420	0.755	2.0042
	1.0028			
country	(0.03158)	420	0.7062	0.06344
	1.0253			
time	(0.02991)	420	0.737	3.30E-14
	1.0284			
industrial countries	(0.09521)	126	0.4806	0.0382
	1.0237			
country	(0.07754)	126	0.581	0.1313
	1.285***			
time	(0.1093)	126	0.5232	6.52E-06
Swamy Random Coefficients Model				
	1.2417***			z
	(0.09052)	420		0.2477

Note) Dummy Variable Model indicate standard error modified by MacKinnon and White (1985)'s HC3 when there exist heteroskedasticity.

Standard error in parenthesis

Three asterisks(***) indicate statistically significant at the 1 percent level.

Base country:USA

Terms:1974-1994

Table.4 Relative PPP based on WPI

	α	sample	R ²	
Dummy Variable Model				
	0.9567			
whole	(0.03936)	336	0.8948	
	0.9071**			
country	(0.04204)	336	0.8426	
	0.8879			
time	(0.3396)	336	0.6941	
Error Components Model				
	0.9301			m
whole	(0.08834)	336	0.2469	48.279***
	0.9228			
country	(0.07584)	336	0.3051	0.09245
	0.9089			
time	(0.08228)	336	0.2654	2.75E-13
Swamy Random Coefficients Model				
	0.9013			z
	(0.1304)	336		3.0129

Note) Standard error in parenthesis
 Three(***) and two(**) asterisks indicates statistically significant at the
 1 and 5 percent levels, respectively.
 Base country:USA
 Terms:1974-1994