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Purchasing Power Parity and Country Characteristics: Evidence from Time Series Analysis

Chia-Cheng Ho
Department of Finance, National Chung Cheng University

Su-Yin Cheng
Department of Finance, National Chung Cheng University

Han Hou
Department of Finance, National Chung Cheng University

Abstract

This paper investigates the relationships between country characteristics and the validity of PPP. We use three alternative time series methods to test for the stationarity of real exchange rates for each of the 72 countries over the period from 1976 to 2005. Our result shows that the evidence of PPP exhibits geographic difference. It is most likely to find stationary real exchange rates for European countries, whereas it is least likely to obtain the result of supporting PPP for Asian countries. We then use a probit regression model to examine if county characteristics are related to the validity of PPP. The probit regression result reveals that the validity of PPP decreases with inflation rate and increases with nominal exchange rate volatility.

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1. Introduction

The Purchasing Power Parity (PPP) asserts that the exchange rate between one country and another is determined by the relative national aggregate price levels. The PPP hypothesis has aroused a lot of interest in the empirical arena because it is the foundation of a number of theoretical models in international finance. Nevertheless, empirical results for the validity of PPP so far have been somewhat mixed.

In relation to time series analysis of real exchange rates, panel unit root tests have been an increasingly popular alternative for investigating the stationarity of real exchange rates. The panel data approach may increase statistical power due to the relatively large sample size. However, the problems of heterogeneity and cross-section dependence among the individual members in the panel must be addressed to make the panel technique robust. O'Conell (1998) suggests that panel rests could be biased without controlling cross-section dependence. Papell (1997) indicates panel results are sensitive to the panel size. McDonald (1996), Oh (1996), Papell (1997), and Im et al. (2003) use panel techniques to examine the stationarity of real exchange rates, yet the results are somewhat mixed. Besides, panel unit root tests examine the null hypothesis of a unit root for all pooled real exchange rates. Rejecting the null of a panel unit root does not necessarily imply that each individual component has no unit root because it is possible that only a subset of the real exchange rates are stationary. Specifically, the panel model essentially provides no information on the stationarity of an individual country's real exchange rates.

On the other hand, an increasing number of academic researches have recently started to investigate if the validity of PPP is related to country characteristics. For example, Cheung and Lai (2000) find that inflation and persistence in PPP deviations are negatively correlated. Holmes (2001) finds that PPP does not hold in high inflation countries. Alba and Papell (2007) document that PPP tends to hold for European and Latin American countries. They further find that the evidence of PPP is stronger for countries with less restriction on trade, a shorter distance from the U.S., lower inflation rates, moderate nominal exchange rate volatility, and growth rates of per capita real GDP similar to the U.S. The results of all these studies are based on the simple correlation between a single country characteristic and the evidence of PPP. However, the country factors may be interdependent in their relations with the validity of PPP. Therefore, it is interesting to investigate if the single-factor result holds when the interactions between the country characteristics are considered.

In this paper, we investigate whether country characteristics can affect the validity of PPP using the probit regression model for 72 countries. We first follow a similar approach with Cheung and Lai (2000) to use the augmented Dickey–Fuller (ADF) test, the KPSS unit root test, and the unit root test developed by Zivot and

Andrews (1992) to test for the stationarity of real exchange rates for each country. The country-by-country analysis of these univariate time series models allows us then to construct a dummy variable, taking value of 1 when PPP holds in the country and 0 otherwise, for the dependent variable of the probit regression model. Through the probit model we investigate if any relation exists between the validity of PPP and country characteristics. A major advantage of the approach is that it can determine which of the county characteristics are related to the validity of PPP and simultaneously controls the effects of potential interdependencies between the country characteristics. Our results show that U.S. dollar-based real exchange rates are stationary in 40 of the 72 countries investigated. The validity of PPP exhibits geographic difference. It is most likely to find stationary real exchange rates in European countries, whereas it is least likely to obtain the results of supporting PPP in Asian countries. Furthermore, the probit regression result indicates that the validity of PPP is negatively associated with inflation rate and positively related to nominal exchange rate volatility.

2. The purchasing power parity model and the methodology

The PPP states that the prices of a standard market basket of goods between two countries expressed in a common currency should be the same[1]. It can be written as follows:

$$P_t = S_t P_t^* \tag{1}$$

Where P_t is the domestic price level, P_t^* is the base country (the United States) price level and S_t is the bilateral nominal exchange rate between the two countries. In logarithmic form equation (1) becomes:

$$s_t = p_t - p_t^* \tag{2}$$

and hence the real exchange rate measuring deviations from PPP is calculated as follows:

$$q_t = s_t + p_t^* - p_t \tag{3}$$

[1] The absolute PPP assets that price levels across countries should be equal when expressed in a common currency. However, the relative PPP states that ratios of price levels across countries remain constant.

It follows that a stationary real exchange rate can be taken as evidence supporting the validity of PPP. Three alternative time series methods are utilized to test for the stationarity of real exchange rates for each country. They are augmented Dickey–Fuller (ADF) test, KPSS unit root test, and Zivot and Andrews (ZA) test. The ADF test has been the most popular and standard method for examining the stationarity of the real exchange rate. Unlike most of the unit root test methods defining the existence of a unit root as the null hypothesis, the KPSS test takes stationarity as the null hypothesis. The ZA unit root test developed by Zivot and Andrews (1992) allows for structure breaks in the time series examined. Zivot and Andrews (1992) show that the presence of a structural break may lead traditional ADF test to fail to reject the null of unit roots. In addition, they emphasize that the breakpoint should be estimated rather than fixed (Perron, 1990) even if structural breaks (e.g., Great Crash or the oil-price shock) are caused by exogenous events. Accordingly, Zivot and Andrews (1992) modify the ADF test to allow for structural change:

$$q_t = \hat{\mu} + \hat{\theta} \times DU_t\left(\hat{\lambda}\right) + \hat{\beta} t + \hat{\alpha} q_{t-1} + \sum_{j=1}^{K} \hat{c}_j \Delta q_{t-j} + \hat{e}_t \qquad (4)$$

where q_t is the (logarithmic) real exchange rate defined in equation (3), $DU_t\left(\lambda\right)$ equals 1 for $t > T\lambda$ and 0 otherwise, $\lambda = T_B / T$ represents the timing of the structural change, and T and T_B represent total sample size and the data when the structural breaks occurred respectively. Zivot and Andrews (1992) simulate a set of critical values for different λ s.

We use monthly, end-of-period nominal exchange rates[2] and Consumer Price Indexes (CPI) data for 72 countries mostly obtained form the International Monetary Fund International Financial Statistics (IFS)[3]. The data for Taiwan are from Central Bank of Taiwan, and the CPI data for Ireland and Iceland are from the official website of Organization for Economic Co-operation and Development (OECD) statistics Portal. Data series for all the 72 countries span a 30-year period from January 1976 to December 2005 to reflect the post-Bretton Woods period.

[2] For the European Union countries switching to the euro, we collect the nominal exchange rate currency by euro on January 1st, 1999 (e.g., the exchange rate of euro against Germany Mark is 1.95583). We then collect the euro by dollar exchange rate from 1999 to 2005 and convert in currency by dollar using the prefixed exchange rates.

[3] The countries we choose for the study are mostly a subset of those used in Alba and Papell (2007). We are left with only 72 countries since we require the countries to have complete data over the 30-year time span. Also, we use interpolation to complete data series for several countries whose data series have only a few missing observations.

3. Empirical results

3.1 Summary of unit root tests

As a first step, we apply three alternative time series unit root tests to examine the stationarity of real exchange rates for each of the 72 countries. Table 1 displays the test results. Test models with and without a time trend are both conducted. Papell (2001) indicates that test model without including a time trend would be more theoretically consistent with long-run PPP. On the other hand, Obstfeld (1993) suggests that a time trend in the real exchange rate may be a necessary consideration for countries experiencing substantial changes in differential productivity growth between tradables and nontrdables. Therefore, we adopt a two-pass filtering procedure to test for stationarity of real exchange rates. The model without a time trend is used in the first pass to screen out countries for which PPP does not hold. We then use the model with a time trend to re-examine the stationarity of real exchange rates for these countries that were screened out in the first pass.

Table 1 shows that we can reject the null of unit root at the conventional level for 5 countries according to the ADF test. This corroborates the traditional finding that ADF tests have very low power to provide evidence supporting PPP. This calls for other alternative tests for the validity of PPP. Results in Table 1 also show that the KPSS test provides corroborative evidence for stationarity of real exchange rates in 25 countries. Of the 25 countries, 4 countries are also on the list of the 5 countries under the ADF test. Therefore, in relation to the ADF test, the KPSS test uncovers additional evidence for PPP. Nevertheless, the KPSS test still can reject its null of stationarity in 47 of the 72 counties being examined. This prompts us to consider alternative tests that can take into account .any of the special features of real exchange rates. Given the extensive literature emphasizing the need for structure models to counter the specific effects of unusual exchange rate volatility (Cheung and Lai, 1998a; Wu et al., 2004; Harris et al., 2005). We thus apply the ZA test, which allows for structural instability in the time series being examined, to test for the stationarity of real exchange rates. The results show that the ZA test significantly rejects the null of a unit root in 18 countries. Of the 18 countries, there are 4 countries and 3 countries also on the lists of the ADF and KPSS tests respectively. After subtracting some overlapping countries in terms of the other test results, the ZA test generates 13 new cases of supporting PPP. As a whole, the three tests provide evidence for PPP in 40 countries (about 55% of the 72 counties under investigation).

3.2 Grouped by geographic region

Previous studies document that the validity of PPP appears to vary across geographic locations because the similarity in economic conditions of member

countries differs from area to area (Cheung and Lai, 2000; Alba and Papell, 2007). We hence segregate the 72 countries by geographic region into African, European, Latin American, and Asian countries. Table 2 reports the result of the unit root tests by geographic region. The number of member countries in each area shows little disparity, ranging from 20 in Europe, 18 in Latin America, to 16 in both Africa and Asia. However, the number and proportion of countries with stationary real exchange rates both differ widely across the four areas. Specifically, PPP is found to hold in 75 % of the European countries but only in 31% of the Asian countries. Furthermore, the difference is statistically significant since the null hypothesis that the proportion of countries with stationary real exchange rates is the same across the four areas is rejected based on a χ^2 test. Our finding is consistent with Cheung and Lai (2000) and Alba and Papell (2007) who suggest that PPP is more likely to hold for European countries.

3.3 Relations between country characteristics and the validity of PPP

Real-world imperfections can cause deviations from PPP. Previous studies have identified at least five country characteristics that may affect the validity of PPP. They are trade openness, geographical distance, inflation rate, growth rate of per capita real GDP, and nominal exchange rate volatility. Alba and Papell (2007) indicate that restraints on trade may impede arbitrage opportunity among countries, which prevents PPP from holding. Besides, higher transportation costs associated with greater distance may undermine trade and arbitrage. Therefore, PPP may hold better for countries more open for international trade or closer to the base country.

Cheung and Lai (2000) indicate that inflation and persistence in PPP deviations are negatively correlated. However, Alba and Papell (2007) document that the evidence of PPP is stronger in countries with low inflation rates. Holmes (2001) finds that PPP does not hold in high inflation countries. As a result, there appears to be no unanimous conclusion on the relationship between inflation rate and PPP. Similarly, mixed empirical results on the link between economic growth and PPP have been reported. Alba and Papell (2007) find that PPP is stronger in countries with economic growth comparable to the United States. In contrast, Cheung and Lai (2000) do not find any association between economic growth and PPP. With respect to nominal exchange rate volatility, theories related to PPP have not specified exactly how it can be associated with the validity of PPP. Alba and Papell (2007) empirically find stronger evidence of PPP in countries with moderate exchange rate volatility.

We now investigate if these country characteristics can account for the validity of PPP by running a probit regression. The dependent variable of the probit model takes a value of 1 if its real exchange rates are found to be stationary, and 0 otherwise.

We follow Alba and Papell (2007) to measure the independent variables (i.e., country characteristics) of the model. Trade openness is measured by dividing the sum of merchandize exports and imports by GDP. Distance is measured by the square root of air miles between a country's capital city and Washington DC. Growth rate is calculated using the World Bank's least squares method. Inflation rate is the mean of the annual changes in CPI and nominal exchange rate volatility is the average of the absolute value of the annual percentage changes of a country's bilateral exchange rate against the U.S. dollar[4]. Besides, as shown in Table 2 that the validity of PPP varies across geographic locations, we therefore account for the geographic effect by adding three regional dummies into the regression model.

Table 3 reports the results of the probit regression with various combinations of independent variables. When all the independent variables are added into the model, the validity of PPP is found to only be negatively associated with inflation rate and positively related to nominal exchange rate volatility at the conventional level.[5] Taken as a whole, the main conclusion is still robust even when some variables are omitted from the probit regression model.

Consistent with Alba and Papell (2007), the evidence of PPP is stronger for countries with lower inflation. On the other hand, the positive relationship between nominal exchange rate volatility and the validity of PPP does not exactly support Alba and Papell (2007). They find that PPP is stronger for countries with moderate exchange rate volatility. Nevertheless, their test result[6] shows that the p-value for the sub-panel of highest exchange rate volatility is 0.111, which is closed to 10% significant level. On the other hand, the p-value for the sub-panel of lowest exchange rate volatility is 0.990, which is far from supporting PPP. As indicated by Alba and Papell (2007), the association between PPP and nominal exchange rate volatility is complicated and nuanced. They argue that PPP may hold better with low nominal exchange rate volatility for developed countries, whereas low nominal exchange rate volatility may imply the restrictions on exchange rate movements that prevent PPP from holding for developing countries.

4. Conclusions

The purpose of this paper is to investigate whether the validity of PPP is related to country characteristics. Although panel unit root models have been widely used to

[4] All of the data we use to calculate countries characteristics is from IFS except for distance data which are taken from the website of Bali and Indonesia (http://www.indo.com/distance/).

[5] Although none of the regional dummies is significant at the conventional level, the result is not necessarily inconsistent with the geographic difference in the validity of PPP shown in Table 2 of the study. The effect of these dummies on the validity of PPP is measured in relation to that of Latin America, while the geographic difference documented in Table 2 consider mutual disparities across the four geographic regions.

[6] See Table 2 on page 248 of Alba and Papell (2007).

test for the stationarity of real exchange rates, they can only provide evidence of PPP for the set of countries considered together but offer no information on the validity of PPP for each component country. In this study, we follow an approach similar with Cheung and Lai (2000) to test for the stationarity of real exchange rates for 72 countries over a 30-year period from 1976 to 2005. In particular, we use the augmented Dickey–Fuller (ADF) test, the KPSS unit root test, and the unit root test developed by Zivot and Andrews (1992) to examine if PPP holds in each individual country. Our result shows that geographic difference plays a role in the validity of PPP. The evidence of supporting PPP is more likely to be found for European countries, whereas it is less likely to be found for Asian countries. Finally, we use the probit regression model, which allows us to address the problem of potential interdependencies between the country characteristics, to examine if county characteristics are related to the validity of PPP. The probit regression result reveals that the validity of PPP decreases with inflation rate and increases with nominal exchange rate volatility.

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Table 1
Unit-root rejections based on ADF, KPSS, and ZA tests

ADF				KPSS			ZA			
Countries	Lag	Model	Statistics	Countries	Model	Statistics	Countries	Break	Model	Statistics
Seychelles	3	C	-2.713*	Burkina Faso	C&T	0.110	Ethiopia	1992:10	C	-7.946***
Greece	12	C	-2.693*	Malta	C&T	0.077	Ghana	1983:10	C	-5.904***
Costa Rica	9	C&T	-3.131**	Niger	C&T	0.119	Madagascar	1986:08	C	-4.811**
El Salvador	0	C&T	-3.941**	*Seychelles*	C	0.333	*Seychelles*	1985:07	C	-4.792*
St. Lucia	0	C	-3.762***	South Africa	C&T	0.116	*Costa Rica*	1981:02	C	-8.639***
				Swaziland	C&T	0.077	Dominican Republic	1985:01	C	-8.200***
				Belgium	C	0.169	Ecuador	1985:12	C	-4.670*
				Denmark	C	0.147	*El Salvador*	1986:01	C&T	-5.318**
				Finland	C	0.200	Guatemala	1986:06	C	-11.351***
				France	C	0.151	Honduras	1990:04	C	-10.463***
				Germany	C	0.246	Jamaica	1983:11	C	-6.167***
				Greece	C	0.213	*Mexico*	1981:09	C	-5.345***
				Iceland	C&T	0.111	*St. Lucia*	1982:05	C&T	-6.418***
				Ireland	C&T	0.092	Trinidad and Tobago	1985:12	C&T	-6.478***
				Italy	C&T	0.119	Thailand	1997:07	C	-5.276**
				Luxembourg	C	0.181	India	1991:01	C&T	-4.819*
				Netherlands	C	0.220	Indonesia	1997:08	C&T	-4.926*
				Norway	C	0.270	Jordan	1988:05	C&T	-5.506***
				Spain	C&T	0.116				
				Switzerland	C	0.251				
				United Kingdom	C&T	0.074				
				Mexico	C	0.273				
				St. Lucia	C&T	0.099				
				Fiji	C&T	0.107				
				Malaysia	C&T	0.101				

ADF, KPSS, and ZA stand for unit root tests developed by Dickey and Fuller (1979, 1981), Kwaitkowski et al. (1992), and Zivot and Andrews (1992), respectively. Both ADF and ZA tests specify the existence of a unit root to be the null hypothesis. In contrast, the null hypothesis under the KPSS test states that there exists a stationary series. The lag order is selected using the AIC (while only a maximal lag of 12 is allowed for). "C" denotes the case where the test is implemented without a time trend and "C&T" is for the case where the test is implemented with a time trend. '*', '**', and '***' indicate rejection of the null at the 10%, 5%, and 1% levels respectively.

Table 2
The validity of PPP by geographic region

Country Group	No. of Countries	No. of countries where PPP holds	Evidence for PPP under various tests		
			ADF	KPSS	ZA
All Countries	72	40 (55.5%)	5 (6.9%)	22 (30.6%)	13 (18.0%)
Africa	16	9 (56.3%)	1 (6.3%)	5 (31.3%)	3 (18.7%)
Europe	20	15 (75.0%)	1 (5.0%)	14 (70.0%)	0 (0.0%)
Latin America	18	10 (55.6%)	3 (16.7%)	1 (5.6%)	6 (33.3%)
Asia	16	5 (31.3%)	0 (0.0%)	2 (12.5%)	3 (18.8%)
X^2 -test (v=3 df)= 6.893*					

Africa includes Botswana, Burkina Faso, Burundi, Cameroon, Ethiopia, Ghana, Kenya, Madagascar, Malta, Morocco, Niger, Nigeria, Senegal, Seychelles, South Africa and Swaziland. Europe includes Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom. Latin America includes Bahamas, Barbados, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Paraguay, St. Lucia, Trinidad and Tobago, and Venezuela. Asia includes Hong Kong, Fiji, Japan, Korea, Malaysia, Singapore, Taiwan, Thailand, India, Indonesia, Myanmar, Nepal, Pakistan, Philippines, Samoa, and Sri Lanka.Two countries, Canada and Jordan, are not classified to any of the four areas due to their different geographic locations from others. ADF, KPSS, and ZA stand for unit root tests developed by Dickey and Fuller (1979, 1981), Kwaitkowski et al. (1992), and Zivot and Andrews (1992), respectively. Both ADF and ZA tests specify the existence of a unit root to be the null hypothesis. In contrast, the null hypothesis under the KPSS test states that there exists a stationary series. The numbers in parentheses denote the percentage of countries with stationary real exchange rates. The χ^2 goodness of fit test with the given degree of freedom (df) examines the null hypothesis that percentages of countries with stationary real exchange rates across the four geographic areas are equal. '*' indicates rejection of the null at the 10% level.

Table 3
Results of the Probit regression model

Model	I	II	III	IV	V
Constant	4.316	2.299	0.758	0.028	-0.115
	(0.839)	(0.522)	(1.055)	(0.073)	(-0.416)
Inflation	-0.125*	-0.091*	-0.078**	-0.065*	-0.064*
	(-1.714)	(-1.759)	(-2.063)	(-1.773)	(-1.758)
Volatility	0.079*	0.078**	0.079**	0.072**	0.074**
	(1.706)	(2.254)	(2.302)	(2.064)	(2.099)
Trade Openness	-0.110	-0.137	-0.154	-0.160	
	(-0.384)	(-0.489)	(-0.562)	(-0.587)	
Distance	0.010	-0.010	-0.010		
	(0.686)	(-1.246)	(-1.260)		
Growth Rate	-4.114	-1.477			
	(-0.818)	(-0.351)			
Africa	-1.034				
	(1.147)				
Europe	-0.164				
	(-0.218)				
Asia	-1.188				
	(-1.363)				
-2 Log Likelihood	87.969	92.080	92.186	93.746	93.994
Adj-R^2	0.111	0.069	0.068	0.052	0.050

Trade openness is measured by dividing the sum of merchandize exports and imports by GDP. Distance is measured by the square root of air miles between a country's capital city and Washington DC. Growth rate is calculated using the World Bank's least squares method. Inflation rate is the mean of the annual changes in CPI and nominal exchange rate volatility is the average of the absolute value of the annual percentage changes of a country's bilateral exchange rate against the U.S dollar. Africa is an indicator that takes the value of 1 if a country belongs to Africa and 0 others. Europe is an indicator that takes the value of 1 if a country belongs to Europe and 0 others. Asia is an indicator that takes the value of 1 if a country belongs to Asia and 0 others. The numbers in parenthesis refer to t-statistic. '*' and '**' indicate rejection of the null at the 10% and 5% level respectively.