Purchasing Power Parity and Country Characteristics:
Evidence from Panel Data Tests

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September 2005

Abstract

We examine long-run purchasing power parity (PPP) using panel data methods to test for unit roots in US dollar real exchange rates of 84 countries. We find stronger evidence of PPP in countries more open to trade, closer to the United States, with lower inflation and moderate nominal exchange rate volatility, and with similar economic growth rates as the United States. We also show that PPP holds for panels of European and Latin American countries, but not for African and Asian countries. Our findings demonstrate that country characteristics can help explain both adherence to and deviations from long-run PPP.

JEL classification: F31, O57

Keywords: Purchasing power parity, country characteristics, panel unit root tests.

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We are grateful to Carlos Vegh and an anonymous referee for helpful comments. Papell thanks the National Science Foundation for financial support.

I. Introduction

Purchasing Power Parity (PPP) has been one of the most enduring concepts in international

economics. In its strongest form, absolute PPP implies that one could buy the same basket of goods in any

country for the same value when prices are denominated in a common currency. This concept is based on

the law of one price, which presumes that arbitrage in a wide range of goods equalizes prices across

countries. After the collapse of the gold standard during World War I, Cassel (1922) proposed the use of

PPP to restore relative gold parities. He suggested that countries set their post-war exchange rates

according to PPP by setting the change in their post-war and pre-war exchange rates equal to the

difference between their post-war and pre-war inflation rates. Since that time, economists have used PPP

in setting and forecasting exchange rates, in adjusting for cross-country incomes to account for

differences in prices and as a foundation of models in international macroeconomics.[1]

Despite a vast empirical literature, many questions remain regarding the validity of PPP. Since short-

run PPP is almost never an economically relevant proposition, empirical investigation has focused on

long-run PPP. This usually involves testing for unit roots in real exchange rates. If the test rejects the unit

root hypothesis, the real exchange rate reverts to its mean and long-run PPP holds. In addition, because

price indexes are used to construct real exchange rates, these methods are necessarily tests of a weaker,

relative, form of PPP. Since the price indexes are equalized in an arbitrary base year, what can be tested is

whether relative prices denominated in the same currency revert to a constant long-run mean, not whether

one could ever buy the same basket of goods for the same prices in different countries.

The first studies on PPP in developed countries use univariate Augmented Dickey-Fuller (ADF) tests

with post-1973 flexible (nominal) exchange rate data and often do not find evidence for long-run PPP.[2] A

common explanation why these studies mostly failed to find evidence of PPP is the lack of power of unit

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[1]Rogoff (1996) surveys the literature on PPP.
[2]Early investigations of PPP sometimes also tested for cointegration among nominal exchange rates, domestic price levels and foreign price levels, and rejection of the null hypothesis of no cointegration was interpreted as even weaker evidence of long-run PPP. Cointegration, however, is a necessary but not a sufficient condition for long-run PPP, which holds only if domestic and foreign prices are symmetric and relative prices and the nominal exchange rate are proportional.

root tests in small samples. To address the small sample problem, researchers use long horizon (up to 200 years) data of developed countries and generally show stronger rejections of the unit root hypothesis. However, long horizon data combine fixed and floating exchange rate periods and cannot determine whether PPP would hold over a century (or more) of a stable exchange rate regime. [3]

To address the low power of the univariate unit-root tests with post-1973 data, researchers have turned to panel methods that allow for cross-section variation, as developed by Levin, Lin and Chu (2002) and Im, Pesaran and Shin (2003). The empirical evidence has been, overall, supportive of PPP. While early studies such as Frankel and Rose (1996) and Jorion and Sweeney (1996) find strong support for PPP, work incorporating serial correlation in Papell (1997) and contemporaneous correlation in O'Connell (1998) find much weaker evidence. More recently, panel unit root tests that extend post-1973 quarterly real exchange rate data with the US dollar as numeraire currency through 1997 or 1998 tend to provide strong support of PPP for developed countries. Examples of this work include Higgins and Zakrajšek (2000), Wu and Wu (2001) and Papell (2005). Papell and Theodoridis (2001) show stronger rejections of the unit root hypothesis with European rather than non-European numeraire currencies.

For less developed countries, panel unit root tests have not provided much support of PPP. Using real exchange rates constructed from price indexes and black market quotations of nominal exchange rates, Phylaktis and Kassimatis (1994) reject the unit root hypothesis for eight Pacific Basin countries. Oh (1996) uses data from Summers and Heston's (1991) Penn World Table and mostly fails to reject the unit root hypothesis in real exchange rates of less developed countries during the flexible rate period. Both studies use Levin, Lin and Chu (2002) tests. Holmes (2001) uses panel unit root tests, as developed by Im, Pesaran and Shin (2003), and fails to reject the unit root hypothesis in panels of countries with high inflation and of countries located outside Africa. Hence, while panel methods have significantly increased the power of unit root tests, studies using these methods fail to show convincing evidence of PPP.

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[3] Another approach is to use more powerful univariate tests. Cheung and Lai (2000), using the DF-GLS tests of Elliott, Rothenberg and Stock (1996), report more rejections of the unit root hypothesis, but mostly at a weak (10 percent) significance level. Elliott and Pesavento (2004) and Amara and Papell (2005) find stronger rejections using covariate-augmented tests.

The purpose of this paper is to move beyond the developed/developing country dichotomy to investigate the role of individual country characteristics on PPP. This requires a sample that includes both developed and developing countries because the former contain too little variation to address the question. There are a number of reasons why PPP might vary systematically with country characteristics. PPP may hold better for countries more open to trade because trade barriers hinder international arbitrage and among countries that are geographically closer because high transportation costs associated with greater distance could hinder trade and arbitrage. PPP may also hold better between countries with similar inflation rates because, with differences in inflation, countries can prevent their nominal exchange rates from adjusting to parity. The relation between PPP and nominal exchange rate volatility is more nuanced. For developed countries, PPP may hold better among countries with low nominal exchange rate volatility because rigidities may prevent prices from adjusting to parity. For developing countries, however, low nominal exchange rate volatility may signal restrictions on exchange rate movements that prevent PPP from holding. Finally, Balassa (1964) and Samuelson (1964) posit that countries with high productivity growth in traded goods will have appreciating real exchange rates. In that case, PPP will not hold between high-growth and low-growth countries.

We investigate long-run PPP by testing for unit roots in US dollar real exchange rates of 84 countries during the floating exchange rate period. Using panel methods based on Levin, Lin and Chu (2002), we cannot reject the unit root hypothesis in a panel of real exchange rates of 84 countries. We then conduct unit root tests in real exchange rates of countries with panels organized according to geographic and country characteristics. We can reject the unit root hypothesis, and thus provide evidence of PPP, for panels of real exchange rates for European and Latin American countries. We also find evidence of PPP for panels of countries more open to trade, nearer and with similar growth and inflation as the United States, and with moderate nominal exchange rate volatility. Our results are consistent with the conceptual explanations of why PPP may hold for countries with certain types of characteristics.

Several other studies have considered how country characteristics affect PPP. In contrast with our results, Cheung and Lai (2000) find that openness and per capita GDP growth cannot explain the

persistence of deviations from PPP. They also find that inflation and persistence of deviations from PPP are negatively correlated implying that evidence of PPP is stronger in high inflation countries. Cheung and Lai infer the impact of country characteristics on PPP using the relationship between country characteristics and persistence of deviations from PPP, calculated using half-lives of shocks to parity measured for 94 real exchange rates using separate unit root tests for each country rather than panel methods. Consistent with our results, Holmes (2001) cannot reject the unit roots in high inflation countries using the IPS panel unit-root tests. However, other than high inflation, Holmes only considers groupings of 30 developing countries by geographic region.

II. Univariate and Panel Unit Root Tests

As a preliminary step, we investigate unit roots in real exchange rates using ADF tests. We use data mostly from the International Financial Statistics (on-line, August 2004) of monthly CPI and end-of-period nominal exchange rates of 84 less developed countries and developed countries. The CPI data for Hong Kong, Ireland, Taiwan and Iceland and the nominal (dollar) exchange rate of Taiwan are from DataStream International.[4]

The real exchange rate is calculated as follows:

$$q = e + p^* - p , \tag{1}$$

where q is the real exchange rate, e is the nominal US dollar exchange rate, p is the domestic price index and p^* is the price index of the United States. q, e, p and p^* are in logarithms.

The univariate ADF tests involve running regressions on the following equation:

$$\Delta q_t = \mu + \alpha q_{t-1} + \sum_{i=1}^{k} c_i \Delta q_{t-i} + \varepsilon_t , \tag{2}$$

where Δq_t is the first difference of the real exchange rate and k is the number of lagged first differences. k is determined following the recursive t-statistic procedure proposed by Hall (1994). We choose a

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[4]Because old CPI series (HKCPALLTF) of Hong Kong was discontinued in March 1997, we extend the old CPI series from March 1997 to December 2002 by assuming it would have changed by the same percentage as the new CPI series (HK164....F). In extending the nominal (dollar) exchange rates of European-Union member countries from January 1999 to December 2002, we

maximum value of k equal to 24, with the significance determined at the 10% level of the asymptotic normal distribution.[5] The test is specified without a time trend for consistency with long-run mean reversion implied by PPP. The null hypothesis is a unit root and the alternative is level stationarity, and the null hypothesis is rejected in favor of the alternative hypothesis if α is significantly less than zero.

Using ADF tests on the CPI-based US dollar real exchange rates of 84 countries, we can reject the unit root null in favor of level stationarity in the real exchange rates of five countries at the 5% or higher levels of significance, and for 12 additional countries at the 10% level. These results are consistent with earlier studies failing to show much evidence of PPP during the current float.

The failure to reject unit roots in real exchange rates could be due to the low power of univariate ADF tests in small samples. In order to increase power, we use panel methods that allow for variation across countries as well as across time. The panel unit root tests are conducted by running regressions on the following equations:

$$\Delta q_{jt} = \mu_j + \alpha q_{jt-1} + \sum_{i=1}^{k} c_{ji} \Delta q_{jt-1} + \varepsilon_{jt} \tag{3}$$

where μ_j represents heterogeneous intercept and the subscript j is the country index. The lag length k and the coefficients c_{ji} are heterogeneous across countries. Equation (3) is estimated using feasible GLS (SUR), with the values of k taken from the results of univariate ADF tests. The α coefficients are equal across countries. The restriction on α follows the panel unit root tests developed by Levin, Lin and Chu (2002). The t-statistic on α is the test statistic. If α is negative and significantly different from zero, the null hypothesis that all the real exchange rates in the panel have unit roots is rejected in favor of the alternative hypothesis that all the real exchange rates in the panel are level stationary.

We use Monte Carlo methods to calculate the critical values of the test statistics. We first estimate optimal autoregressive (AR) models (using the Bayesian information criterion) for the first differences of

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assume that they would have changed by the same percentage as the euro. All series are from January 1976 to December 2002. Dominica's CPI series has two missing observations. To complete the series, we use interpolation.

each series. Considering the optimal estimated AR models as the true data generating processes, we generate residuals of each series, from which we calculate the covariance matrix Σ in order to preserve the cross-sectional dependence in the data. Using the optimal AR models with iid $N(0, \Sigma)$ errors, we construct pseudo samples equal to the number of actual observations for the series. We then take partial sums so the generated series contain a unit root by construction. Based on 5,000 Monte Carlo replications, we obtain the critical values for the finite-sample distributions from the sorted vector of replicated test statistics.

Table 1 shows the results of the unit root tests for a panel of 84 countries. We cannot reject the unit root null hypothesis in favor of the alternative hypothesis of level stationarity at the 10% level of significance. Because the α coefficients are equal across countries in the Levin, Lin and Chu (LLC) test, the choices are stark. The null hypothesis is that *all* of the series contain unit roots and the alternative hypothesis is that *all* of the series are stationary. Given the span and width of our panel, the LLC tests will have very high power. We can therefore interpret the non-rejection as strong evidence that not all of the series are stationary, but it does not constitute evidence that all of the series have unit roots.

The restriction that the α coefficients are equal across countries can be relaxed. Im, Pesaran and Shin (2003) develop tests where the α coefficients can vary across countries. The null hypothesis for these tests is the same as for the LLC tests, *all* of the series contain a unit root, but the alternative hypothesis is that *at least one* of the members of a panel is stationary. The test statistic is the t-bar statistic, which they show converges to a standard normal distribution under the null of nonstationarity. Using the Im, Pesaran and Shin (IPS) tests, Table 1 also shows that we can reject the null hypothesis that all 84 real exchange rates have unit roots in favor of the alternative hypothesis that at least one of the 84 series is stationary at the 1 percent level of significance. Combining the results of the ADF, LLC, and IPS tests, we conclude that we cannot characterize all of the real exchange rates as either stationary or containing a unit root. Put

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[5]Campbell and Perron (1991) and Ng and Perron (1995) show that Hall's (1994) procedure has better properties than other data-dependent methods.

differently, PPP neither holds nor does not hold for all countries. We therefore turn attention to see what we can learn from smaller groupings of countries.

We organize real exchange rates in panels according to geographical region because countries from the same region often have similar levels of development. Africa and Latin America include mostly less developed countries while Europe includes developed countries. In contrast, Asia includes countries at different levels of development, such as the highly developed country of Japan and the underdeveloped country of Myanmar. For Asia, we also organize panels of Asian countries according to high income and low income.[6]

Table 1 also shows unit root tests of panels organized by geographical region. We can reject the unit root hypothesis against the alternative of level stationarity for the real exchange rates of European and Latin American countries with the United States dollar as the numeraire currency at the 1% level of significance. We cannot, however reject the unit root hypothesis against the alternative of level stationarity at even the 10% level of significance for African, all Asian, high-income Asian, and low-income Asian countries. This provides strong evidence of PPP for two regions, Europe and Latin America, and no evidence of PPP for two additional regions, Africa and Asia.

III. Country Characteristics

What could cause much stronger evidence of PPP for some regions than in others? Distance appears to be a factor, as Europe and Latin America are closer to the United States than are Africa and Asia. The results seem to suggest stronger evidence for high-income developed countries than low-income less developed countries, although high-income Asian countries are the exception. The evidence of PPP is also stronger for larger panels of Latin America and of Europe than for smaller panels of Africa and of Asia. Since the power of panel unit root tests increases with the size of the panels, the stronger evidence in favor of PPP could be due to the different sizes of the panels. In order to understand the effect of factors beyond geography on PPP and to control for the effect of the size of the panel on the power of the tests,

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[6] We measure income as the country's 1998 per capita real GDP in PPP-adjusted international dollars.

we organize countries according to their characteristics in panels of equal size. The characteristics that we consider are trade openness, distance between countries, inflation experience, per capita real GDP growth and nominal exchange rate volatility.

The concept of PPP is based on arbitrage of goods prices across countries, but trade barriers or geographic distances among countries may make transaction costs too high for arbitrage to be profitable. Without arbitrage, there will be no excess demand of foreign currency and no movement in the foreign exchange rate. Hence, PPP may not hold in countries less open to trade and in countries that are geographically far apart.

If countries have different inflation rates and flexible exchange rates, arbitrage could increase the demand for foreign goods and foreign currency in the high-inflation country. The high-inflation country's exchange rate would then depreciate vis-à-vis the low-inflation country until PPP is restored. However, despite the inflation differential with its trading partners, a country could intervene in the foreign exchange market to prevent the adjustment of its exchange rate so that PPP may not hold. Hence, PPP may not hold in countries with different inflation rates that fix their exchange rates.

Balassa (1964) and Samuelson (1964) predict that relative PPP would not hold between high-growth and low-growth countries. If growth of per capita real GDP reflects growth in productivity of a country, the higher productivity in the tradable sectors of a high-growth country increases the wages in both the tradable sectors and the nontradable sectors. Because higher wages in the nontradable sectors are unaccompanied by higher productivity, employers must raise prices of nontraded goods. This increases domestic prices, causing higher inflation, in the high-growth country. Assuming the same rate of money supply growth in both countries, the inflation rate of the high-growth country would be higher than the inflation rate in the low-growth country. Hence, the evidence of relative PPP would be weaker between high-growth and low-growth countries than between similar-growth countries.[7]

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[7] If money supply growth rates are different between two countries, they will have different inflation rates but PPP will still hold if the exchange rate of the high inflation country depreciates to match the inflation differential. If the high per capita real GDP

Countries with different nominal exchange rate volatility may exhibit less evidence of PPP than countries with similar nominal exchange rate volatility. Among developed countries with similar, relatively low, inflation rates, high nominal exchange rate volatility could imply longer deviations of the real exchange rate from parity. Even if long-run PPP held, this would lower the power of unit root tests and decrease the evidence of PPP. Less developed countries, however, could have both inflation and restrictions that prevent its nominal exchange rate from adjusting to parity. In that case, countries with low nominal exchange rate volatility would exhibit the longer deviations from, and consequently less evidence of, PPP.

Since the data used in this paper use price indexes to construct real exchange rates, we can only test for relative PPP, not for absolute PPP.[8] Using the US dollar as the numeraire currency, we measure distance relative to the United States. Our hypothesis is that countries closer to the United States should show stronger evidence of PPP. Similarly, the Balassa-Samuelson model predicts that evidence of relative PPP should be stronger for countries with similar per capita real GDP growth as the United States and weaker for countries with per capita real GDP growth that is higher or lower than the United States.[9]

We investigate the effects country characteristics on PPP by conducting panel unit root tests for real exchange rates of countries organized according to their country characteristics. All of the panels use the United States dollar as the numeraire currency. We use as a measure of openness merchandize exports plus imports divided by GDP. Distance is measured using the square root of air miles between a country's capital city and Washington D.C. The growth rate of PPP-adjusted per capita real GDP is calculated using

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growth country is also the low money supply growth country, the country with the lower inflation can also have an appreciating real exchange rate.

[8] Since we cannot test the absolute form of PPP, we have no basis to hypothesize about the relation of the level of income to the strength of evidence for PPP. The hypothesis that the absolute form of PPP may not hold between low-income and high-income countries is based on the empirical regularity, known as the Penn effect, as discussed in Kravis, Heston and Summers (1978).
[9] While the Balassa-Samuelson model or, more generally, any model with real shocks, will predict that countries with different growth rates will exhibit divergences from PPP, there is much disagreement regarding the form of the divergences. These include a unit root; Engel (2000), a deterministic trend; Obstfeld (1993), and a one-time change in the mean; Dornbusch and Vogelsang (1991). We do not address the form of the divergences in this paper.

the World Bank's least squares method.[10] This method minimizes the effect of large fluctuations in a country's annual growth rates.[11] We measure inflation as the average of the annual change in CPI. 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 US dollar.[12]

For each characteristic, we divide the 84 countries in our sample into four groups, depending upon how they measure against that particular criterion. As shown in Table 2, on the basis of the 'openness' characteristic, the 21 countries with the highest ratios of trade to GDP are classified as 'most open' and the 21 countries with the lowest ratios of trade to GDP are classified as 'least open.' The countries falling in the middle of the sample range are classified as either 'more open' and 'less open.' The countries are also divided according to the other criteria, distance from USA, inflation, growth, and exchange rate volatility, in a similar manner. Based on the groupings, the United States can be classified as 'least open,' 'higher growth' and 'low inflation'

Table 2 shows the results of the panel unit root tests of real exchange rates for groups of countries organized according to country characteristics. We can reject the unit root hypothesis at the 5% or higher levels of significance for panels of countries labeled as most, more and less open to trade, but cannot reject the null at the 10% level for the panel that is least open to trade. This is in accord with the hypothesis that more open economies will have greater evidence of PPP. We also reject the unit root hypothesis at the 5% or higher levels of significance for panels of countries labeled as nearest and nearer to the United States, but cannot reject the null at the 10% level for the panels that are farther and farthest

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[10]As discussed in the World Development Report (2003), a country's average annual growth rate is calculated by running a regression on the logarithm of the PPP-adjusted per capita real GDP on a constant and a time trend. The average growth rate is one plus the exponential of the coefficient of the time trend.

[11] Myanmar and Samoa have only few observations of PPP-adjusted per capita real GDP. Because of limited data on Myanmar and Samoa, we calculate the per capita real GDP growth as the average of the change of PPP-adjusted per capita real GDP.

[12]Data on merchandize exports, imports, GDP, PPP-adjusted per capita real GDP in 1995 international dollars and the average yearly change in CPI are mostly from the World Development Indicator (CD-ROM 2004). PPP-adjusted per capita real GDP for Grenada, Seychelles and Taiwan are from the Penn World Table 6.1. Data on PPP-adjusted per capita real GDP for Myanmar are from various issues of the United Nations Development Programme's Human Development Report. Data on distance are from the website: http://www.geobytes.com/CityDistanceTool.htm. The data are available from the authors upon request.

from the United States. This is in accord with the hypothesis that evidence of PPP is negatively correlated with distance.

For the panels organized by growth, we can reject the unit root hypothesis at the 5% or higher levels of significance for panels of countries labeled as higher growth and lower growth, but cannot reject the null at the 10% level for the panels labeled as highest growth and lowest growth. The United States ranks forty-ninth in PPP-adjusted per capita real GDP growth, which puts it in the higher growth panel, but closer to lower growth than to highest growth. The rejections and lack of rejections are in accord with the prediction of the Balassa-Samuelson model that evidence of relative PPP should be stronger for countries with similar per capita real GDP growth as the United States and weaker for countries with per capita real GDP growth that is higher or lower than the United States.

We can reject the unit root hypothesis at the 5% or higher levels of significance for the panel of countries with lowest inflation, but cannot reject the null at the 10% level for the other three panels of countries with higher inflation. Since the United States is in the lowest inflation group, this is in accord with the hypothesis that low inflation economies will have greater evidence of PPP. Finally, we can reject the unit root hypothesis at the 5% level of significance for the panel of countries with higher nominal exchange rate volatility and at the 10% level of significance for the panel of countries with lower nominal exchange rate volatility. We cannot reject the null at the 10% level for the panels with highest and lowest nominal exchange rate volatility. This is in accord with the hypothesis that countries with moderate nominal exchange rate volatility will have more evidence of PPP than countries with high or low nominal exchange rate volatility.

There are (at least) two caveats to our results. Because the null hypothesis of the LLC test is that all of the series contain unit roots and the alternative hypothesis is that all of the series are stationary, it is possible to reject the unit root null with a mixed panel of stationary and nonstationary series.[13] The implication of this issue for our results is that, for example, we cannot conclude that PPP necessarily

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[13] Breuer, McNown, and Wallace (2001) discuss this issue.

holds for all 21 real exchange rates of the countries closest to the United States. Since, continuing with the same example, we are interested in how the evidence of PPP decreases as the distance of the countries from the United States increases, this does not affect the economic interpretation of the results.

Another issue is that the country characteristics are not necessarily independent. We first consider the three characteristics for which the strength of the evidence of PPP is monotonic or close to monotonic: distance, inflation, and openness. Using Spearman's rank correlation coefficient, the results in Table 3 show that the null hypothesis of no correlation can be rejected between openness and inflation, but not between distance and openness or between distance and inflation. Since more open economics have lower inflation, we cannot determine whether our results that the evidence of PPP is stronger for more open and lower inflation countries is caused by openness, inflation, or both. Since distance is not correlated with either openness or inflation, we can conclude that our result that the evidence of PPP is stronger for countries closer to the United States is not caused by either openness or inflation.

We proceed to consider the two characteristics, growth and nominal exchange rate volatility, for which the strength of the rejections is not monotonic. The null hypothesis of no correlation can be rejected between growth and volatility: countries with higher growth have lower nominal exchange rate volatility. We therefore cannot determine whether our results that the evidence of PPP is stronger for moderate growth and nominal exchange rate volatility countries than for either high or low growth and volatility countries is caused by growth, volatility, or both.

IV. Conclusions

Purchasing Power Parity is usually studied as an "all or nothing" proposition. Either the unit root hypothesis is rejected and evidence of PPP is found, or the unit root hypothesis is not rejected and evidence of PPP is not found. While this perspective is appropriate for investigating PPP among developed countries with similar characteristics, it is not appropriate for studying PPP among a more diverse group of developed and developing countries.

In this paper, we use panel unit root tests with the United States dollar as the numeraire currency to investigate PPP for a very diverse group of 84 developed and developing countries. First, using tests on

the entire panel, we show that it is not correct to conclude that PPP either holds or does not hold for all 84 countries. Second, we find that PPP holds for panels of European and Latin American countries, but not for panels of African and Asian countries. Third, and most importantly, we show that PPP depends on country characteristics in ways that are consistent with economic theory. The evidence of PPP is stronger for countries that are more open to trade, are closer to the United States, and have lower inflation. It is also stronger for countries that have growth rates of per capita real GDP similar to the United States and have moderate nominal exchange rate volatility.

Several of the country characteristics that we have associated with stronger evidence of PPP can be expected to further strengthen PPP in the future. Countries are becoming increasingly open to trade, and lower inflation has become almost a worldwide phenomenon. While countries are not moving closer to the United States, transport costs are decreasing. The number of countries with irrevocably fixed or flexible nominal exchange rates is increasing relative to those countries with fixed but adjustable nominal exchange rates, although the effect of this on PPP is not clear. If these trends continue, and especially if growth rates of developing countries converge to growth rates of developed countries, it would be expected that evidence PPP will increase over time.

References

Amara, J., Papell, D., 2005. Testing for purchasing power parity using stationary covariates. Forthcoming, Applied Financial Economics.

Balassa, B., 1964. The purchasing-power parity doctrine: a reappraisal. Journal of Political Economy 72, 584 -- 596.

Breuer, J., McNown, R., Wallace, M., 2001. Misleading inferences from panel unit root tests with an illustration from purchasing power parity. Review of International Economics, 9, 482 -- 493.

Campbell, J., Perron, P., 1991. Pitfalls and opportunities: What macroeconomists should know about unit roots. NBER Macroeconomics Annual, 141-- 201.

Cassel, G., 1922. Money and Foreign Exchange After 1914. The MacMillan Company, New York.

Cheung, Y., Lai, K., 2000. On cross-country differences in the persistence of real exchange rates. Journal of International Economics 50, 375 -- 397.

Dornbusch, R., Vogelsang, T., 1991. Real exchange rates and purchasing power parity. Trade Theory and Economic Reform: North, South and East, Essays in Honnor of Bela Balassa. Basil Blackwell, Cambridge, MA.

Elliott, G., Pesavento, E., 2004. Higher power tests for bilateral failure of PPP after 1973. Manuscript, Emory University.

Elliott, G., Rothenberg, T., Stock, J., 1996. Efficient tests for an autoregressive unit root. Econometrica 64, 813 -- 836.

Engel, C., 2000. Long-run PPP may not hold after all. Journal of International Economics 57, 243 -- 273.

Frankel, J., Rose, A., 1996. A panel project on purchasing power parity: mean reversion within and between countries. Journal of International Economics 40, 209 -- 224.

Hall, A., 1994. Testing for a unit root in time series with pretest data-based model selection. Journal of Business and Economic Statistics 12, 461 -- 470.

Higgins, M., Zakrajšek, E., 2000. Purchasing power parity: Three stakes through the heart of the unit root null. Manuscript, Federal Reserve Board.

Holmes, M., 2001. New evidence on real exchange rate stationarity and purchasing power parity in less developed countries. Journal of Macroeconomics 23, 601 -- 614.

Im, K., Pesaran, M. H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. Journal of Econometrics 115, 53 -- 74.

Jorion, P., Sweeney, R., 1996. Mean reversion in real exchange rates: evidence and implications for forecasting. Journal of International Money and Finance 15, 535 -- 550.

Kravis, I., Heston, A., Summers, R., 1978. International Comparisons of Real Product and Purchasing Power. Johns Hopkins University Press, Baltimore.

Levin, A., Lin, C. F., Chu, C. S. J., 2002. Unit root tests in panel data: asymptotic and finite-sample properties. Journal of Econometrics 108, 1 -- 24.

Ng, S., Perron, P., 1995. Unit root tests in ARMA models with data-dependent methods for the selection of the truncation lag. Journal of the American Statistical Association 90, 268 -- 281.

Obstfeld, M., 1993. Model trending real exchange rates. Center for International and Development Economics Working Paper C93-011, University of California at Berkeley.

O'Connell, P., 1998. The overvaluation of purchasing power parity. Journal of International Economics 44, 1 -- 19.

Oh, K.Y., 1996. Purchasing power parity and unit root tests using panel data. Journal of International Money and Finance 15, 405 -- 418.

Papell, D., 1997. Searching for stationarity: Purchasing power parity under the current float. Journal of International Economics 43, 313 -- 332.

Papell, D., 2005. The panel purchasing power parity puzzle. Forthcoming, Journal of Money, Credit, and Banking.

Papell, D., Theodoridis, H., 2001. The choice of numeraire currency in panel tests of purchasing power parity. Journal of Money, Credit, and Banking 33, 790 -- 803.

Phylaktis, K., Kassimatis, Y., 1994. Does the real exchange rate follow a random walk? The Pacific Basin perspective. Journal of International Money and Finance 13, 476 -- 495.

Rogoff, K., 1996. The purchasing power parity puzzle. Journal of Economic Literature 34, 647 -- 668.

Samuelson, P., 1964. Theoretical notes on trade problems. Review of Economics and Statistics 46, 145 -- 154.

Summers, R., Heston, A., 1991. The Penn World Table (Mark 5): An expanded set of international comparisons, 1950-1988. Quarterly Journal of Economics 106, 327 -- 368.

Wu, J., Wu S., 2001. Is purchasing power parity overvalued? Journal of Money, Credit, and Banking 33, 804 -- 812.

Table 1
Panel unit root tests of real exchange rates organized by geographic region

$$\Delta q_{jt} = \mu_j + \alpha q_{jt-1} + \sum_{i=1}^{k} c_{ji} \Delta q_{jt-1} + \varepsilon_{jt}$$

Country group	Number of countries	α	t-statistic	p-value	Critical values		
					1%	5%	10%
Levin, Lin and Chu (LLC) test							
All Countries	84	-0.014	-14.231	0.209	-16.125	-15.317	-14.856
Africa	19	-0.015	-5.937	0.360	-7.683	-7.119	-6.768
Latin America	25	-0.024	-10.412	0.001	-8.655	-8.028	-7.686
Europe	21	-0.023	-9.017	0.003	-7.801	-7.244	-6.892
Asia	16	-0.002	-1.461	0.999	-7.257	-6.629	-6.258
Asia - High Income	8	-0.011	-4.029	0.346	-5.764	-5.176	-4.836
Asia - Low Income	8	-0.000	-0.037	1.000	-5.628	-5.022	-4.702
Im, Pesaran and Shin (IPS) test							
All Countries	84		-1.780		-1.73	-1.67	-1.64

Notes: Africa includes Botswana, Burkina Faso, Burundi, Cameroon, Congo (Democratic Republic), Cote D'Ivoire, Ethiopia, Ghana, Kenya, Madagascar, Malta, Mauritius, Morocco, Niger, Nigeria, Senegal, Seychelles, South Africa and Swaziland. Latin America includes Argentina, Bahamas, Barbados, Bolivia, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Paraguay, Peru, St. Lucia, Suriname, Trinidad and Tobago, Uruguay and Venezuela. Europe includes Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and United Kingdom. High-income Asian countries are Fiji, Hong Kong, Japan, Malaysia, Korea, Taiwan, Thailand and Singapore. Low-income Asian countries are India, Myanmar, Nepal, Pakistan, Indonesia, Sri Lanka, Philippines and Samoa. Income is defined as per capita real GDP in terms of PPP-adjusted international dollars. In addition to the above countries, All Countries include Canada, Israel and Jordan. The LLC test has a null that all the real exchange rates in the panel have unit roots and an alternative hypothesis that all the real exchange rates in the panel are stationary. The IPS test has the same null as the LLC test but the alternative is that at least one of the real exchange rate in the panel is stationary. Unlike the LLC test, which assumes the same α for all countries, the IPS calculates α_j's for j countries. Hence, we do not report any α_j values. For the IPS test, the t-statistic is the t-bar statistic with the exact critical values given in Im, Pesaran and Shin (2003).

Table 2
Panel Unit root tests of real exchange rates organized by country characteristic

$$\Delta q_{jt} = \mu_j + \alpha q_{jt-1} + \sum_{i=1}^{k} c_{ji} \Delta q_{jt-1} + \varepsilon_{jt}$$

Country group	Number of countries	α	t-statistic	p-value
Openness				
Most open	21	-0.019	-8.251	0.013
More open	21	-0.023	-8.679	0.006
Less open	21	-0.018	-7.681	0.033
Least open	21	-0.003	-2.874	0.973
Distance				
Farthest to USA	21	-0.002	-1.644	0.999
Farther to USA	21	-0.012	-6.354	0.315
Nearer to USA	21	-0.017	-7.475	0.039
Nearest to USA	21	-0.025	-9.873	0.001
Growth				
Highest growth	21	-0.003	-2.892	0.997
Higher growth	21	-0.016	-7.483	0.036
Lower growth	21	-0.015	-7.705	0.039
Lowest growth	21	-0.016	-6.069	0.462
Inflation				
Highest inflation	21	-0.007	-4.409	0.949
Higher inflation	21	-0.015	-6.161	0.345
Lower inflation	21	-0.009	-5.773	0.532
Lowest inflation	21	-0.018	-8.156	0.008
Nominal Exchange rate Volatility				
Highest volatility	21	-0.019	-7.075	0.111
Higher volatility	21	-0.023	-8.967	0.002
Lower volatility	21	-0.017	-7.406	0.057
Lowest volatility	21	-0.004	-3.637	0.990

Notes: We measure openness using the average of merchandize exports plus merchandize imports divided by gross domestic product. We define distance as the square root of the average air miles between the country's capital city and Washington D. C. We calculate annual growth rate of per capital real GDP in terms of PPP-adjusted international dollars using the least square method described in World Development Report (2003). We measure inflation using the average annual change in CPI. We calculate average exchange rate volatility vis-à-vis the US dollar using the formula in Papell and Theodoridis (2001). We calculate critical values for each panel using Monte Carlo simulation. The average critical values are -8.096, -7.461 and -7.124 at the 1%, 5% and 10% significance levels respectively.

Table 3
Nonparametic tests of association among country characteristics
using Spearman's rank correlation coefficient

	Openness	Distance	Growth	Inflation	Exchange Rate Volatility
Openness		-0.040	0.189[*]	-0.368[***]	-0.306[***]
Distance			0.300[***]	-0.109	-0.055
Growth				-0.449[***]	-0.406[***]
Inflation					0.381[***]
Exchange rate volatility					

Notes: We measure openness using the average of merchandize exports plus merchandize imports divided by gross domestic product. Distance is defined as the square root of the average air miles between the country's capital city and Washington D. C. We calculate annual growth rate of per capital real GDP in terms of PPP-adjusted international dollars using the least square method described in World Development Report (2003). Inflation is calculated using the average annual change in CPI. We calculate average exchange rate volatility vis-à-vis the US dollar using the formula in Papell and Theodoridis (2001).