Forthcoming: *Journal of Money, Credit, and Banking*

The Choice of Numeraire Currency in Panel Tests of Purchasing Power Parity

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Revised: March 2000

We investigate the implications of the choice of numeraire currency on panel tests of Purchasing Power Parity under the current regime of flexible exchange rates by conducting panel unit root tests with twenty-one different base currencies. We show that the conditions necessary for numeraire irrelevancy are not supported empirically, and that the choice of numeraire currency can and does matter for PPP. The evidence of PPP is stronger for European than for non-European base currencies. Distance between the countries and volatility of the exchange rates are the most important determinants of the results.

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We thank Mardi Dungey, John Fahy, Peter Hartley, Nelson Mark, Adrian Pagan, two anonymous referees, and participants in seminars at the University of Miami, UCLA, University of Southern California, Federal Reserve Bank of New York, Federal Reserve Board, and the Southern Economic Association Meetings for helpful comments and discussions.

I. INTRODUCTION

When the Bretton Woods System ended in 1971, there was a widespread belief that short-run Purchasing Power Parity (PPP) would characterize movements in exchange rates. While high real exchange rate variability quickly shattered that belief, attention turned towards the question of whether PPP held in the long run. Testing for long-run PPP is closely related to investigating unit roots in real exchange rates. If the unit root hypothesis can be rejected, the real exchange rate is stationary and PPP is said to hold.

The most common way to test for PPP is to run Augmented-Dickey-Fuller (ADF) tests for unit roots in real exchange rates. When these tests are run using the dollar as the numeraire (or base) currency, the unit root hypothesis can be rejected only infrequently. One explanation comes from the low power of these tests with short time spans of data. Froot and Rogoff (1995), for example, show that if the real exchange rate follows a stationary AR(1) process, and the half life of a PPP deviation is three years, it would take 72 years of data to reject the unit root null using the 5% Dickey-Fuller critical value.

One response is to use long horizon data sets. Following Frankel (1986), researchers have used data that span up to two hundred years and generally find evidence of long-run PPP. The problem is that these studies use data from both fixed and floating exchange rate periods, and thus do not answer the initial question concerning the flexible exchange rate regime.

Another way of improving the power of unit root tests is by introducing cross-section variation. The evidence from panel unit root tests with the United States dollar as the numeraire currency and Consumer Price Indexes (CPI) for domestic and foreign prices has been mixed. Hakkio (1984) was unable to reject the random walk model with four exchange rates against the United States dollar and Abuaf and Jorion (1990) found only weak rejections using ten exchange rates. More recently, Jorion and Sweeney (1996), Wu (1996), and Frankel and Rose (1996) report stronger rejections. Papell (1997), accounting for serial correlation, finds strong evidence for PPP with monthly, but not with quarterly, data.

One of the most striking findings to come out of these panel tests is that the evidence of PPP is much stronger when the German mark, rather than the United States dollar, is used as the base currency. Jorion and Sweeney (1996), Papell (1997), and Papell and Theodoridis (1998), using CPIs, and Wei and Parsley (1995) and Canzoneri, Cumby, and Diba (1999), using tradable goods prices, all report stronger rejections of unit roots in real exchange rates with the mark as the numeraire.[1]

These findings have recently been questioned. Engel, Hendrickson, and Rogers (1997) observe that the elements of two (or more) panels of real exchange rates constructed from the same set of countries with different numeraires are linear combinations of each other. Since, if all elements of one panel are stationary, the elements of the other panel must be stationary, they argue that panel tests of PPP should be constructed to be invariant to the choice of numeraire currency.[2] O'Connell (1998a) shows that, under certain conditions, controlling for cross-sectional dependence in panel tests of PPP makes the choice of numeraire currency irrelevant. O'Connell's results, however, are only valid if there is no serial correlation or if the serial correlation properties

[1] Edison, Gagnon and Melick (1997) report similar findings with univariate tests.

[2] The alternative hypothesis in most panel unit root tests, however, is that at least one element of the panel, rather than all elements of the panel, are stationary.

of each real exchange rate are assumed to be the same. In the absence of these restrictions, the choice of numeraire currency can matter to the evidence of PPP.

With quarterly data from 1973 to 1996 for industrialized countries, we construct 21 panels of real exchange rates from nominal exchange rates and national consumer price indexes, while using the currency of each country as the numeraire.[3] We show that the restrictions necessary to produce numeraire irrelevancy are not supported empirically. Furthermore, we show that, not only *can* the choice of numeraire currency matter to the evidence of PPP, it *does* matter. The evidence against the unit root hypothesis is much stronger for European than for non-European base currencies. These results generalize previous studies that show that the evidence for PPP is stronger when the German mark, rather than the United States dollar, is used as the numeraire.

We proceed to investigate whether we can find an economic explanation for our results. Three reasons are generally cited for why PPP holds better with the mark as the numeraire. The German mark is less volatile than the United States dollar (volatility), the geographical proximity of European countries makes goods arbitrage more effective since transaction costs are low (distance), and trade is a much larger fraction of GDP for European countries than for the United States (openness). With two data points, there is no hope for choosing among these three explanations.

We then construct measures of volatility, distance, and openness. Considered informally, all three appear to be consistent with the relative strength of the evidence of PPP with the mark, rather than the dollar, as the numeraire. More formal analysis,

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[3] We use quarterly data because, in Papell (1997), the unit root null could be rejected with monthly data with both the dollar and the mark as numeraire.

however, shows that distance and, to a lesser extent, volatility are significant determinants of the strength of the evidence against unit roots in real exchange rates while openness to trade is insignificant.

This paper is organized as follows: In Section II, we describe the data and give the results of univariate ADF tests for unit roots in real exchange rates with all currencies used as the numeraire. Section III presents the results of the panel unit root tests, with particular attention paid to the effects of accounting for serial correlation. In Section IV, we present measures of the volatility of the currencies, the distance between countries and the openness of the economies to international trade, and show how these three variables can explain the results in Section III. Conclusions are discussed in Section V.

II. UNIVARIATE TESTS

We use quarterly, nominal, end-of-period exchange rates and Consumer Price Indexes for industrialized countries, obtained from the International Monetary Fund's International Financial Statistics (CD-ROM for 6-97). There are twenty-three countries that are considered industrialized by the IMF. We do not use data for Iceland because of the existence of gaps in its CPI and for Luxembourg because it has a currency union with Belgium. The 21 remaining countries provide 20 real exchange rates for each of the base currencies. The data start in the first quarter of 1973 and end in the fourth quarter of 1996.

The real exchange rate is calculated as follows:

$$q = e - e^* + p^* - p \qquad (1)$$

where q is the logarithm of the real exchange rate, e is the logarithm of the nominal (dollar) exchange rate of the domestic country, e^* is the logarithm of the nominal (dollar) exchange rate of the country whose currency we use as the numeraire currency, p is the logarithm of the domestic Consumer Price Index, and p^* is the logarithm of the Consumer Price Index of the country whose currency we use as the numeraire currency.

We conduct Augmented- Dickey-Fuller (ADF) tests for all twenty-one numeraire currencies, and present the results in Table 1. The most rejections (seven out of twenty exchange rates at the 5% level) of the null hypothesis of a unit root are with the New Zealand dollar as the numeraire currency, followed by the French franc with five. The tests provide more rejections of the unit root null with the German mark (three) as the numeraire than with the U.S. dollar (one) or the Japanese yen (none). Overall, the ADF tests do not provide much strong support for long-run PPP. Except for New Zealand, the unit root null cannot be rejected, at the 5% level, for more than one-quarter of the real exchange rates for any of the 21 numeraire currencies.[4]

The univariate ADF tests display considerable evidence of serial correlation. We report the means, medians, and standard deviations of the values of k, selected by the recursive t-statistic procedure as described by Campbell and Perron (1991), for each of

[4] The ADF tests do, however, provide somewhat more weak support for PPP, with several additional rejections at the 10% level.

the countries in Table 1. These statistics illustrate two points. First, both the means and the medians are 3 or larger for 17 of the 21 countries, indicating the importance of accounting for serial correlation. Second, the standard deviations are quite large in relation to the possible values (0 to 8), indicating a wide range of serial correlation within the 20 real exchange rates for each numeraire currency.

III. PANEL UNIT ROOT TESTS

In response to the difficulty of rejecting the null hypothesis of a unit root in real exchange rates with the use of univariate ADF tests, researchers have turned to panel methods that exploit both cross-section and time series variation in the data. Panel unit root tests for non-trending data, which allow for both a heterogeneous intercept and heterogeneous serial correlation, can be conducted by estimating the following equations:

$$\Delta q_{jt} = m_j + a q_{jt-1} + \sum_{i=1}^{k} c_{ij} \Delta q_{jt-i} + e_{jt} \qquad (2)$$

where the subscript j indexes the countries, and μ_j denotes the heterogeneous intercept. We estimate equation (2) using feasible GLS (SUR) to account for contemporaneous correlation, with the values for k taken from the results of the univariate ADF tests. The null hypothesis of a unit root is rejected in favor of the alternative of level stationarity if α is significantly different from zero.[5]

[5] We do not include a time trend in equation (2) because such an inclusion would be theoretically inconsistent with long-run PPP.

These tests follow Levin, Lin, and Chu (1997) in restricting α to be equal across countries. Im, Peseran, and Shin (1997) develop tests where α can vary across countries. Based on the results of univariate ADF tests, this does not appear to be important for real exchange rates among industrialized countries.[6] Bowman (1999) shows that there is a loss of power of the IPS tests, relative to the LLC tests, when α is equal across members of the panel. He also shows that size adjusted power falls much faster for the LLC test than for the IPS test when only a subset of the members of a panel are stationary. Since rejection of the unit root null is normally interpreted as evidence that all real exchange rates are stationary, even though the alternative hypothesis of the tests is that at least one element is stationary, we view this as an advantage of the LLC tests.

O'Connell (1998a) has shown that, if there is no serial correlation or if both the lag lengths and the values of the c's are the same for each country, panel unit root tests of real exchange rates using GLS or FGLS are invariant to the choice of numeraire currency. With our methods, both the lag lengths and the c's are heterogeneous across the countries that comprise the panel, and the results can differ according to the choice of numeraire. Based on the means, medians, and standard deviations of the values of k from the univariate ADF tests, reported in Table 1, there appears to be considerable variation across the countries in each panel. This indicates that it would not be appropriate to restrict the lag lengths to be identical across countries.

Even if one is willing to impose identical lag lengths, numeraire invariance requires homogeneous (identical c's) serial correlation across countries. For each potential lag

[6] Univariate ADF tests on real exchange rates find the α's to be negative, but generally not significantly different from zero. If the α's are not significantly different from zero, it is not clear why they should be

length (2 - 8), we tested the null of homogeneous serial correlation against the alternative of heterogeneous serial correlation for panels with all 21 numeraire currencies. Using likelihood ratio tests, we could reject the homogeneous null against the heterogeneous alternative (at the 5 percent level) for at least 19 of the 21 panels at each lag length.[7]

We calculate critical values using Monte Carlo methods. For each of the 21 numeraire currencies, we fit univariate autoregressive (AR) models to the first differences of the 20 real exchange rates, treat the optimal estimated AR models as the true data generating processes for the errors in each of the series, and construct real exchange rate innovations from the residuals.[8] We then calculate the covariance matrix Σ of the innovations. For each of the 21 panels of 20 real exchange rate differences we use the optimal AR models with iid $N(0,\Sigma)$ innovations to construct pseudo samples of size equal to the actual size of our series (96 observations). Since Σ is not diagonal, this preserves the cross-sectional dependence found in the data. We then take partial sums so that the generated real exchange rates have a unit root by construction.

We proceed to perform the estimation procedure described above on the generated data. For each panel, we first estimate univariate ADF models for the 20 series, using the recursive t-statistic procedure to select the value of k. We then estimate equation (2) using feasible GLS (SUR), with the values for k taken from the results of the univariate ADF tests. Repeating the process 5000 times, the critical values for the finite sample

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significantly different from one another.

[7] For several panels (with different price indices) of real exchange rates for 15 industrialized countries, O'Connell (1998b) reports that, with equal lag lengths, heterogeneous serial correlation is selected over homogeneous serial correlation.

[8] We use the BIC to choose the optimal AR model. While it would be desirable to allow the first differences of the other real exchange rates to enter into the AR model, the size of the cross-section relative to the number of observations makes this infeasible.

distributions are taken from the sorted vector of the replicated statistics. A subset of the 21 sets of critical values are reported in Table 2, including the largest; New Zealand, smallest; Spain, and median; Italy, (at the 5 percent level), as well as those for Germany and the United States. We also report a set of critical values calculated using artificially generated data with iid $N(0,\sigma^2)$ innovations, where σ^2 is the estimated innovation variance of the optimal AR model. These critical values, which assume cross-sectional independence, are close to the median critical values from the 21 sets that incorporate cross-sectional dependence.[9]

The results of the panel unit root tests are reported in Table 2. Using the critical values that incorporate cross-sectional dependence, we can reject the null hypothesis of a unit root at the one percent significance level for the panels with the German mark, Italian lira, and the Norwegian krone as the numeraire currency. At the five percent significance level, we can also reject the unit root null for the panels with the Austrian schilling, Belgian franc, British pound, Danish krone, Dutch guilder, Finnish markka, French franc, Greek drachma, Irish pound, New Zealand dollar, Spanish peseta, Swedish krona and the Swiss franc as the numeraire currency. At the ten percent significance level, we can further reject the unit root null for panels with the Australian dollar and the Canadian dollar as the numeraire currency. We are unable to reject the null hypothesis for the real exchange rates that use the Japanese yen, Portuguese escudo and the United States dollar

[9] Papell (1997) shows that, for post-1973 real exchange rates, these critical values are very close to the critical values obtained from fitting an AR model to first-differences of the actual data (under the assumption of cross-sectional independence). O'Connell (1998a) and Higgins and Zakrajsek (1999) report that the distribution of the FGLS estimate of α is invariant to the degree of correlation between real exchange rate innovations. Both of these papers, however, impose homogeneous serial correlation.

as the numeraire currency.[10] The results are not particularly sensitive to whether or not the data generating process for the critical values incorporates contemporaneous correlation.[11]

We check the sensitivity of the results by performing the tests on panels of 19, 18, and 17 countries that sequentially eliminate the countries for which, according to the univariate tests, there is most evidence against the unit root null.[12] The p-values for the smaller panels are reported in Table 2. While, as would be expected both from exclusion of the most "stationary" element of the panels and from the loss of power by decreasing the size of the panels, the unit root rejections are weaker as the panels become smaller, the effect is gradual. It is clear that the evidence of PPP is not being driven by the inclusion of one or two stationary exchange rates.[13]

When we compare our results between the exchange rates that use the German mark as the numeraire currency and the exchange rates that use the United States dollar as the numeraire currency, we get results that are consistent with previous research. We can reject the unit root hypothesis at the 1 percent significance level when we use the German mark as the numeraire currency, while we are unable to reject the unit root null at the 10 percent level when we use the United States dollar as our numeraire currency.

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[10] We also estimated the model (and calculated critical values) for numeraire irrelevant panels with homogeneous serial correlation. The unit root null can be rejected at the 5% level with $k = 1$ to 4, can be rejected at the 10% level with $k = 1$ and $k = 8$, and cannot be rejected at the 10% level with $k = 5$ to 7.

[11] If we had used the critical values that imposed cross-sectional independence, the unit root null rejection levels would have fallen from 1 percent to 5 percent for Italy, fallen from 5 percent to 10 percent for Finland and Ireland, and risen from 5 percent to 1 percent for New Zealand.

[12] The critical values reflect the smaller size of the panels but do not incorporate cross-sectional dependence. Except for France and New Zealand, the panels with 17 countries do not include any real exchange rates for which the univariate rejections were significant at the 5% level.

[13] The only anomaly is for the Portuguese escudo, where the exclusion of the Austrian schilling to create a panel of 19 strengthens the rejection of the unit root null.

The panel unit root tests provide much more evidence of PPP when the European instead of the non-European currencies are used as the numeraire currency. At the 5 percent significance level, we can reject the unit root hypothesis for 15 out of 16 real exchange rates with European currencies as the numeraire currency, but can only reject the null for 1 out of 5 real exchange rates (New Zealand) with non-European currencies as the numeraire.

It may seem surprising (it certainly did to us) that the evidence of PPP is so strong much stronger for New Zealand than for Australia, two countries which are located a great distance away from most of the countries in the panel. We believe that the reason lies in New Zealand's exchange rate policies. New Zealand did not let its dollar float until March of 1985. For most of the period, it maintained a fixed exchange rate regime, with more or less frequent devaluations in response to inflation differentials with the countries to which it was pegged. From July 1979 - June 1982, it maintained a crawling peg policy that adjusted the nominal exchange rate on a monthly basis taking into account inflation differentials with its main trading partners. While these rules did not produce short-run PPP, they are consistent with achieving long-run PPP. Australia, in contrast, maintained a fixed trade-weighted nominal exchange rate until the early 1980s, and floated thereafter. [14]

IV. VOLATILITY, DISTANCE AND OPENNESS

Generalizing earlier work for the United States dollar and the German mark, we find that Purchasing Power Parity holds better for exchange rates that use European instead of non-European currencies as the numeraire currency. Previous researchers have offered three explanations for the stronger evidence of PPP with the mark than with the dollar, which are all potentially applicable to the European versus non-European results. First, because European countries limited nominal exchange rate movements among themselves in the 1980s much more than they limited movements versus the dollar, real exchange rate volatility for panels with European numeraires would be expected to be lower than for a panel with the dollar as numeraire. Since the power of unit root tests is inversely related to the volatility of the series, sharper results can be obtained by using currencies that are less volatile relative to each other. Second, the geographical proximity (distance) of European countries makes goods arbitrage more effective since transaction costs are lower. Third, European countries are more open than the United States to international trade.[15] In this section we attempt to differentiate among these explanations.[16]

The volatility of the exchange rate between two currencies can be calculated by the following:

$$VOLATILITY_{jk} = \sum_{t=1}^{T} \left| \frac{exchangerate_{t+1} - exchangerate_{t}}{exchangerate_{t}} \right| \div T \qquad (3)$$

where j denotes the country of the base currency, k denotes the country of any of the

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[14] Another factor that might contribute to achieving PPP for New Zealand is high labor mobility. Massey (1995) and Grimes (1996) discuss New Zealand's exchange rate policies.

[15] Jorion and Sweeney (1996) discuss the first two explanations.

[16] Since the strong evidence of PPP for New Zealand appears to be better explained by its exchange rate policies than by the above considerations, we exclude it from further analysis.

other nineteen currencies and T denotes the number of periods. This formula gives us the volatility of the exchange rate between two currencies (those of countries j and k) for the entire time period of our data.

The average volatility for the exchange rates of the base currency with all the other currencies can be calculated as follows:

$$VOLATILITY_{COUNTRYj} = \frac{\sum_{k=1}^{K} VOLATILITY_{jk}}{K} \quad (4)$$

where j denotes the country of the base currency and K denotes the countries of the other nineteen currencies. This gives us the average volatility of the exchange rates between the currency of country j and all the other currencies for the entire time period.

Our measure of distance is as follows:

$$DISTANCE_{COUNTRYj} = \sqrt{\sum_{k=1}^{K} DISTANCE_{jk}} \quad (5)$$

where j denotes the country of the base currency, K denotes the countries of the other nineteen currencies and $DISTANCE_{jk}$ denotes the air distance in statute miles between the capitals of countries j and k. This formula gives us the square root of the total air distance between the capital of the country whose currency we use as the base currency and the capitals of all the other countries in the panel.[17]

[17] We use the square root of the total air distance because it is unlikely that factors which might influence PPP, such as transport costs, would be affected linearly.

We use the following formula to measure openness:

$$OPENNESS_{COUNTRYj} = \frac{EXPORTS_{COUNTRYj} + IMPORTS_{COUNTRYj}}{GDP_{COUNTRYj}} \tag{6}$$

where j denotes the country of the base currency. This formula shows the ratio of trade (exports plus imports) to GDP for each of our countries in 1992. The data is from the International Monetary Fund's Direction of Trade Statistics and the International Financial Statistics Yearbook.

The measures of volatility, distance, and openness, as well as their rank orderings, are presented in Table 3. The measures of volatility, distance, and openness are not independent. According to Kendall's coefficient of concordance of the rank orderings, the null hypothesis that the variables are uncorrelated can be rejected for each pair at either the 5% or the 10% level and for all three at the 1% level.[18]

These measures help explain why we cannot reject unit roots in real exchange rates when we use the United States dollar and the Japanese yen as the base currencies. They are two of the four most volatile currencies, are two of the three countries which are further away from all the other countries, and are the two least open economies to international trade. They also help explain previous research which showed that long-run Purchasing Power Parity holds better when the German mark, instead of the United States dollar, is used as the base currency. The German mark is thirty-five percent less volatile than the United States dollar, the United States is more than twice as far away from the rest of the countries than Germany, and the ratio of exports plus imports to GDP is almost three times as large for Germany than for the United States.

In order to generalize our findings for panels with the dollar, mark, and yen as the numeraire currencies, we run regressions with one minus the p-value of the panel unit root tests as the dependent variable and the measures of distance, volatility, and openness as the independent variables. There are 20 observations (21 numeraire currencies minus New Zealand) and the p-values (for the panels of 20 countries) are reported in Table 2. The results are presented in Table 4. We would expect the dependent variable, which measures the strength of the evidence of PPP, to be positively related to openness and negatively related to volatility and distance. Considering each measure separately, all three variables have the expected signs, distance is significant at the 1% level, volatility is significant at the 5% level, but openness is not significant at even the 10% level. Evaluated two at a time, both distance and volatility have the expected sign and are significant (at the 1% and 5% levels, respectively) when paired with openness, but only distance is significant (at the 5% level) when paired with each other. When all three variables are included in the regression, only distance is significant (at the 5% level).[19]

The result that distance and, to a lesser extent, volatility are significant determinants of the t-statistics in the panel unit root tests can help explain why we get stronger results when we use European instead of non-European base currencies. Our panels consist mostly of European countries (16 out of 20) which are close to each other and thus have low transportation costs. The non-European currencies are also the four

[18] The computation of the coefficient of concordance and the test for significance are described in Kendall and Stuart (1977), p. 410-421.

most volatile currencies. Of the European countries, a number have limited nominal exchange rate variability among themselves since 1979 through the European Monetary System, which contributes to lower real exchange rate variability.

V. CONCLUSIONS

The purpose of this paper was to generalize previous work which found that evidence of Purchasing Power Parity from panel unit root tests of real exchange rates is stronger when the German mark, rather than the United States dollar, is used as the numeraire currency. Using quarterly data since the advent of generalized floating in 1973, we analyze panels of real exchange rates for industrialized countries with 21 different numeraire currencies.

Following O'Connell's (1998a) result that, with homogeneous serial correlation, panel unit root tests of real exchange rates using feasible GLS are invariant to the choice of numeraire, it is first necessary to ask whether this is a valid research question. We demonstrate that, since neither of the conditions necessary to achieve homogeneous serial correlation can be supported empirically, is important to account for heterogeneous serial correlation. Once heterogeneous serial correlation is modeled, panel unit root tests of PPP are no longer numeraire irrelevant.

With panel methods, we can reject unit roots in real exchange rates for 3 of the 21 numeraire currencies at the 1% level, for 13 more at the 5% level, and for 2 more at the 10% level. The German mark is included in the strongest rejection group, while the null cannot be rejected with either the United States dollar or the Japanese yen as numeraire.

[19] The decreased significance of distance and volatility when additional variables are included in the

While volatility, distance, and openness all appear to be consistent with the results for the dollar, mark, and yen, only distance and volatility are significant in more formal tests involving a wider range of countries.

Do the results in this paper increase or decrease the evidence of PPP that can be found by panel methods beyond what previous work has found with the dollar and the mark as numeraire? At first glance, the answer is obviously yes. Out of the 21 numeraire currencies, 18 exhibit significantly stronger rejections of the unit root null than is found with the dollar. But there is another perspective. Suppose we group the countries into Europe and non-Europe. The strength of the evidence of PPP in this paper comes from the fact that, of the 21 panels, 16 are with European currencies. Except for New Zealand, all of the strong (5% or higher) evidence of PPP comes from panels with European currencies as numeraire. The other panels with non-European numeraire currencies either display weak (Australia and Canada) or no (Japan and the United States) rejections.

Lothian (1998) has recently suggested that the difficulty of finding evidence of PPP with the United States dollar as the numeraire currency is caused by one episode, the large appreciation and subsequent depreciation of the dollar in the 1980s. Papell and Theodoridis (1998) support this view, showing that the evidence of PPP with the dollar as numeraire strengthens as the sample is extended past 1985, and suggest that we may see stronger evidence of PPP with a few more years of data. But perhaps we should end on a cautionary note. At least as of the time that this paper is being written, we can (except for New Zealand) find strong evidence of Purchasing Power Parity from panel unit root tests only with European numeraire currencies.

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regressions can be explained by the dependence among the variables.

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TABLE 1

REJECTIONS OF THE UNIT ROOT NULL WITH UNIVARIATE ADF TESTS

Numeraire	1%	5%	10%	Mean of k	Median of k	Standard Deviation of k
Australia	0	1	4	1.70	1.50	1.90
Austria	1	2	0	4.60	4.50	3.02
Belgium	0	2	1	4.10	4.00	2.79
Canada	0	1	1	5.30	7.00	2.83
Denmark	0	2	1	4.10	4.00	3.34
Finland	0	3	4	3.55	4.00	2.56
France	2	3	3	3.50	3.00	2.44
Germany	1	2	2	4.05	3.00	2.82
Greece	0	1	1	2.50	1.00	2.80
Ireland	0	1	1	4.10	4.50	3.35
Italy	0	0	4	4.35	6.50	3.66
Japan	0	0	4	4.95	5.00	2.42
Netherlands	1	1	3	3.95	4.00	3.07
New Zealand	0	7	4	4.35	3.00	3.38
Norway	0	1	2	3.80	4.50	2.98
Portugal	0	1	2	4.90	5.50	3.28
Spain	0	1	4	2.75	2.50	2.75
Sweden	0	2	4	3.75	4.00	2.88
Switzerland	1	2	2	2.35	1.00	2.30
United Kingdom	0	1	2	3.55	3.50	3.41
United States	0	1	2	4.65	4.00	2.64

Note: The entries denote the number of times, out of a maximum of 20, that the unit root null can be rejected at the various significance levels. The critical values are from MacKinnon (1991), adjusted for 96 observations.

TABLE 2

PANEL UNIT ROOT TESTS

Numeraire	a 20 countries	t-statistic 20 countries	p-value 20 countries	p-value 19 countries	p-value 18 countries	p-value 17 countries
Australia	-0.066	-7.853	0.099	.075	.064	.078
Austria	-0.069	-8.312	0.030	.049	.081	.113
Belgium	-0.069	-8.377	0.023	.043	.054	.053
Canada	-0.068	-7.922	0.064	.126	.151	.184
Denmark	-0.069	-8.303	0.029	.041	.062	.108
Finland	-0.068	-8.056	0.040	.065	.107	.109
France	-0.075	-8.331	0.023	.050	.042	.057
Germany	-0.073	-9.048	0.006	.013	.010	.015
Greece	-0.071	-8.270	0.039	.048	.035	.035
Ireland	-0.068	-8.099	0.039	.065	.123	.047
Italy	-0.075	-8.797	0.009	.018	.028	.042
Japan	-0.063	-7.335	0.129	.189	.186	.204
Netherlands	-0.070	-8.409	0.026	.039	.051	.059
New Zealand	-0.087	-9.064	0.012	.007	.010	.007
Norway	-0.085	-9.172	0.003	.012	.022	.031
Portugal	-0.064	-7.638	0.125	.049	.067	.080
Spain	-0.075	-8.521	0.011	.027	.042	.072
Sweden	-0.075	-8.505	0.041	.017	.026	.022
Switzerland	-0.085	-8.254	0.039	.030	.040	.071
United Kingdom	-0.077	-8.551	0.011	.025	.042	.070
United States	-0.065	-7.614	0.114	.127	.161	.237

SELECTED CRITICAL VALUES (For Panels of 20 Countries)

Country	One Percent	Five Percent	Ten Percent
Germany	-8.847	-8.099	-7.730
Italy	-8.741	-8.043	-7.674
New Zealand	-9.145	-8.349	-7.973
Spain	-8.575	-7.860	-7.509
United States	-8.792	-8.075	-7.695
Independent Errors	-8.808	-8.124	-7.720

TABLE 3

DATA FOR VOLATILITY, DISTANCE AND OPENNESS

Numeraire	Volatility	Rank	Distance	Rank	Openness	Rank
Australia	4.711	19	430.784	20	0.346	18
Austria	2.875	3	188.255	8	0.796	4
Belgium	2.865	2	179.365	1	1.435	1
Canada	4.541	18	276.159	17	0.508	12
Denmark	2.884	5	183.246	4	0.656	8
Finland	3.195	9	196.298	13	0.476	13
France	2.843	1	183.284	5	0.451	14
Germany	2.876	4	182.888	3	0.616	9
Greece	3.572	14	213.258	16	0.449	15
Ireland	3.034	8	189.555	10	1.141	2
Italy	3.289	11	195.581	12	0.384	16
Japan	4.292	16	334.063	19	0.209	20
Netherlands	2.885	6	180.527	2	1.037	3
Norway	2.924	7	188.544	9	0.748	5
Portugal	3.393	12	209.559	15	0.669	7
Spain	3.466	13	201.107	14	0.375	17
Sweden	3.286	10	189.847	11	0.595	10
Switzerland	5.136	20	184.280	7	0.728	6
United Kingdom	3.675	15	183.507	6	0.511	11
United States	4.357	17	286.059	18	0.214	19

Variables	Coefficient of Concordance	Significance
Volatility, Distance and Openness	0.775	1%
Volatility and Distance	0.864	5%
Volatility and Openness	0.772	10%
Distance and Openness	0.858	5%

TABLE 4

REGRESSIONS WITH DISTANCE, VOLATILITY, AND OPENNESS

Dependent Variable: One minus the p-value of the unit root tests (20 countries).

Distance		**Volatility**		**Openness**		**Adjusted R^2**
t-statistic	**p-value**	**t-statistic**	**p-value**	**t-statistic**	**p-value**	
-4.271	.000					.476
		-2.767	.013			.259
				1.643	.118	.082
-2.739	.014	-0.590	.563			.456
-3.573	.002			0.014	.989	.445
		-2.118	.049	0.578	.571	.231
-2.576	.020	-0.583	.563	-0.111	.913	.422

Note: The p-value is the marginal significance level of a (two-tailed) test for a zero coefficient, using a t-distribution with 20 observations (adjusted for degrees of freedom). A constant is included in the regressions.