Review of International Economics, 15(1), 1–16, 2007
DOI:10.1111/j.1467-9396.2007.00631.x

Convergence to Purchasing Power Parity at the Commencement of the Euro*

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Abstract

We investigate convergence towards purchasing power parity (PPP) within the eurozone and between the eurozone and its main partners using panel data methods. We find strong rejections of the unit-root hypothesis, and therefore evidence of PPP, in the eurozone for different *numéraire* currencies, as well as in the eurozone plus the United States with the dollar as the *numéraire* currency, starting between 1996 and 1999. The process of convergence towards PPP, however, begins earlier, following the currency crises of 1992 and 1993, adoption of the Maastricht Treaty, and official completion of the Single Market.

1. Introduction

The European Union's (EU) efforts towards monetary and economic stabilization culminated with the commencement of the euro in January 1999. But, as in the academic sense, the "commencement" involved an end as well as a beginning. Since the abandonment of the Bretton Woods system in 1971, the EU tried several alternatives (the "Snake" and the European Monetary System) before reaching its goal. As delineated by the Treaty of Maastricht, membership in the euro required the achievement of five criteria, including inflation convergence and nominal exchange rate stability within its member states.

The purchasing power parity (PPP) hypothesis considers a proportional relation between the nominal exchange rate and the relative price ratio, which implies that the real exchange rate reverts to a constant level over time. The most common way to test for PPP consists in investigating unit roots in real exchange rates. If the unit root can be rejected in favor of level stationarity, then deviations from parity are temporary and PPP is said to hold in long run. The literature on testing for PPP has become voluminous in recent years.

Since inflation convergence plus nominal exchange rate stability implies real exchange rate convergence, the commencement of the euro created an almost ideal case study for the PPP hypothesis. While we would expect that, following the adoption of the euro, long-run PPP would hold within the eurozone, issues involving the transition to the euro are not so obvious. Did PPP hold within the eurozone during the EMS period, or was there convergence to PPP? If there was convergence to PPP, did it occur following the Maastricht Treaty, the Single Market, at the time of the irrevocable fixing of exchange rates, or elsewhere? Does PPP, or a transition to PPP, hold between the eurozone countries and other European, industrialized, and negotiating countries?

The basic problem with testing for PPP in the post-Bretton Woods period is that the lack of power of univariate unit-root tests with 30 years of data makes the results

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obtained unreliable. Since extending the span of the data is not an option, Abuaf and Jorian (1990) and Levin et al. (2002) propose the use of panels to exploit the cross-sectional information.[1] The attraction of these tests is that they have good power with the time-series and cross-section dimensions of available data. Panel unit-root tests have been used to investigate the hypothesis of long-run PPP by Frankel and Rose (1996), Jorion and Sweeney (1996), McDonald (1996), Oh (1996), Wu (1996), and Papell (1997). More recent work—including O'Connell (1998), Taylor and Sarno (1998), Papell and Theodoridis (2001), and Wu and Wu (2001)—allows for contemporaneous correlation of real exchange rates under both the null and alternative hypotheses.

We investigate the behavior of real exchange rates, both within the euro area and between the euro area and a number of its trading partners, during the 1973–2001 post-Bretton Woods time period. We use a finite-sample panel unit-root procedure that accounts for country-specific serial correlation and data-specific contemporaneous correlation, assumes the same speed of mean reversion across countries under the alternative hypothesis, and allows for the results to change depending on the *numéraire* currency.[2] We generate critical values using Monte Carlo methods.

The central result of this paper is that there is a sharp distinction between finding statistical *evidence* of PPP and finding *convergence* towards PPP. Within the eurozone, strong rejections of unit roots in real exchange rates, and thus statistical evidence of PPP, starts to hold between 1996 and 1999 depending on the *numéraire* currency. The beginning of convergence, however, occurs in 1992 or 1993. While the achievement of PPP generally occurs after the actions taken by countries to satisfy the criteria for membership in the euro, the start of convergence towards PPP coincides with the Maastricht Treaty on European Union and the completion of the Single Market.

The above-cited factors, however, cannot completely account for the pattern of convergence towards PPP. The p-values of the panel unit-root tests fall dramatically for most of the countries during 1992 or 1993. Papell (2006) shows that the p-values of panel unit-root tests for PPP are very sensitive to the value of the data at the end of the sample. The outcome of the currency crises of 1992 and 1993 was to sharply move most of the real exchange rates towards their sample mean, thus quickly increasing the perceived evidence of PPP. While the p-values fall more slowly between 1994 and 1999, the evidence of PPP continues to strengthen by more than would be expected solely from increases in the sample size.

Our concept of convergence towards PPP has both a statistical and an economic interpretation. The statistical interpretation is straightforward. We define convergence to PPP as a fall in the p-values of the panel unit-root tests that subsequently lead to rejections of the unit-root null, even if the null cannot be rejected (at conventional significance levels) at the point of the fall. The economic interpretation is less straightforward. Before the currency crises of 1992 and 1993, there is no visual or econometric evidence of PPP among the members of the eurozone. Does this imply that real exchange rates were nonstationary during the pre-crises EMS period, and then suddenly became stationary? Since we do not know the counterfactual—what would have happened if the currency crises had not occurred—we cannot differentiate between a shift from a nonstationary to a stationary regime and a movement towards the long-run mean of the real exchange rate within a stationary regime.[3]

We also investigate PPP between the countries of the eurozone and a number of different countries, using the currency of the non-euro countries as the *numéraire*. The pattern between the United States and the euro countries closely follows the pattern among the euro countries, convergence starting in 1992 and achievement of PPP starting in 1997. While the pattern is the same, the reasons are very different and can be explained by the rise and fall of the dollar from 1980 to 1987. Among European countries that are not in the eurozone, only Denmark exhibits strong evidence of PPP, while Greece, Sweden, and the United Kingdom do not. Among the countries negotiating to join the euro, the strongest evidence of PPP is for Malta and Hungary.

2. The Euro

The Economic and Monetary Union (EMU) resulted from a long and slow process, starting in 1954 with the Treaty of Rome. We focus, however, on the last and most successful aspect, resulting in the advent of the euro. The Treaty of Maastricht in 1992 established the timetable of achievements, along with the five convergence criteria defining access to the single currency.[4] For the purpose of investigating the behavior of real exchange rates, the two most important criteria were that the rate of inflation for each country could not exceed the average rates of inflation of the three member states with the lowest inflation by more than 1.5% and that the national currency could not have been devalued during the two previous years and must have remained within the EMS 2.25% margin of fluctuation.

The member states had to achieve the economic convergence during a transitional period of four years, 1994 to 1998. In this effort of cohesion, the European Monetary Institute (EMI) was created to facilitate and reinforce the coordination of their monetary policies, to promote the use of the ECU (European Currency Unit) and to prepare for the creation of the European Central Bank (ECB).[5] Finally, in May 1998, the European Council defined the list of countries joining the new exchange rate mechanism (ERM II). Those are Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain. Greece joined the euro in January 2001. Exchange rates were fixed in January 1999, followed by circulation of the coins and notes in January 2002.

The almost 10 years of effort toward the establishment of the euro creates an unprecedented opportunity for PPP analysis. Since the euro resulted from preset nominal exchange rates and inflation convergence within the EMS, the long process towards its creation offers many candidates for both convergence and achievement of PPP. Three of these are 1992–93 with the implementation of the Single Market and the Treaty of Maastricht, 1997–98, when the criteria are observed, and 1999 with the switch from the semi-flexible to the fixed exchange rate regime.

3. The Model and Test Procedure

Let e and p be the nominal exchange rate and the consumer price index, respectively, of the studied country, and e^* and p^* be the nominal exchange rate and the consumer price index, respectively, of the country base. The real exchange rate q (in logarithms) is calculated as:

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

As stipulated earlier, PPP is said to hold if the process q does not contain any unit root, then the process is defined as stationary. For a single real exchange rate between two countries, we could test for PPP by using univariate augmented Dickey–Fuller (ADF) tests:

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

The null hypothesis of a unit root in the real exchange rate would be rejected in favor of the alternative hypothesis of level stationarity (PPP) if α is significantly less than 0. The problem with these tests is that they have low power for the span of post-Bretton Woods data.

One method to increase power is to exploit the cross-section dimension of the data. Suppose we have N real exchange rates. A panel version of the ADF test for the real exchange rate of country j at time t, q_{jt}, is defined by the following equation:

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

where $j = 1, \ldots, N$ indexes the countries, and $i = 1, \ldots, k$ the number of lags. We allow for heterogeneous intercepts (μ_j) and serial correlation ($\Sigma_{i=1}^{k} c_{ij} \Delta q_{jt-1}$). Equation (3) is estimated using feasible GLS (FGLS) to account for contemporaneous correlation with the lag length k set equal to the value chosen by univariate estimation—we use the recursive t-test procedure proposed by Campbell and Perron (1991) because of its size and power properties; see also Hall (1994) and Ng and Perron (1995).[6] Following Levin et al. (2002) (LLC), we restrict α to be equal across the countries and reject the null hypothesis of a unit root in favor of the alternative of level stationarity (PPP) if α is significantly less than zero.

Since the members of the eurozone are all industrialized countries with well-developed trade and financial linkages, we do not consider the maintained hypothesis of homogeneity to be as problematic as it would be in some other contexts.[7] Im et al. (2003) (IPS) allow α to be heterogeneous, in which case the alternative hypothesis is that at least one series in the panel is stationary. If the maintained hypothesis of homogeneity is correct, the LLC test has greater power than the IPS test if $\alpha < 0$ and both tests are correctly sized if $\alpha = 0$. If the maintained hypothesis of homogeneity is not correct, one possibility is that there is a mixed panel; some of the α's are less than 0 and some of the α's are equal to 0. In that case, the IPS test has greater power than the LLC test. The higher power of the IPS test for mixed panels, however, is a disadvantage for investigating PPP, which holds only if all of the real exchange rates in a panel are stationary. While both the LLC and the IPS tests reject the null too often for mixed panels when rejection is interpreted as evidence of PPP, the problem is worse for the IPS tests than for the LLC tests.[8]

We calculate critical values using Monte Carlo methods. First, we generate data-specific empirical distributions. For each panel and each span of data, we estimate the real exchange rate using univariate ADF tests. We treat the estimated parameters as true values, defining the data-generating process for the errors in each of the series. Then, using the residuals, we construct real exchange rate innovations and calculate the covariance matrix Σ, which allows us to produce pseudo-samples based on the estimated process with i.i.d. $N(0, \Sigma)$ innovations. The size of the generated samples equals the actual size of our series (from 88 to 166 observations). We then take partial sums so that the generated real exchange rates have a unit root by construction.

The finite-sample critical values are calculated from the generated data. Using the recursive t-statistic procedure with the univariate estimation, we define the number of lags (k) needed for each series. We estimate equation (3) 5000 times, sort the resultant t-statistics and deduce the critical values for each panel and for each time period that we consider. We analyze 23 panels constructed from five groups of countries. We also consider different periods of time, which implies a variation in the span of data from

88 to 166 observations. For each panel and time period, we need to generate a different set of critical values (around 450 sets in total).

Because of the number of panels and periods considered, we report our critical values as graphs instead of tables. We first illustrate the general behavior of the real exchange rates. Then, if convergence to PPP occurs, we focus on the last seven years of the period and offer a more detailed approach, plotting the *t*-statistics on α from estimating equation (3) and the 1%, 5%, and 10% critical values of the unit-root test.

4. Empirical Investigation

The Data

We use quarterly, nominal exchange rates in US dollars and consumer price indices for 23 countries from 1973(1) to 2001(4).[9] For the countries switching to the euro, we collect the nominal exchange rate currency by dollar from 1973 to 1998, then the euro by dollar exchange rate from 1999 to 2001 and convert in currency by dollar using the prefixed exchange rates.

Our analysis is based on the following groups:

- *Eurozone:* The member states as of 1998 are Austria, Belgium, Finland, France, Germany, Ireland, Italy, Netherlands, Portugal, and Spain. Luxembourg is excluded because of its currency union with Belgium.
- *Europe:* Greece, Denmark, Sweden, and United Kingdom. Greece is considered in the second category because it did not join the euro until 2000. The other three countries, while not part of the euro, belong to the European Union (EU).
- *Negotiating countries:* Cyprus, Hungary, and Poland started negotiating to become members in 1998 while Malta waited until 2000. Several aids were created to facilitate the economic and social transition of prospective member states and, in May 2004, these four countries were part of the EU enlargement.
- *Industrialized countries:* The United States and Japan are the two main trading partners of the European Union, while Switzerland is a direct neighbor of the eurozone.
- *Mediterranean countries:* Morocco and Turkey were included because geographical proximity, strong historical and cultural links, and the possibility of achieving a Euro-Mediterranean free-trade area by 2010 makes those countries important partners.

PPP within the Euro Zone

Since the abandonment of the Bretton Woods system of fixed exchange rates pegged to the US dollar in 1971, exchange rates and inflation stabilization have been policy goals of European countries. We focus on the post-Maastricht period of the European Monetary System (1992–97) and the advent of the single currency (1999–2001).

For the 10 countries in the eurozone, we conduct panel unit-root tests on the resultant nine real exchange rates, using each country's currency as a *numéraire*. For each panel, we first conduct a panel unit-root test for the period 1973(1) to 1980(1). We then add observations quarter-by-quarter, ending with the period 1973(1) to 2001(4). The critical values for the tests reflect both the increasing span of the data and the different *numéraire* currencies. The *p*-values from the unit-root tests from panels ending between 1980 and 2001 are graphed in Figure 1a and the Dickey–Fuller *t*-statistics and appropriate critical values are depicted in Figure 1b.

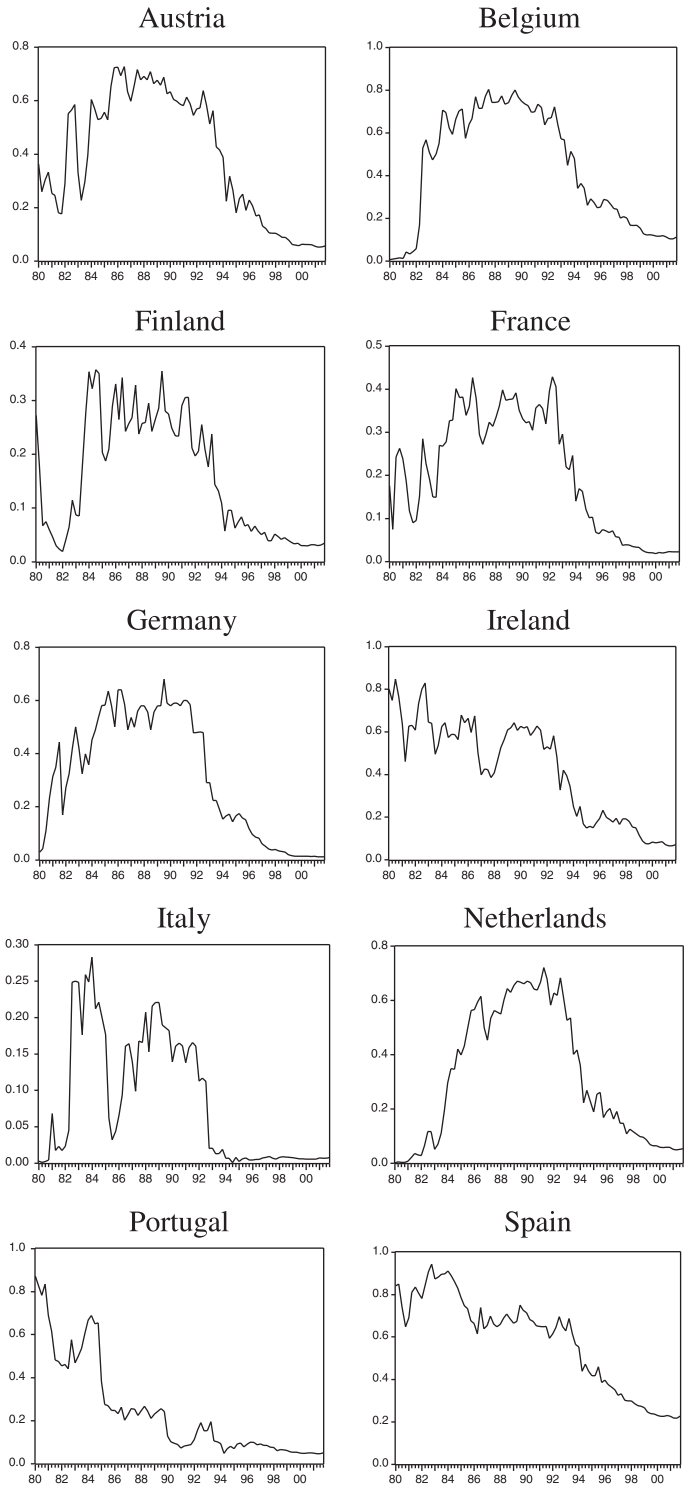

Figure 1a. Eurozone, p-Values

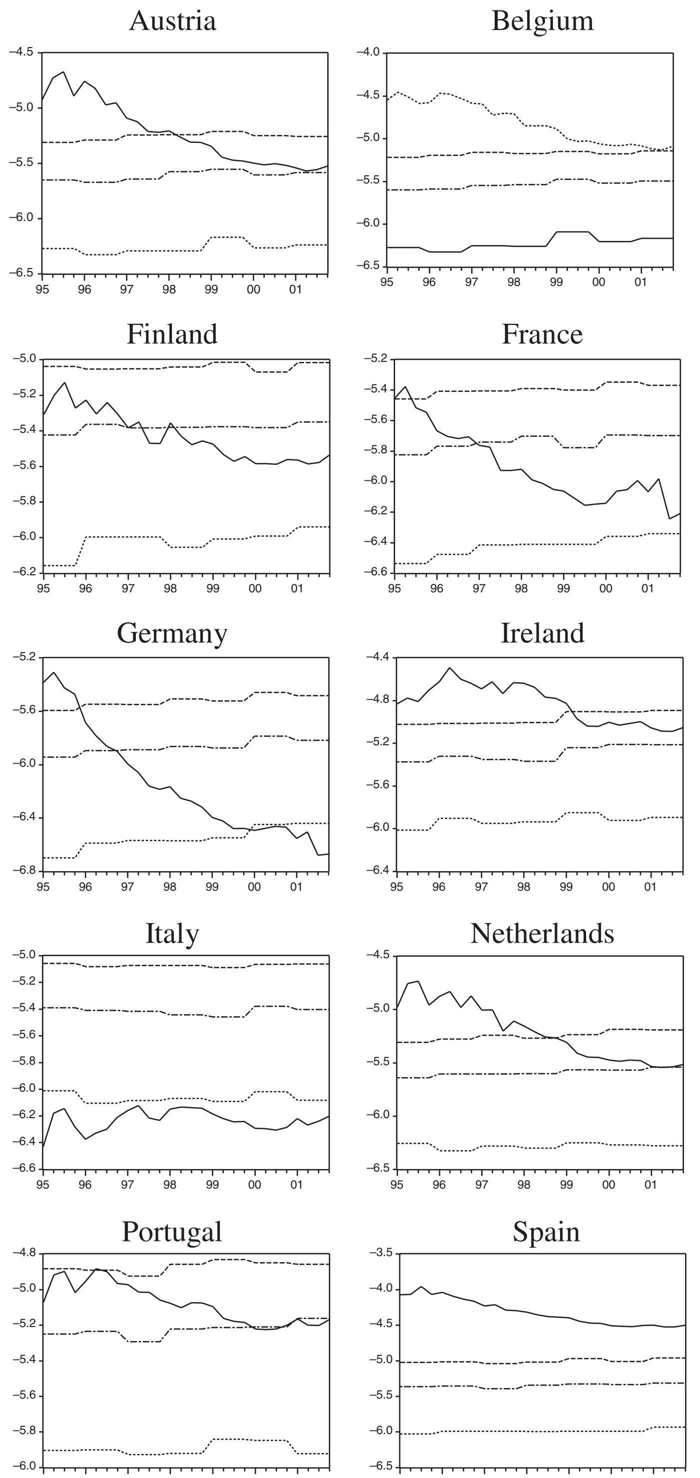

Figure 1b. Eurozone, DF Statistic, and 1%, 5%, 10% Critical Values

We obtain 10 graphs with a mostly common pattern. The years 1992 and 1993 symbolize the start of convergence towards PPP that leads (in most cases) to a strong rejection of the unit-root hypothesis. The statistical rejections themselves, however, mostly occur between 1996 and 1999. While the establishment of the convergence criteria (1992), the Single European Market (1993), and the year for achieving the criteria to join the euro (1997) are strongly associated with the convergence process, the "actual" switch to the irrevocably fixed regime (1999–2001) does not have a strong influence on the real exchange rate behavior. In most of the cases, PPP holds before this benchmark. This is consistent with the original vision for European Monetary Union: exchange rate and inflation stability followed by a single currency.

Strong evidence of convergence to PPP occurs with the three largest members of the eurozone, France, Germany, and Italy, as the *numéraire* currency. The results for France and Germany are remarkably similar. There is no evidence of PPP before 1992, with the *p*-values being over 0.40 at the start of that year. Beginning in 1992, there is rapid convergence to PPP, with significant rejections (at the 5% level) starting in 1996. For Italy, the process of convergence starts at the same time but is much more rapid, with significant rejections occurring as early as 1993.

The pattern of convergence extends to the smaller countries in the eurozone. Austria, Belgium, Finland, Ireland, Netherlands, Portugal, and Spain all start converging to PPP in 1992 or 1993. The final result, however, varies among the countries. Finland follows the pattern described above, with strong rejections starting in 1997. Austria, Netherlands, and Portugal do not achieve strong rejections until 2000 or 2001. Belgium and Ireland have weak rejections (at the 10% level) starting between 1999 and 2001. Finally, the unit-root null is never rejected for Spain.

What caused the pattern of convergence to PPP? We conjecture that the sharp fall in the *p*-values (1992 and 1993) was caused by the changes in nominal exchange rates in the aftermath of the EMS currency crises while the achievement of significant rejections (1996 to 1999) was caused by the continued process of integration and convergence towards the euro.

The average real exchange rates (with an appreciation depicted as an increase) are graphed in Figure 1c. We first focus on Germany. The Deutschmark depreciated (although not monotonically) during the 1980s and then sharply appreciated in 1992 and (especially) 1993. The depreciation in the 1980s is consistent with German inflation being low relative to the other future eurozone countries, with the inflation differentials not completely compensated for by nominal realignments. The appreciation in 1992 and 1993 is clearly caused by nominal exchange rate movements brought on by the currency crises. Papell (2006) shows that panel unit-root tests for PPP are very sensitive to the value of the real exchange rate at the end of the sample. When the data at the end of the sample are close to the value of the sample mean, there is strong evidence of PPP, and vice versa. While the German real exchange rate moved away from its sample mean during most of the 1980s, it jumped to about its sample mean during 1992 and 1993. This can explain both why the *p*-values of the panel unit-root tests, reported in Figure 1a, rose during the 1980s and then fell sharply during 1992 and 1993. Although there are some country-by-country differences, Figure 1c depicts a general pattern of movements away from PPP during the 1980s followed by sharp movements towards PPP in 1992 and 1993.

The pattern of convergence to PPP is not simply an artifact of increasing the sample size.[10] Papell (2006) shows that, if the real exchange rate is a stationary autoregressive process (calibrated to estimates of actual data), the *t*-statistics of panel unit-root tests will fall slowly (become more negative) as the sample size increases. In Figure 1b, it is

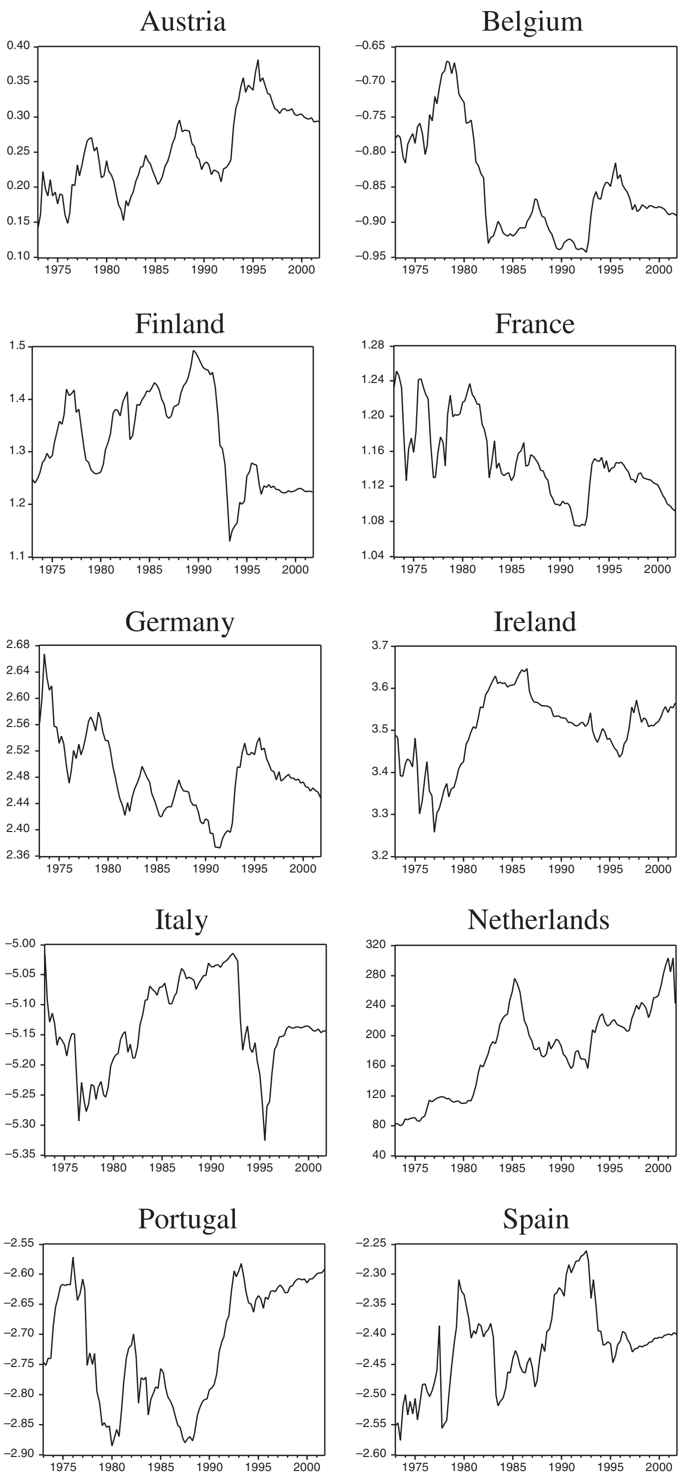

Figure 1c. Eurozone, Average Real Exchange Rates

shown that, as the sample size increases, the critical values will increase slowly (become less negative). It is extremely unlikely that a combination of slowly evolving t-statistics and critical values would produce the sharp drops in the p-values for 1992 and 1993 depicted in Figure 1a. It is also highly unlikely that the continued fall in the p-values between 1994 and 1999 is solely caused by increases in sample size. For example, the fall in the t-statistics reported for Germany in Figure 1b is an order of magnitude greater than the fall of the t-statistics for the simulated data reported in Papell (2006).

PPP between the Eurozone and Other Countries

We proceed to investigate the pattern of convergence to and achievement of PPP between members of the eurozone and a number of other countries. For each "external" country, we construct panels of 10 real exchange rates, with the currency of the external country being the *numéraire*. The results for several western European countries are depicted in Figures 2a and 2b. These countries were chosen because they all took part in at least one effort of stabilization of their real exchange rates with the eurozone countries (Snake, ERM or ERM II).

The pattern of convergence to PPP for Denmark mirrors that of the eurozone countries. The convergence process begins in 1993 and statistically significant rejections occur, starting in 1995. This should not be surprising since Denmark successfully took part in the EMU's two first stages but decided to opt out of the third stage. The United Kingdom, which decided not to join the EMU after the second stage, also displays convergence towards PPP starting in 1993. The evidence is weaker, however, with the only (weak) rejection occurring at the end of 2001. Sweden also displays convergence

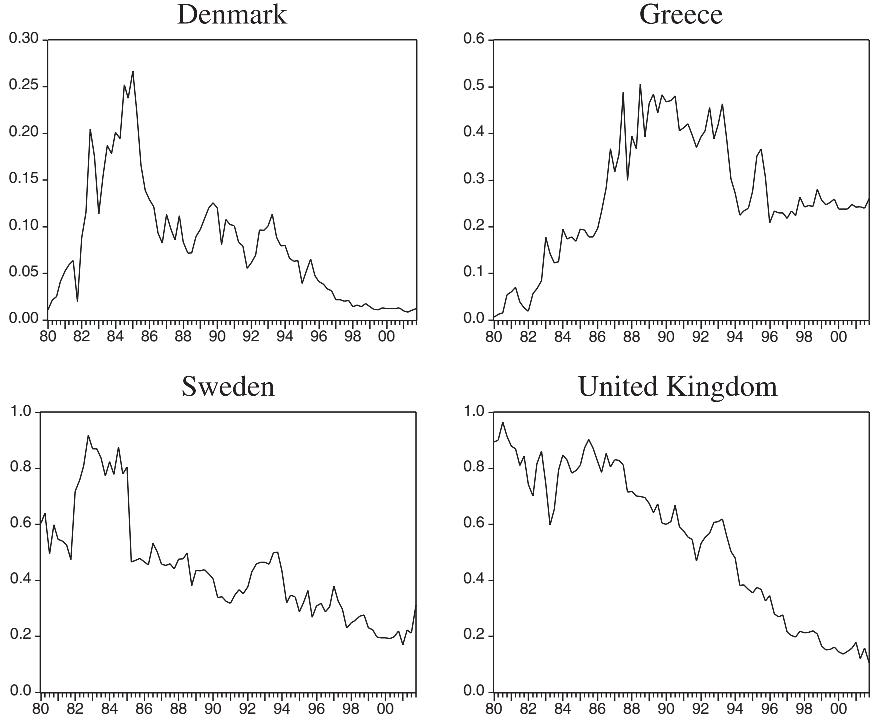

Figure 2a. Europe, p-Values

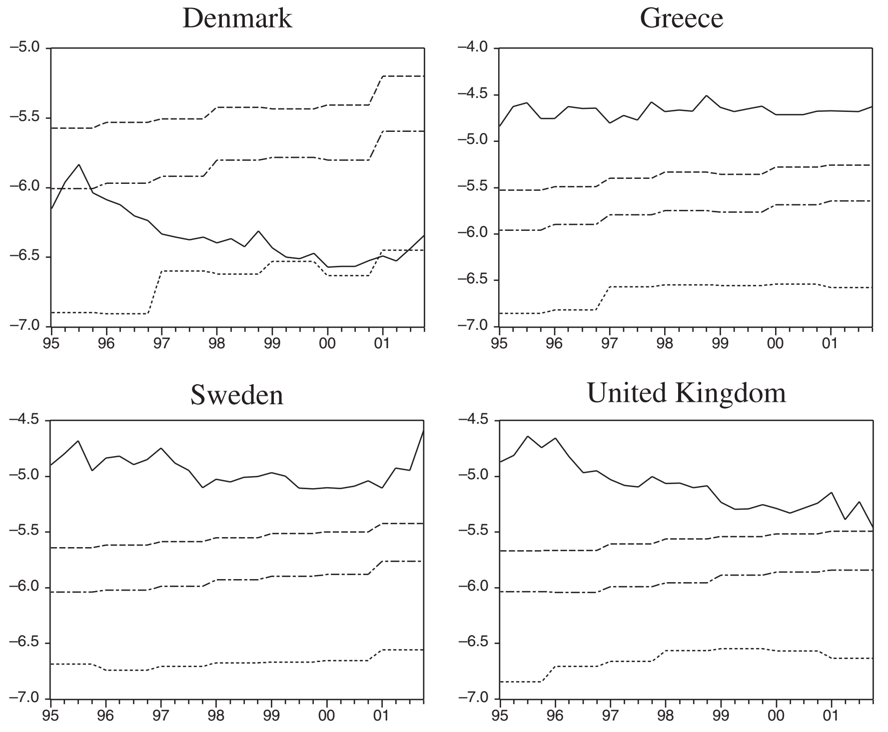

Figure 2b. Europe, DF Statistic, and 1%, 5%, 10% Critical Values

towards PPP starting in 1993, but the evidence never comes close to even a weak rejection of the unit-root hypothesis. Greece, which entered the eurozone in 2001, does not display evidence of either convergence towards or achievement of PPP.

At the time of writing, a number of countries are currently negotiating to join the eurozone. Based on availability of data, we focus on four successful candidates: Cyprus, Hungary, Malta, and Poland.[11] The results for these countries are illustrated in Figures 3a and 3b. Convergence towards PPP is observed for all four countries, with the convergence starting in 1992 or 1993 for Cyprus, Hungary, and Malta, and in 1995 for Poland. The end result, however, varies considerably among the countries. Strong evidence of PPP (rejections at the 5% level) is found for Hungary starting in 1996 and for Malta starting in 2000. Evidence of PPP is not found for Cyprus or Poland.

The evidence of convergence for several industrialized countries is depicted in Figures 4a and 4b. The pattern when the United States dollar is the *numéraire* currency mimics the pattern within the eurozone. The process of convergence to PPP starts in 1993 with a rejection of the unit-root hypothesis at the 5% level beginning in 1998. The reasons for the pattern of convergence to PPP between the United States and the eurozone, however, are very different than within the eurozone. As depicted in Figure 4c, because of the large appreciation and depreciation of the dollar in the 1980s, all real appreciations of the dollar from 1988 to 1999 represent movements towards the sample mean. The dollar appreciated sharply in 1993, coinciding with the sharp drop in the *p*-values, and appreciated again, starting in 1997. This is consistent with the evidence, described above, that panel unit-root tests for PPP are very sensitive to the value of the real exchange rate at the end of the sample.[12] The results for Japan

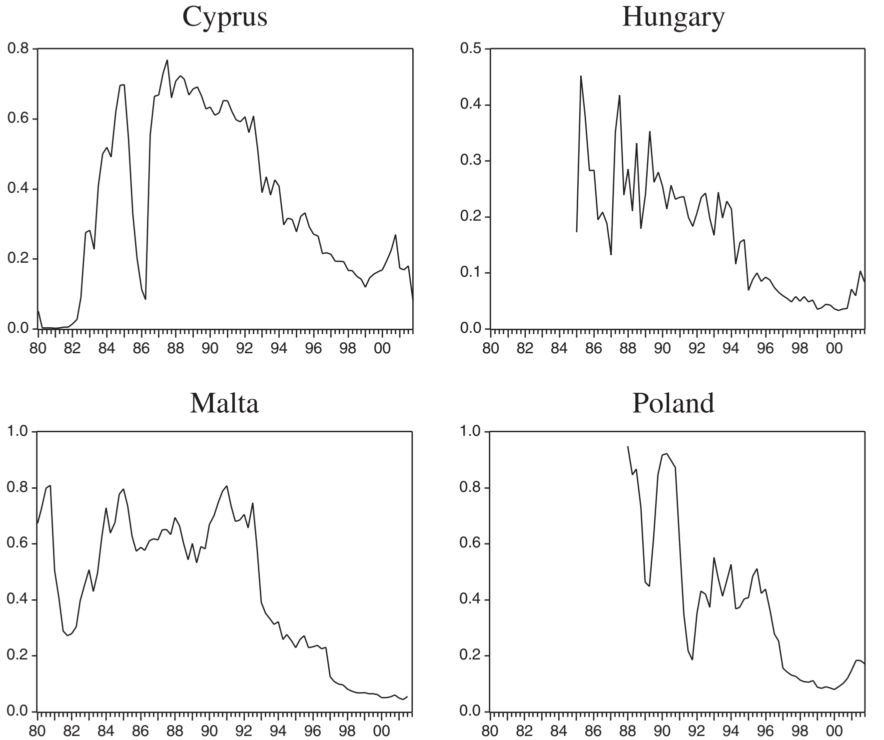

Figure 3a. Negotiating Countries, p-Values

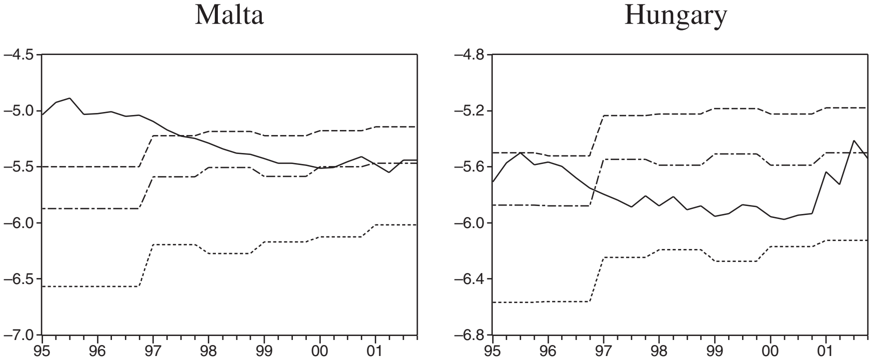

Figure 3b. Negotiating Countries, DF Statistic, and 1%, 5%, 10% Critical Values

and Switzerland are much weaker. Although convergence towards PPP appears to begin for both countries in 1995, there are no strong rejections of the unit-root hypothesis.

We also investigated convergence for two Mediterranean countries, Turkey and Morocco. The results for these countries are shown in Figure 5. Convergence towards PPP for Turkey starts around 1992 and begins to strengthen in 1996, coinciding with the start of its customs union with the EU. Convergence towards PPP for Morocco also begins in 1992. Neither country, however, displays strong rejections of the unit-root hypothesis.

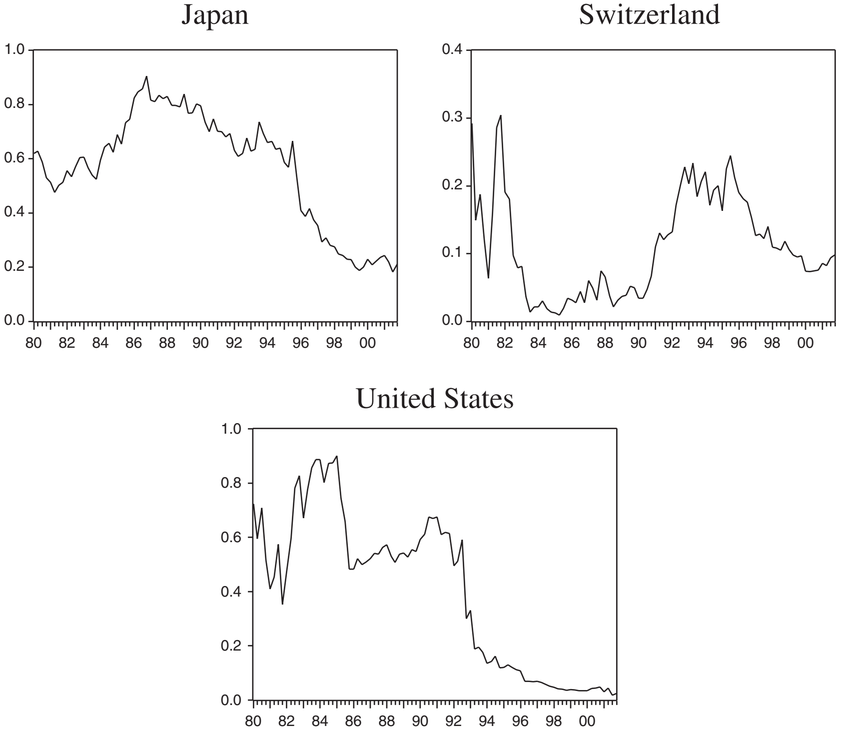

Figure 4a. Industrialized Countries, p-Values

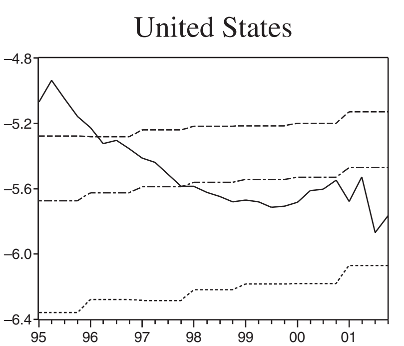

Figure 4b. Industrialized Countries, DF Statistic, and 1%, 5%, 10% Critical Values

5. Conclusions

The purpose of this paper is to analyze the impact of the euro on the purchasing power parity (PPP) hypothesis when analyzed within Europe and with its closest partners. We focus on two questions. First, is the evidence of PPP stronger within the eurozone than the evidence between the eurozone and a number of other countries? Secondly, did convergence to PPP occur with its adoption in 1999, or did the process start earlier?

The evidence of PPP is clearly stronger within the eurozone than between the eurozone and other European, negotiating, industrialized, and Mediterranean countries.

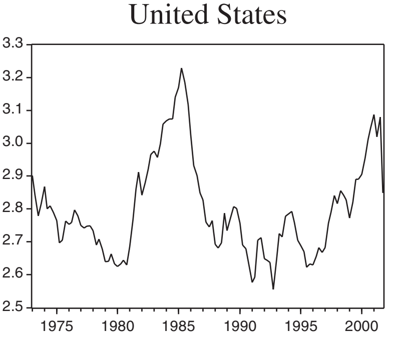

Figure 4c. Industrialized Countries, Average Real Exchange Rate

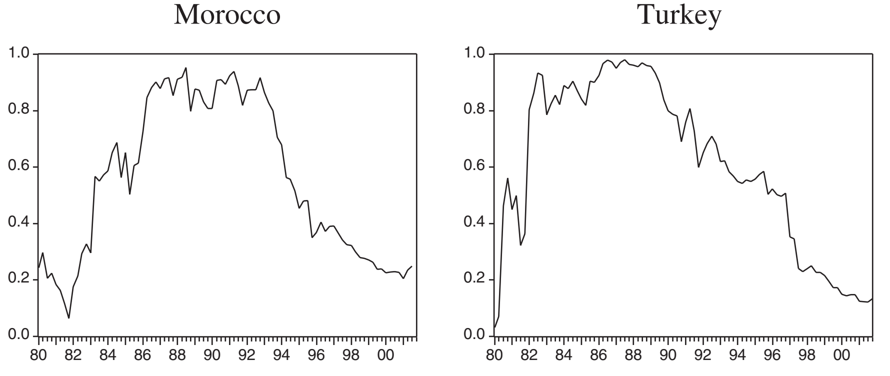

Figure 5. Mediterranean Countries, p-Values

Even within the eurozone, however, the choice of *numéraire* currency makes a considerable difference. The evidence of PPP is stronger for the largest countries in the eurozone, France, Germany, and Italy, than for the smaller members. There is one important exception, and that is the United States. The timing and strength of the evidence of PPP when the US dollar is the *numéraire* currency, strong rejections of the unit-root hypothesis starting in 1997, is typical for the panels that are comprised solely of eurozone countries.

Our other major result is that there is a sharp distinction between the start of convergence towards PPP and statistical evidence of PPP. Both within the eurozone and between the eurozone and other countries, strong rejections of the unit-root hypothesis, when they occur, generally start between 1996 and 1999. The process of convergence towards PPP, in contrast, begins earlier, generally in 1992 or 1993. We conclude that there has been a two-stage process of convergence towards PPP. The process started in 1992 and 1993 with the sharp changes in real exchange rates in the aftermath of the EMS currency crises, continued with the adoption of the Maastricht Treaty and the official completion of the Single Market, and culminated, in the form of statistically significant evidence, with the achievement of convergence criteria in 1997 and 1998 and the adoption of the euro in 1999.

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Notes

1. Another promising alternative is to use stationary covariates, as in Elliott and Pesavento (2006).

2. Papell and Theodoridis (2001) discuss the rationale for the latter two assumptions.
3. Test for structural change with multiple unknown break-points, as in Bai and Perron (1998) and Bai (1999), cannot answer this question because they identify changes in the intercept and/or slope of a series assuming regime-wise trend stationarity, not changes from a stationary to a non-stationary series.
4. The other three criteria were: (i) long-term interest rates shall not vary by more than 2% in relation to the average interest rates of the three member states with the lowest interest rates; (ii) national budget deficits must be close to or below 3% of GNP; and (iii) public debt may exceed 60% of GNP only if the trend is declining towards this level.
5. Created in 1999, the ECB is independent of national governments and manages the monetary policies of all the member states joining the single currency.
6. The maximum number of lags considered is $k_{\max} = 12$ with a selection at 10%.
7. Choi et al. (2006) do not reject homogeneity of α for an annual panel dataset of real exchange rates for 21 OECD countries from 1973 to 1998.
8. Bowman (1999) and Breuer Boucher et al. (2001) investigate these issues. It is also possible for homogeneity to be violated with all of the α's less than 0. In this case, the power of the IPS test relative to the LLC test depends on the specific form of heterogeneity.
9. The source of the data is *International Financial Statistics*, CD-ROM for March 2002.
10. An alternative methodology would be to use rolling, rather than recursive, panel unit-root tests so that the sample size remains constant. The disadvantage of this procedure is that, while the recursive tests used in the paper are sensitive to the value of the real exchange rate at the end of the sample, the rolling tests are sensitive to its value at both the end and the beginning of the sample. While the use of a rolling window provides faster evidence of convergence to PPP, the estimates are unstable and are very sensitive to the size of the window.
11. Cyprus, Hungary, Malta, and Poland joined the EU in May 2004.
12. Papell (2006) finds a similar pattern of unit-root rejections for a panel of 21 industrialized countries with the United States dollar as the *numéraire* currency.