Purchasing Power Parity and the European Single Currency: Some New Evidence

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Abstract
The effect of the single currency on the Purchasing Power Parity (PPP) hypothesis is examined in this study. The latter parity for the 15 EU countries, vis a vis the US dollar, before and after the advent of the euro is investigated. For this reason we employ a recently developed nonlinear unit root test on the time series dimension. On the other hand, Pesaran's (2007) panel unit root test that takes into account cross sectional dependence is estimated. The results before and after the introduction of the single currency are presented and compared.

Keywords: Purchasing Power Parity, nonlinear unit roots, panel unit roots, heterogeneity

JEL: F31; F33; G15

Introduction

Purchasing Power Parity (PPP) is a theory which states that exchange rates between currencies are in equilibrium when their purchasing power is the same in each of the two countries. This means that the nominal exchange rate between two countries should be equal to the ratio of aggregate price levels between the two countries, namely:

$$S_t = \frac{P_t}{P_t^*}, \qquad (0.1)$$

where P_t denotes the aggregate price level in terms of the domestic currency at time t, P_t^* is the aggregate price level in terms of the foreign currency at time t and S_t is the nominal exchange rate expressed as the domestic price of the foreign currency at time t. When a country's domestic price level is increasing (i.e., a country experiences inflation), that country's exchange rate must depreciated in order to return to PPP. In logarithmic form we have:

$$s_t = p_t - p_t^* \qquad (0.2)$$

The basis for PPP is the "law of one price". In the absence of transportation and other transaction costs, competitive markets will equalize the price of an identical good in two countries when the prices are expressed in the same currency.

This concept of PPP is often termed "absolute PPP". "Relative PPP" is said to hold when the rate of depreciation of one currency relative to another is equal to the difference in aggregate price inflation between the two countries concerned. According to the relative PPP condition, we have in logarithmic form:

$$\hat{s}_t = \pi_t - \pi^*_t, \qquad (0.3)$$

where $\hat{s}_t = \left(S_{t+1} - S_t\right)/S_t$ is the growth rate of the nominal exchange rate, $\pi_t = \left(P_{t+1} - P_t\right)/P_t$ and $\pi^*_t = \left(P^*_{t+1} - P^*_t\right)/P^*_t$ are the domestic and foreign inflation rate, respectively.

If the nominal exchange rate is defined simply as the price of one currency in terms of another, then the real exchange rate Q_t is the nominal exchange rate adjusted for relative national price level differences, namely:

$$Q_t = S_t \left(\frac{P_t^*}{P_t} \right), \qquad (0.4)$$

where the ratio $\frac{P_t^*}{P_t}$ denotes the relative price level, i.e. the price in which domestic goods are traded for foreign goods. In logarithmic form, we have:

$$q_t \equiv s_t - p_t + p_t^* \qquad (0.5)$$

When PPP holds, the real exchange rate is a constant so that movements in the real exchange rate represent deviations from PPP. Hence, a discussion of the real exchange rate is tantamount to a discussion of PPP.

The empirical evidence on PPP is extremely large and PPP condition has been widely tested in the literature. According to Sarno and Taylor (2002), it is useful to separate the enormous empirical evidence on PPP into six different stages: the early empirical literature on PPP, tests of the random walk hypothesis for the real exchange rate and cointegration studies, long-span studies and panel data studies, in order to overcome the low power problem in testing for mean reversion in the real exchange rate and finally, studies employing nonlinear econometric techniques.

However, the empirical evidence on PPP concerning the European Economic and Monetary Union (EMU) is still scant. The purpose of this paper is to test the validity of the PPP hypothesis between the European Union and the USA in the past 4 decades and to examine whether the introduction of the new currency has affected the relationship, using recently developed nonlinear unit root tests, as well as panel unit root tests.

The organisation of the paper is as follows. Section 2 briefly develops some empirical evidence that has been shown in the literature. Section 3 describes the dataset and methodology used, while Section 4 discusses the results. Finally, Section 5 concludes.

Empirical Evidence

The influence of the European economic integration process on price convergence and the stationarity of real exchange rates has fuelled the interest of several authors in the last years. Koedijk et al. (2004), using the Augmented Dickey-Fuller (ADF) unit root test in the context of Seemingly Unrelated Regression (SUR) methodology, test the PPP hypothesis within the Euro Area. For this purpose they collect a dataset of consumer price index (CPI) and nominal exchange rates against the US dollar for 10 euro area countries for the period 1973-2003 and construct the real exchange rates using the German Mark as the numéraire currency. They provide evidence in favour of PPP, when a common mean reversion coefficient is assumed, while with different mean reversion coefficients they find evidence in support of PPP only for Belgium, Finland, France and Spain.

They also test the PPP hypothesis between the Euro Area, as a separate economic entity, and other major economies, such as UK, Canada, Denmark, Japan, Norway, Switzerland, Sweden and US, using the “synthetic” euro[1] up to December 1998. Evidence of PPP is only detected between the Euro Area and Switzerland, when heterogeneous mean reversion is assumed, while the assumption of homogeneous mean reversion presents evidence in favour of PPP for the full panel.

Finally, they assess the impact of the Maastricht Treaty and the introduction of the euro on the convergence toward PPP. They confirm that especially the former event had an important impact on the stationarity of real exchange rates in the Euro Area, since strong evidence in favour of PPP is detected after 1992.

Gadea et al. (2004), using the ADF procedure, as well as unit root tests with structural break, study the evolution of the US dollar real exchange rate vis a vis the EU currencies during the recent floating regime, before and after the birth of the euro, over the period 1974-2001. They argue that the omission of some structural breaks which affect the behaviour of the real exchange rates may cause the unit root hypothesis to be accepted, resulting the apparent lack of evidence in support of PPP and allow for three breaks; the first at the beginning of the 1980's, the second around 1985, while the third break appearing in 1996.

They split the period into two subperiods which reflect the pre and post-euro creation process, with 1997 the key year which marked the beginning of the process of monetary union. The economies considered are 14 EU Euro Area and non-Euro Area countries.

They find no evidence in favour of the PPP hypothesis when the whole period is considered; nevertheless, strong evidence of PPP is provided for the period prior to the transition to the euro for those currencies closely related to the German Mark, namely those of Austria, Belgium, Denmark, France and the Netherlands, when allowing for two changes in the mean. Thus, they consider that a weaker version or quasi long-run PPP holds.

Lopez and Papell (2007) claim that the choice of the numéraire currency plays an important role on the evidence of PPP. They use panel data on CPI and nominal exchange rates in US dollars for 23 countries from 1973 to 2001 and split the countries into 5 groups, namely the Eurozone, other Europe countries, negotiating countries, industrialized countries and Mediterranean countries. The methodology they use is a panel version of the ADF test with country-specific intercepts and serial correlation structures.

They find strong evidence of convergence to PPP within the Eurozone, with the three largest members, France, Germany and Italy, as the numéraire currency, but they find no evidence of PPP before 1992; however, there is rapid convergence to PPP, starting in 1996. Moreover, they test the PPP hypothesis between the Eurozone and the other countries, but the evidence is weaker. When the US dollar is used as the numéraire currency, however, strong evidence of PPP is provided,

[1] The synthetic euro consists of the exchange rates of the euro legacy currencies, which are geometrically weighted together using trade weights.

with the process of convergence starting in 1993 and a rejection of the unit root hypothesis beginning in 1998.

Dwyer et al. (2007), on the other hand, find evidence not supportive of PPP within the Eurozone, using data of real exchange rates for eleven countries, from 1957 to 2005, with Germany being the numéraire country. Using univariate, as well as panel unit root tests, such as the standard ADF test and the SUR methodology employed by Koedijk et al. (2004), there is scant support for PPP in the Euro Area. The unit root hypothesis is inconsistent with the data for half of the countries during the whole period, while there is even less support when they split the sample into two subperiods, namely from 1973 to 2005 and from 1993 to 2005.

In a Bayesian framework they test the probability of a unit root versus the probability of there not being a unit root and conclude that a unit root is less likely; in other words PPP receives support from these data.

Stronger support for PPP is provided by Zhou et al. (2008), using the nonlinear unit root test proposed by Kapetanios et. al (2003) to the bilateral real exchange rates of both European and other industrial countries, with the French franc and German mark (and the euro after 1998), as well as the US dollar as numéraire currencies. They suggest that convergence toward PPP between the EU countries, especially the Euro Area countries, tends to be nonlinear, because of factors such as transportation costs and trade barriers, as well as official interventions in the foreign exchange market. Using two sample periods, 1975-1998 and 1975-2006, they test whether the adoption of the euro has contributed to PPP to hold better.

Their results show that, during the first period, there is evidence of PPP for most of the counties, by either the linear or the nonlinear tests. As far as the second period is concerned, the evidence of PPP is even stronger, with the nonlinear tests showing more evidence to reject the null of nonstationarity, when the real exchange rates are expressed with respect to the currencies of France and Germany; however, when they are expressed with respect to the US dollar, the linear tests show more evidence to reject the null.

Overall, Zhou et al. (2008) suggest that PPP tends to hold well within the EU even before the adoption of the euro, while there is no evidence that the use of the euro has played an essential role for better performance of the PPP hypothesis within the Eurozone.

Data and Methodology

Data

The dataset used comprises period-ending nominal exchange rates against the US dollar, as well as consumer price indices (CPI) for the fifteen countries of the EU-15. The countries under consideration are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. Additionally to the twelve member states of the Eurozone, Denmark, Sweden and the UK were also considered, in order to test the impact of the euro outside the Euro Area.

All series are monthly and seasonally adjusted and the sample period spans from 1/1970 to 12/2007[2]. Two breakpoints are also considered, the first in 12/1991 and the second in 12/1998, in order to test whether the Treaty of Maastricht and the advent of the single currency have affected the relationship. CPI data are obtained from the OECD Economic Indicators, while nominal exchange rates data are obtained from the International Monetary Fund (IMF)'s International Financial Statistics. Summary statistics of the data are given in the Appendix.

For 1999-2007, the dollar exchange rates of the Euro Area countries are calculated by $s_i = s_{euro} + s_j$ where s_{euro} is the log of the euro price of a dollar and s_j is the log of a Eurozone country's currency conversion rate of a euro.

Methodology

For each country *i*, the bilateral real exchange rate with US dollar is defined as follows:

$$q_i = s_i - p_i + p_{us} , \qquad (2.1)$$

where q_i is the real exchange rate, s_i is country *i*'s currency price of a dollar, p_i and p_{us} are the price indices of country *i* and the US, respectively. All these variables are in their logarithmic form.

As mentioned above, if PPP holds perfectly, the real exchange rate is constant. This means that the process q_i does not contain any unit root, then the process is defined as stationary. Several unit root and stationarity tests were applied to the data, described below.

Univariate unit root tests

The Augmented Dickey-Fuller (1979) test [ADF]

First, the ADF test was applied to the real exchange rates. The ADF test is carried out by estimating the following equation:

$$\Delta q_t = \alpha + \eta t + \delta q_{t-1} + \sum_{i=1}^{p} \beta_i \Delta q_{t-i} + \varepsilon_t , \qquad (2.2)$$

where $\delta=\beta$-1, t is the time or trend variable and the p augmentations are used to correct for correlation up to order p in the series. The null and alternative hypotheses may be written as:

$$H_0: \ \delta = 0$$
$$H_A: \ \delta < 0,$$

while under the null, there is a unit root. The null hypothesis is evaluated using the conventional t-ratio for δ:

$$t_\delta = \frac{\hat{\delta}}{se\left(\hat{\delta}\right)} , \qquad (2.3)$$

where $\hat{\delta}$ is the estimate of δ and $se\left(\hat{\delta}\right)$ is the coefficient standard error.

The Kapetanios, Shin and Snell (2003) test [KSS]

A nonlinear unit root test, proposed by Kapetanios et. al (2003) and employed by Zhou et al. (2008), was also applied to the real exchange rates. KSS developed a new technique for the null hypothesis of a unit root against an alternative of nonlinear stationary smooth transition. Their test is based on the following exponential smooth transition autoregressive (ESTAR) specification:

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[2] The CPI data for Ireland exist only after 11/1975.

$$\Delta q_t = \gamma q_{t-1}\left[1-\exp\left\{-\theta q^2_{t-1}\right\}\right]+\varepsilon_t, \quad \theta \geq 0 \tag{2.4}$$

where q_t is the series of real exchange rates and $\left[1-\exp\left\{-\theta q^2_{t-1}\right\}\right]$ is the exponential transition function adopted in the test to present the nonlinear adjustment. The null hypothesis of a unit root in q_t implies that $\theta = 0$, hence we test

$$H_0: \theta = 0$$

against the alternative

$$H_A: \theta > 0$$

Because γ in equation (2.4) is not identified under the null, we cannot directly test H_0: $\theta = 0$. To deal with this issue, KSS suggest reparametrize equation (2.4) by computing a first-order Taylor series approximation to specification (2.4) to obtain the auxiliary regression:

$$\Delta q_t = \delta q^3_{t-1} + \varepsilon_t \tag{2.5}$$

Assuming a more general case where the errors are serially correlated, regression (2.5) is extended to:

$$\Delta q_t = \sum_{j=1}^{p} \rho_j \Delta q_{t-j} + \delta q^3_{t-1} + \varepsilon_t \tag{2.6}$$

with the p augmentations, which are used to correct for serially correlated errors. The null hypothesis of nonstationarity to be tested with either equation (2.5) or (2.6) is:

$$H_0: \delta = 0$$

against the alternative

$$H_A: \delta < 0$$

and the t-statistic is

$$t_{NL} = \frac{\hat{\delta}}{se\left(\hat{\delta}\right)} \tag{2.7}$$

KSS show that the t_{NL} statistic does not have an asymptotic standard normal distribution. They tabulate the asymptotic critical values of the t_{NL} statistics via stochastic simulations.

To accommodate stochastic processes with nonzero means and/or linear deterministic trends, KSS modify the data as follows. In the case where the data has nonzero mean they use the de-meaned data, while for the case with nonzero mean and nonzero linear trend they use the de-meaned and de-trended data.

In this paper, t_{NL} statistics were estimated using regression (2.5), due to the fact that the optimal number of lags, according to the Schwarz Information Criterion (SIC), was zero. The maximum number of lags was set to 12, for the monthly data. To obtain the de-meaned or de-trended data, we first regress each series on a constant or on both a constant and a time trend, respectively, and then we save the residuals, which are used to carry out the test.

Panel unit root tests

Adding the cross-sectional dimension to the usual time dimension is very important in the context of nonstationary series, because it allows solving the low power issue of unit root tests in small samples. However, the issue of heterogeneity in the parameters is introduced, when using panel data instead of individual time series and this heterogeneity must be taken into account.

Three types of panel unit root and stationarity tests were applied to the real exchange rates. Such tests are the *Im, Pesaran and Shin* (2003) and the *Pesaran* (2007) panel unit root tests, as well as the *Hadri* (2000) panel stationarity test. With the exception of the *Hadri* (2000) test the other two tests employ the assumption of heterogeneity in the parameters.

The Im, Pesaran and Shin (2003) test [IPS]
The IPS test is based on:

$$\Delta q_{i,t} = \alpha_i + b_i q_{i,t-1} + \sum_{j=1}^{p_i} \phi_{i,j} \Delta q_{i,t-j} + X_{i,t}\delta_i + \varepsilon_{i,t} \qquad (2.8)$$

where i=1, 2,…, N cross-section units or series, that are observed over periods t=1, 2,…, T and $X_{i,t}$ represents the exogenous variables in the model, including any fixed effects or individual trends.

The null hypothesis of a unit root can be now defined as

$$H_0: b_i = 0, \text{ for all } i$$

against the alternative

$$H_A: b_i < 0 \text{ for } i = 1, 2, ..., N_0 \text{ and } b_i = 0 \text{ for } i = N_0+1, ..., N, \text{ with } 0 < N_0 \leq N.$$

The alternative hypothesis allows unit roots for some (but not all) of the individual. Therefore, the IPS test evaluates the null hypothesis that all the series contain a unit root against the alternative that some of the series are stationary.

After estimating the separate ADF regressions, the average of the t-statistics for b_i from the individual ADF regressions, $t_{iT_i}(p_i)$:

$$\bar{t}_{NT} = \frac{1}{N}\sum_{i=1}^{N} t_{iT_i}(p_i) \qquad (2.9)$$

is then adjusted to arrive at the desired test statistics. Under the assumption of cross-sectional independence, this statistic is shown to converge to a normal distribution. IPS propose a standardized statistic, denoted $W_{\bar{t}}$, which is based on the theoretical means and variances of $t_{iT_i}(p_i)$, $E(t_{iT_i})$ and $Var(t_{iT_i})$ respectively.

The Pesaran (2007) test [PES]
The IPS test assumes that the time series are independent across i. However, in many macroeconomic applications using country or regional data it is found that the time series are contemporaneously correlated. Pesaran (2007) relaxes the cross-sectional independence assumption and considers an one-factor model with heterogeneous loading factors for residuals and suggests augmenting the standard ADF regression with the cross-section averages of lagged levels and first differences of the individual series. The cross-sectional augmented ADF equation (CADF) is given by:

$$\Delta q_{i,t} = \alpha_i + b_i q_{i,t-1} + c_i \bar{q}_{t-1} + \sum_{j=0}^{p} d_{i,j} \Delta \bar{q}_{t-j} + \sum_{j=0}^{p} \delta_{i,j} \Delta q_{i,t-j} + e_{i,t} \qquad (2.10)$$

where $\bar{q}_{t-1} = N^{-1}\sum_{i=1}^{N} q_{i,t-1}$ and $\Delta\bar{q}_{t-1} = N^{-1}\sum_{i=1}^{N}\left(\bar{q}_t - \bar{q}_{t-1}\right)$. Let $t_i(N,T)$ be the t-statistic of the OLS estimate of b_i. The panel unit root tests are then based on the average of individual cross-sectionally augmented ADF statistics (CADF). PES builds a modified version of IPS $\bar{t}_{NT}$ test:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} t_i(N,T) \ . \qquad (2.11)$$

Pesaran proposes simulated critical values of CIPS for various sample sizes.

The Hadri (2000) test [HAD]

The HAD test is similar to the KPSS test (Kwiatkowski, Phillips, Schmidt and Shin, 1992) and has a null hypothesis of no unit root in any of the series in the panel. Like the KPSS test, the HAD test is based on the residuals from the individual OLS regressions of $q_{i,t}$ on a constant, or on a constant and a trend:

$$q_{i,t} = \alpha_i + \eta_i t + u_{i,t},\ u_{i,t} = \phi_i u_{i,t-1} + \varepsilon_{i,t} \qquad (2.12)$$

Assuming that $\varepsilon_{i,t}$ are I(0) for all i and that $\varepsilon_{i,t}$ are $i.i.d.(0, \sigma^2_\varepsilon)$ and cross-sectionally independent, the null hypothesis of the test is:

H_0: $|\varphi_i| < 1$, for all i

Given the residuals, the HAD test is defined by:

$$LM = \frac{1}{\hat{\sigma}_i^2 NT^2}\left(\sum_{i=1}^{N}\sum_{t=1}^{T} S^2_{i,t}\right), \qquad (2.13)$$

where $S_{i,t}$ is the partial sum of the residuals and $\hat{\sigma}_i^2$ is an estimate of the long run variance of $q_{i,t}$. HAD shows that under mild assumptions,

$$Z = \frac{\sqrt{N}\left(LM - \xi\right)}{\zeta} \rightarrow \mathrm{N}\left(0,1\right), \qquad (2.14)$$

where ξ=1/6 and ζ^2=1/45, if the model only includes constants and ξ=1/15 and ζ^2=11/6300 otherwise. Thus, we should use the right-hand tail of a standard normal distribution for critical values of Hadri's test.

Results

Time series tests

The present section provides the analytical results of all tests. All series have been tested at 5% and 10% level of significance.

Table 1: ADF unit root test

Sample	1970-2007		1970-1991		1992-2007		1970-1998		1999-2007	
Country	t^c	$t^@$	t^c	$t^@$	t^c	$t^@$	t^c	$t^@$	t^c	$t^@$
Austria	-2.175	-2.197	-1.638	-1.659	-1.463	-0.798	-2.160	-2.009	-0.271	-2.933
Belgium	-1.882	-1.886	-1.428	-1.436	-1.223	-0.810	-1.874	-1.807	-0.169	-2.855
Denmark	-2.091	-2.115	-1.535	-1.530	-1.292	-1.070	-2.084	-1.943	-0.300	-2.724
Finland	-2.005	-2.073	-1.443	-1.556	-2.341	-1.847	-2.073	-1.837	-0.480	-2.809
France	-2.099	-2.101	-1.612	-1.606	-1.337	-0.871	-2.140	-2.047	-0.330	-2.829
Germany	-2.165	-2.158	-1.657	-1.656	-1.286	-0.813	-2.139	-2.028	-0.413	-2.878
Greece	-1.434	-1.733	-1.341	-1.271	-0.769	-0.892	-1.818	-1.899	0.117	-2.677
Ireland	-1.597	-1.856	-1.378	-1.753	-0.778	-1.039	-2.251	-2.296	0.321	-2.920
Italy	-1.894	-1.937	-0.842	-1.131	-2.197	-1.904	-2.001	-1.996	-0.178	-2.860
Luxembourg	-1.826	-	-	-	-	-	-	-	-	-

		1.827	1.430	1.464	1.122	0.772	1.844	1.836	0.081	2.861
Netherlands	-2.290	-2.266	-1.831	-1.789	-1.225	-1.014	-2.306	-2.152	-0.264	-2.793
Portugal	-1.682	-1.983	-1.306	-1.349	-0.954	-0.959	-1.903	-1.895	0.008	-2.903
Spain	-1.900	-1.934	-1.012	-1.206	-1.473	-1.178	-2.099	-1.739	0.180	-2.830
Sweden	-1.714	-2.099	-1.042	-0.994	-2.422	-1.609	-1.645	-1.839	-0.818	-2.038
UK	-2.655*	-2.760	-1.669	-1.863	-2.424	-2.566	-2.445	-2.489	-0.841	-2.418
Average	**-1.961**	**-2.062**	**-1.411**	**-1.484**	**-1.487**	**-1.209**	**-2.052**	**-1.987**	**-0.234**	**-2.755**

***Notes:** The optimal lag length is based on SIC. * indicates rejection of the null hypothesis at 10% significance level. Superscript c denotes intercept in test equation, superscript @ denotes intercept and trend in test equation, 5% critical values t^{c}=-2.86, $t^{@}$=-3.41, 10% critical values t^{c}=-2.57, $t^{@}$=-3.13*

Table 1 shows the results of the ADF test, according to which the null hypothesis of a unit root is rejected only for the UK at 10% significance level, for the whole period and with the test equation being estimated only with an intercept. However, when a time trend is added, the test statistic becomes insignificant. In all other cases the PPP condition is not supported.

Table 2 shows the results of the KSS tests applied to the real exchange rates, for different sample periods. As it is obvious, with the exception of Italy and the UK, PPP does not hold for the full sample period, while for the period 1970-1991 PPP does not hold for any country. However, the test statistic becomes significant after 1992, rejecting the unit root hypothesis after the Treaty of Maastricht only in the case of Italy and the UK.

Table 2.A: KSS nonlinear unit root test

Sample		**1970-2007**	
Country	t_{NL}	t_{NL1}	t_{NL2}
Austria	-1.405	-2.137	-2.750
Belgium	-0.878	-2.353	-2.331
Denmark	-1.360	-2.194	-2.502
Finland	-1.063	-2.535	-2.594
France	-1.074	-2.404	-2.395
Germany	-1.659	-2.401	-2.434
Greece	-0.863	-1.703	-2.100
Ireland	-0.519	-1.887	-2.265
Italy	-0.604	-2.809*	-2.826
Luxembourg	-0.798	-2.359	-2.276
Netherlands	-1.838	-2.527	-2.586
Portugal	-1.315	-1.554	-2.122
Spain	-1.388	-2.069	-2.354
Sweden	-0.587	-2.187	-2.516
UK	-1.281	-3.149**	-2.878
Average	**-1.109**	**-2.285**	**-2.462**

***Notes:** t_{NL}, t_{NL1} and t_{NL2} refer to the model with the raw data, the de-meaned data and the de-trended data, respectively. **, * indicate rejection of the null hypothesis at 5% and 10% significance levels, respectively, 5% critical values t_{NL}=-2.22, t_{NL1}=-2.98 and t_{NL2}=-3.40, 10% critical values t_{NL}=-1.92, t_{NL1}=-2.66 and t_{NL2}=-3.13*

As far as the advent of the single currency is concerned, the KSS test is supportive of the PPP condition during the pre-euro period for Sweden and the UK; however, PPP is rejected after the introduction of the single currency. For all other countries, though, the test statistic fails to reject the null of a unit root either before, or after the introduction of the euro.

Table 2.B: KSS nonlinear unit root test

Sample	1970-1991			1992-2007		
Country	t_{NL}	t_{NL1}	t_{NL2}	t_{NL}	t_{NL1}	t_{NL2}
Austria	-1.456	-1.580	-1.988	-0.326	-2.042	-2.039
Belgium	-0.926	-1.781	-1.764	-0.212	-1.828	-1.905
Denmark	-1.355	-1.636	-1.828	-0.399	-2.394	-2.052
Finland	-1.497	-1.540	-1.504	-0.196	-2.053	-2.407
France	-1.104	-1.735	-1.716	-0.319	-1.784	-1.841
Germany	-1.403	-1.721	-1.750	-0.830	-2.096	-2.053
Greece	-0.704	-1.492	-1.604	-0.474	-0.695	-1.469
Ireland	-0.477	-1.512	-1.756	-0.380	-1.182	-1.626
Italy	-0.965	-1.165	-1.210	0.126	-3.122**	-2.947
Luxembourg	-0.785	-1.792	-1.725	-0.269	-1.690	-1.828
Netherlands	-1.620	-1.938	-1.980	-0.821	-2.035	-1.879
Portugal	-1.327	-1.231	-1.388	-0.358	-1.127	-2.223
Spain	-1.808	-1.368	-1.287	-0.049	-2.280	-2.310
Sweden	-1.109	-1.680	-1.135	0.079	-1.484	-2.423
UK	-0.592	-2.338	-2.155	-1.438	-3.451**	-3.208*
Average	**-1.142**	**-1.634**	**-1.653**	**-0.391**	**-1.951**	**-2.147**

Notes: see notes in Table 2A

Panel tests

The results of the panel tests are shown in Table 3. We see that when the homogeneity assumption is employed, the null hypothesis of stationarity is rejected in all cases, that is the HAD test rejects the PPP condition in all sample periods, while there is evidence in favour of PPP, according to the IPS and the PES tests. In particular, both reject the null of a unit root in all series for the whole period, showing evidence of PPP during the past 38 years.

Table 2.C: KSS nonlinear unit root test

Sample	1970-1998			1999-2007		
Country	t_{NL}	t_{NL1}	t_{NL2}	t_{NL}	t_{NL1}	t_{NL2}
Austria	-1.278	-1.943	-2.431	-0.567	-1.245	-1.292
Belgium	-0.670	-2.039	-2.027	-0.597	-1.264	-1.277
Denmark	-1.192	-1.959	-2.155	-0.639	-1.366	-1.354
Finland	-0.912	-2.377	-2.312	-0.551	-1.172	-1.219
France	-0.904	-2.083	-2.067	-0.576	-1.247	-1.261
Germany	-1.488	-2.067	-2.095	-0.782	-1.360	-1.342
Greece	-0.547	-1.729	-1.817	-0.747	-0.222	-1.138
Ireland	-1.411	-2.071	-2.422	0.831	-0.568	-1.139
Italy	-0.354	-2.479	-2.527	-0.584	-1.317	-1.287
Luxembourg	-0.537	-2.044	-1.987	-0.667	-1.220	-1.219
Netherlands	-1.667	-2.202	-2.243	-0.803	-1.432	-1.380
Portugal	-1.090	-1.607	-1.788	-0.739	0.038	-1.425
Spain	-1.109	-1.984	-2.046	-0.836	-0.577	-1.213
Sweden	-0.355	-2.814*	-2.452	-0.517	-0.733	-0.738
UK	-1.325	-2.915*	-2.643	-0.012	-0.901	-1.034
Average	**-0.989**	**-2.154**	**-2.201**	**-0.519**	**-0.972**	**-1.221**

Notes: see notes in Table 2A

However, according to the IPS, the Treaty of Maastricht in 1992 changes the relationship, rejecting the PPP hypothesis in both subperiods. When the introduction of the euro is considered as the breakpoint, the IPS test shows evidence for PPP in the pre-euro period, while in the post-euro period only when a time trend is added to the model, the null of a unit root is rejected.

When cross-sectional dependence is taken into account, that is when the PES test is employed, both breakpoints seem to affect the condition. In particular, in the post-Maastricht, as well as in the post-euro period, the condition changes in favour of PPP, though in the latter the null hypothesis is rejected only when a time trend is added in the model.

Table 3: Panel unit root tests

Sample	1970-2007		1970-1991		1992-2007		1970-1998		1999-2007	
IPS	*c*	*@*	*c*	*@*	*c*	*@*	*c*	*@*	*c*	*@*
$\bar{t}_{NT}$	-1.961*	-2.062	-1.411	-1.484	-1.487	-1.209	-2.052*	-1.987	-0.234	-2.755*
$W_{\bar{t}}$	-1.938* (0.026)	0.575 (0.715)	0.545 (0.707)	3.470 (0.999)	0.199 (0.578)	4.844 (1.000)	-2.352** (0.009)	0.948 (0.828)	5.860 (1.000)	-2.900** (0.001)
PES	*c*	*@*	*c*	*@*	*c*	*@*	*c*	*@*	*c*	*@*
CIPS	-2.264*	-2.362	-1.823	-1.935	-2.317*	-3.300*	-2.109	-2.073	-1.859	-3.264*
HAD	*c*	*@*	*c*	*@*	*c*	*@*	*c*	*@*	*c*	*@*
Z	6.150** (0.000)	5.293** (0.000)	4.484** (0.000)	13.815** (0.000)	6.727** (0.000)	21.826** (0.000)	6.977** (0.000)	7.893** (0.000)	18.145** (0.000)	7.138** (0.000)

Notes: The optimal lag length is based on SIC. IPS, PES and HAD denote the Im, Pesaran and Shin (2003), the Pesaran (2007) and the Hadri (2000) tests respectively. c denotes intercept in test equation, @ indicates intercept and trend in test equation. Corresponding p-values in parentheses, *, ** indicate rejection of the null hypothesis at 5% and 1% significance levels, respectively, 5% critical values IPS: $\bar{t}_{NT}{}^{c}$ =-1.89, $\bar{t}_{NT}{}^{@}$ =-2.51, PES: $CIPS^{c}$=-2.25, CIPS@=-2.75, 10% critical values IPS: $\bar{t}_{NT}{}^{c}$ =-1.81, $\bar{t}_{NT}{}^{@}$ =-2.44, PES: $CIPS^{c}$=-2.15, CIPS@=-2.66

Conclusions

The paper investigates the impact of the European integration process, that is the Treaty of Maastricht in 1992, as well as the introduction of the single European currency in 1999, on Purchasing Power Parity. In particular, real exchange rates of 15 European countries, within and out the Eurozone vis a vis the US dollar are tested for mean reverting behaviour. Univariate, as well as panel unit root and stationarity tests are utilized and the results vary.

Most evidence for PPP is witnessed in the case of the UK. Both with the ADF and the KSS test the real exchange rate of the UK against the US dollar is mean reverting during the whole period. However, it seems that before the Treaty of Maastricht PPP does not hold in the UK, as well as after the introduction of the euro. Italy, on the other hand, shows some evidence for PPP in the whole period, when the KSS test is applied, as well as in the post-Maastricht period, but when the advent of the euro is considered as a breakpoint such relation fails. Finally, Sweden shows some evidence in favour of PPP in the pre-euro period alone, according to the KSS test.

As far as panel unit root tests are concerned, it seems that when cross-sectional dependence is taken into account the results differ, rejecting the unit root hypothesis in the post-Maastricht period, while with cross-sectional independence considered, the unit root hypothesis is rejected in the pre-euro, as well as in the post-euro period.

The overall finding of this paper is that real exchange rates among the EU economies and the USA may be stationary in the long run, although in the short run such relationship cannot be verified.

References

Dickey, D. A. and Fuller, W. A., 1979, "Distribution of the Estimators for Autoregressive Time Series with a Unit Root", Journal of the American Statistical Association, 74, 427-431.

Dwyer, G. P., Jr., Fisher, M., Flavin, T., J. and Lothian, J., R., 2007, "Purchasing Power Parity and the Euro", Working Paper, http://econweb.tamu.edu/workshops/

Gadea, M. D., Montañés, A. and Reyes, M., 2004, "The European Union currencies and the US dollar: from post-Bretton-Woods to the Euro", Journal of International Money and Finance, 23, 1109-1136.

Hadri, K. 2000, "Testing for Stationarity in Heterogeneous Panel Data", Econometrics Journal, 3, 148-161.

Im, K. S., Pesaran, M. H. and Shin, Y. 2003, "Testing for Unit Roots in Heterogeneous Panels", Journal of Econometrics, 115, 53-74.

Kapetanios, G., Shin, Y. and Snell, A., 2003, "Testing for a unit root in the nonlinear STAR framework", Journal of Econometrics, 112, 359-379.

Koedijk, K. G., Tims, B and van Dijk, M., A., 2004, "Purchasing power parity and the euro area", Journal of International Money and Finance, 23, 1081-1107.

Kwiatkowski, D., Phillips, P. C. B., Schmidt, P. and Shin, Y., 1992, "Testing the Null Hypothesis of Stationary against the Alternative of a Unit Root" Journal of Econometrics, 54, 159-178.

Lopez, C. and Papell, D., H., 2007, "Convergence to Purchasing Power Parity at the Commencement of the Euro", Review of International Economics, 15, 1-16.
Pesaran, M. H., 2007, "A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence", Journal of Applied Econometrics, 22, 265-312.
Sarno, L. and Taylor, M. P., 2002, "The Economics of Exchange Rates", Cambridge University Press.
Zhou, S., Bahmani-Oskooee, M. and Kutan, A., M., 2008, "Purchasing power parity before and after the adoption of the Euro", Review of World Economics, 144, 134-150.

Appendix

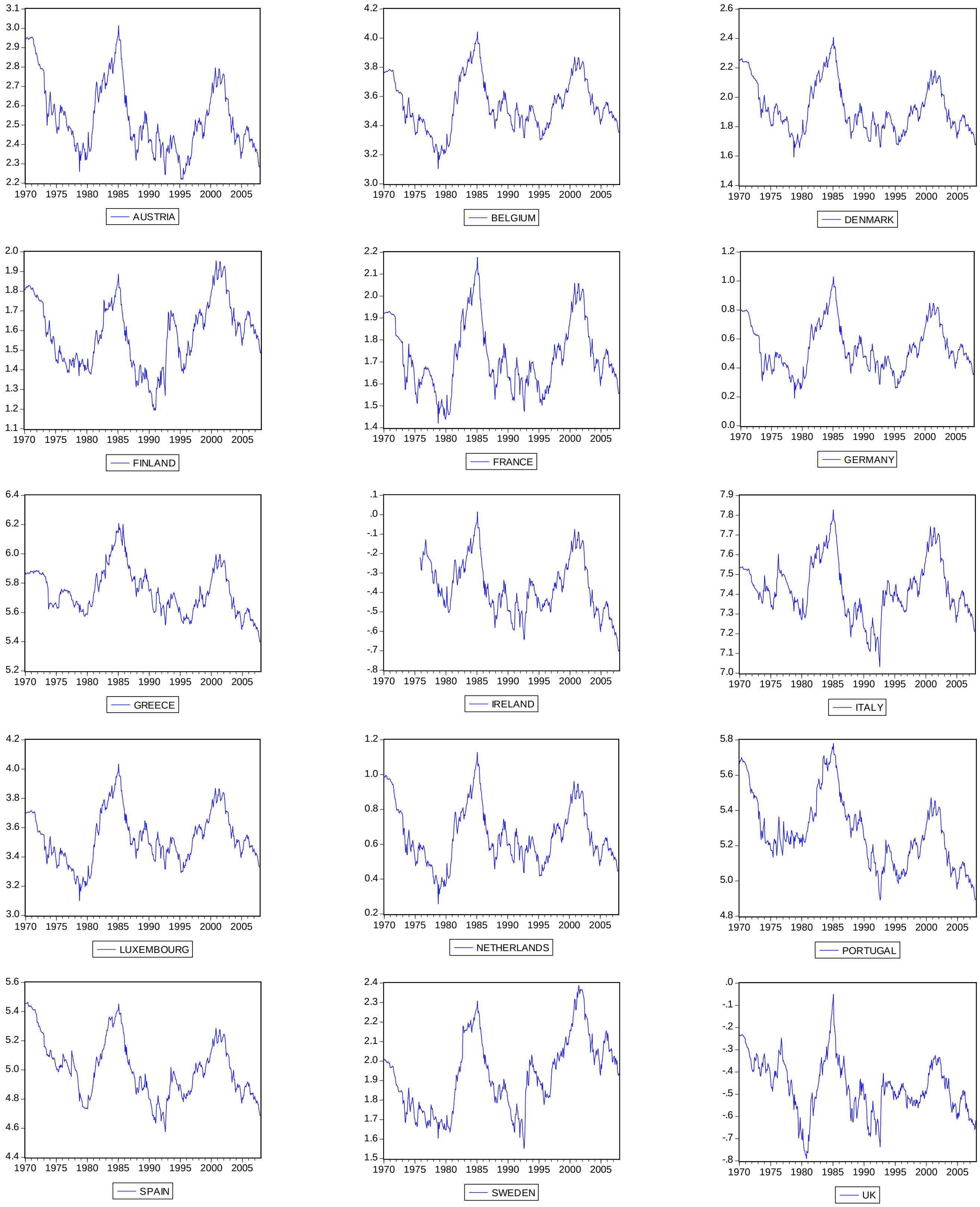

Figure 1. Real exchange rates relative to US dollar

Table A.1. Summary Statistics

	Country	Mean	Std. dev.	Skewness	Kurtosis	J-B
CPI	Austria	4.25783	0.38096	-0.69377	2.36732	44.18498
	Belgium	4.22116	0.44182	-0.83305	2.48989	57.68633
	Denmark	4.11526	0.56484	-0.87394	2.44654	63.86640
	Finland	4.09073	0.60550	-0.95482	2.61531	72.09964
	France	4.13936	0.57176	-0.91721	2.41839	70.36314
	Germany	4.30319	0.31639	-0.59117	2.25201	37.19101
	Greece	3.15474	1.43743	-0.41787	1.68679	46.03660
	Ireland	4.25957	0.47536	-1.04125	3.14785	70.10200
	Italy	3.82717	0.88061	-0.80570	2.25396	59.91076
	Luxembourg	4.23247	0.42672	-0.75646	2.35825	51.31454
	Netherlands	4.28489	0.36392	-0.81502	2.78078	51.39625
	Portugal	3.43318	1.31920	-0.72428	2.06893	56.33898
	Spain	3.81263	0.90585	-0.81356	2.32226	59.03007
	Sweden	4.05096	0.63119	-0.71020	2.08208	54.34168
	UK	4.02424	0.68187	-0.97948	2.67819	74.88023
	USA	4.13469	0.50633	-0.64084	2.16037	44.60543
Exchange rates	Austria	2.66379	0.25882	0.59483	2.45270	32.58221
	Belgium	3.63097	0.18774	0.63398	2.89088	30.77360
	Denmark	1.90671	0.17396	0.88973	3.47571	64.46389
	Finland	1.53846	0.17363	0.51469	2.28146	29.94300
	France	1.72946	0.18768	0.64024	3.23094	32.16692
	Germany	0.70655	0.25374	0.59711	2.46365	32.56336
	Greece	4.76548	0.90613	-0.40117	1.57501	50.81261
	Ireland	-0.47922	0.23226	-0.24523	2.52436	8.86892
	Italy	7.12239	0.39184	-0.63576	2.18748	43.26192
	Luxembourg	3.63097	0.18774	0.63398	2.89088	30.77360
	Netherlands	0.80212	0.22770	0.48915	2.30170	27.44961
	Portugal	4.57556	0.74712	-0.79414	1.98722	67.41885
	Spain	4.69072	0.35734	-0.42482	1.92736	35.57616
	Sweden	1.84627	0.26269	-0.14918	1.95175	22.56881
	UK	-0.57698	0.17899	-0.37752	2.47697	16.02895