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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 for the 15 EU countries, vis a vis the US dollar, before and after the advent of the euro. Standard as well as nonlinear unit root tests are employed on the time series dimension. Unit root tests reject PPP and the highest half-lives are observed after the introduction of the single currency. Panel unit root (Pesaran, 2007) and stationarity tests (Hadri and Kurozumi, 2008) that take into account cross-sectional dependence are also estimated. The results remain inconclusive as panel stationarity tests fail to support PPP whereas panel unit root tests fail to reject PPP for the whole sample and for the period before the introduction of the single currency.

Keywords: Purchasing Power Parity, half-life, nonlinear unit roots, panel unit roots, heterogeneity, cross-section dependence

JEL: F31; F33; G15

1. INTRODUCTION

The Maastricht treaty in 1992 and the subsequent introduction of the euro in 1999 were the cornerstones for the creation of the European single market. Although the verdict for the effect of the introduction of the single currency is still open, we investigate its effects in one of the most examined parities in economics, the purchasing power parity (PPP). The latter suggests the existence of a proportional relationship between the nominal exchange rate (S_t) and the relative price ratio ($\frac{P_t}{P_t^*}$) which implies that the real exchange rate (Q_t) is mean reverting over time. In logarithmic form (lower case), we have:

$$q_t \equiv s_t - p_t + p_t^*$$

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.

The empirical evidence on PPP is extremely large since this parity has been widely tested in the literature. For a review of the vast literature see Sarno and Taylor (2002), Taylor (2002) and Sarno (2005).

However, the empirical evidence on PPP concerning the European Economic and Monetary Union (EMU) is still scant. The purpose of this paper is to fill this gap and test the validity of the PPP hypothesis between the European Union and the USA in the last four decades. In particular, we 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 and stationarity tests that take into account cross-sectional dependence.

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.

2. LITERATURE

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 numeraire 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 breaks, 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 in 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 sample into two subperiods which reflect the pre and post-euro creation process, with 1997 marked as the beginning of the process of the 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, when allowing for two changes in the mean, for the period prior to the transition to the euro for those currencies closely related to the German mark; Austria, Belgium, Denmark, France and the Netherlands. Thus, they conclude that a weaker version or quasi long-run PPP holds.

Lopez and Papell (2007) claim that the choice of the numeraire currency plays an important role on the evidence of PPP. They use panel data on CPI and nominal exchange

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

rates in US dollars for 23 countries from 1973 to 2001 and split the countries into 5 groups; 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 numeraire countries, 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 numeraire currency, however, stronger evidence for the PPP is provided, 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 numeraire 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 numeraire currencies. They suggest that convergence towards 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 (see also Taylor et al., 2001). 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 both the linear and 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.

More recently, Gadea and Gracia (2009), testing for stationarity against a change in persistence to 14 European real exchange rates vis a vis the US dollar, for the period 1975-2003, find that the real exchange rates of Spain, Italy, Portugal, Greece and Finland experienced a change in their order of integration from I(1) to I(0) at sometime in the second half of the nineties. However, the other European real exchange rates do not show any change in the order of integration from I(1) to I(0). This result leads to the conclusion that there is not a general structural break in EU countries as a result of the euro, even though the smaller countries have stabilised their prices and exchange rates.

3. DATA AND METHODOLOGY

3.1. 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 1/1973 to 4/2009[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 (Table A1).

For 1999-2009, 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.

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

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

$$q_i = s_i - p_i + p_{us} , \tag{3.1}$$

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, in logarithmic form.

As mentioned above, if PPP holds, the real exchange rate is expected to be stationary.

3.2 METHODOLOGY

3.2.1 Univariate unit root tests

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

First, the ADF test was applied to the real exchange rates:

$$\Delta q_t = \alpha + \delta q_{t-1} + \sum_{i=1}^{p} \beta_i \Delta q_{t-i} + \varepsilon_t , \tag{3.2}$$

where the p augmentations are used to correct for correlation up to order p in the series. The null hypothesis H_0: $\delta = 0$ is evaluated using the t-ratio:

$$t_\delta = \frac{\hat{\delta}}{se\left(\hat{\delta}\right)} , \tag{3.3}$$

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

The half-life of the deviation from PPP is calculated as $\ln(0.5)/\ln(1+\delta)$. The half-life of the real exchange rate process is defined as the number of months that it takes for deviations from PPP to subside permanently below 0.5 in response to a unit shock in the level of the series.

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:

$$\Delta q_t = \gamma q_{t-1}\left[1 - \exp\left\{-\theta q_{t-1}^2\right\}\right] + \varepsilon_t, \;\; \theta \geq 0 , \tag{3.4}$$

where q_t is the real exchange rate and $\left[1-\exp\left\{-\theta q_{t-1}^2\right\}\right]$ 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 (3.4) is not identified under the null, we cannot directly test H_0: $\theta = 0$. To deal with this issue, KSS suggest reparameterise equation (3.4) by computing a first-order Taylor series approximation to specification (3.4) to obtain the auxiliary regression:

$$\Delta q_t = \delta q_{t-1}^3 + \varepsilon_t . \tag{3.5}$$

Assuming a more general case where the errors are serially correlated, regression (3.5) is extended to:

$$\Delta q_t = \sum_{j=1}^{p} \rho_j \Delta q_{t-j} + \delta q_{t-1}^3 + \varepsilon_t , \tag{3.6}$$

with the p augmentations used to correct for serially correlated errors. The null hypothesis of nonstationarity to be tested with either equation (3.5) or (3.6) is:

$$H_0: \delta = 0$$

against the alternative

$$H_A: \delta < 0$$

and the t-statistic is

$$t_{NL} = \frac{\hat{\delta}}{se\left(\hat{\delta}\right)} . \tag{3.7}$$

KSS show that the t_{NL} statistic does not have an asymptotic standard normal distribution. They tabulate 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 the demeaned data are used, while for the case with nonzero mean and nonzero linear trend the demeaned and detrended data.

In this paper, t_{NL} statistics were estimated using regression (3.5), 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 demeaned or detrended 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.

3.2.2. 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 overcoming 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 needs to be taken into account.

Four 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) and the *Hadri and Kurozumi* (2008) panel stationarity tests. With the exception of the *Hadri* (2000) test, all employ the assumption of heterogeneity in the parameters.

The Im, Pesaran and Shin (2003) test [IPS]

The IPS test is based on:

$$\Delta q_{i,t} = \alpha_i + b_i q_{i,t-1} + \sum_{j=1}^{p_i} \phi_{i,j} \Delta q_{i,t-j} + \varepsilon_{i,t}, \tag{3.8}$$

where i=1, 2,…, N cross-section units or series, that are observed over periods t=1, 2,…, T. The null hypothesis of a unit root can be now defined as

$$H_0 : b_i = 0, \forall i$$

against the alternative

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

The alternative hypothesis allows unit roots for some of the individual series. 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_{iTi}:

$$\bar{t}_{NT} = \frac{1}{N} \sum_{i=1}^{N} t_{iTi} \tag{3.9}$$

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_{iTi}, $E(t_{iTi})$ and $Var(t_{iTi})$ 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 a 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:

$$\Delta q_{i,t} = \alpha_i + b_i q_{i,t-1} + c_i \overline{q}_{t-1} + \sum_{j=0}^{p} d_{i,j} \Delta \overline{q}_{t-j} + \sum_{j=1}^{p} \delta_{i,j} \Delta q_{i,t-j} + \varepsilon_{i,t}, \qquad (3.10)$$

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

$$CIPS = \frac{1}{N} \sum_{i=1}^{N} t_i(N,T). \qquad (3.11)$$

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:

$$q_{i,t} = \alpha_i + u_{i,t}, \; u_{i,t} = \phi_i u_{i,t-1} + \varepsilon_{i,t}. \qquad (3.12)$$

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:

$$H_0 : |\varphi_i| < 1, \forall i.$$

Given the residuals, the HAD test is defined by:

$$LM = \frac{1}{\hat{\sigma}_i^2 N T^2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} S^2_{i,t} \right), \qquad (3.13)$$

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,

$$Z = \frac{\sqrt{N}\left(LM - \xi\right)}{\zeta} \rightarrow \mathrm{N}\left(0,1\right), \tag{3.14}$$

where ξ=1/6 and ζ^2=1/45. Thus, we should use the right-hand tail of a standard normal distribution for critical values of Hadri's test. Following Hobijn et al. (2004) we employed the quadratic spectral kernel method.

The Hadri and Kurozumi (2008) test [HAK]

Hadri and Kurozumi developed a stationarity test that takes into account cross-sectional dependence. Their test is basically the same as the KPSS with the regression augmented by cross-sectional average of the observations, in the spirit of PES that augments the standard ADF regression. The limiting null distribution is the same as the HAD test. In a modified version for serial correlation, the HAK test proposes augmenting equation (3.12) as follows:

$$q_{i,t} = \alpha_i + \varphi_{i,1} q_{i,t-1} + \ldots + \varphi_{i,p} q_{i,t-p} + \psi_{i,0}\overline{q}_t + \ldots + \psi_{i,p}\overline{q}_{t-p} + \varepsilon_{i,t}\,, \tag{3.15}$$

where $\overline{q}_t = N^{-1}\sum_{i=1}^{N} q_{i,t}$. The test statistic is then constructed in the same way as HAD, that is:

$$Z_A = \frac{\sqrt{N}\left(\overline{ST} - \xi\right)}{\zeta} \rightarrow \mathrm{N}\left(0,1\right), \tag{3.16}$$

where $\overline{ST}$ is the average of the KPSS test statistic across *i*.

4. RESULTS

4.1. Time series tests

The results for the ADF test are presented in Table 1. The null hypothesis of a unit root is rejected for the whole period only in the case of the UK at 10% significance level, while for the post-Maastricht period the unit root null is rejected for both the UK and Sweden (both countries do not participate in the Euro). In all other cases there is no support for PPP.

Table 1. ADF unit root test

Sample	1973-2009	1973-1991	1992-2009	1973-1998	1999-2009
Country	*t*	*t*	*t*	*t*	*t*
Austria	-2.345	-1.612	-1.553	-2.118	-0.986
Belgium	-1.914	-1.264	-1.569	-1.682	-0.904
Denmark	-2.187	-1.406	-1.670	-1.944	-0.980
Finland	-2.125	-1.671	-2.279	-2.169	-1.110
France	-2.169	-1.476	-1.670	-1.990	-1.025
Germany	-2.150	-1.437	-1.617	-1.896	-1.102
Greece	-1.758	-1.292	-1.267	-1.792	-0.667
Ireland	-2.024	-1.378	-1.375	-2.251	-0.693
Italy	-2.034	-0.761	-2.153	-1.843	-0.877
Luxembourg	-1.892	-1.265	-1.511	-1.656	-0.865
Netherlands	-2.218	-1.557	-1.590	-2.019	-0.929
Portugal	-1.747	-1.101	-1.430	-1.661	-0.792
Spain	-1.947	-0.793	-1.785	-1.857	-0.697
Sweden	-1.558	-0.880	-2.603*	-1.459	-1.438
UK	-2.621*	-1.532	-2.745*	-2.314	-1.022

*Notes: The optimal lag length is based on SIC. * indicates rejection of the null hypothesis at 10% significance level. 5% critical value -2.86, 10% critical value -2.57*

Table 2 shows the results of the KSS test applied to the real exchange rates, for different sample periods. With the exception of the UK, PPP does not hold for the full sample period, while for the period 1973-1991 PPP does not hold for any country. The test statistic increases in the period after 1992, but the unit root hypothesis is rejected only in the case of Italy and the UK.

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 alone; 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.

From the above, we see that 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, as well as after the Maastricht treaty, while this relation does not hold before 1992. However, PPP is not supported in the UK before or after the introduction of the euro. Italy also shows some evidence for PPP after the treaty of Maastricht, when the KSS test is applied, but when the advent of the euro is considered as a breakpoint this does not hold. Finally, Sweden shows some evidence in favour of PPP in the post-Maastricht period, according to the ADF test and in the pre-euro period, according to the KSS test.

Table 2A. KSS nonlinear unit root test

Sample	**1973-2009**		
Country	t_{NL}	t_{NL1}	t_{NL2}
Austria	-0.804	-1.910	-2.074
Belgium	-0.365	-2.063	-1.940
Denmark	-0.814	-1.768	-1.914
Finland	-0.764	-2.217	-2.634
France	-0.603	-2.040	-1.958
Germany	-1.234	-1.969	-1.871
Greece	-0.721	-1.950	-2.133
Ireland	-1.257	-2.247	-2.316
Italy	-0.235	-2.656	-2.636
Luxembourg	-0.309	-2.138	-1.987
Netherlands	-1.237	-2.065	-2.003
Portugal	-0.675	-1.444	-1.728
Spain	-0.733	-1.909	-1.997
Sweden	-0.008	-2.320	-2.123
UK	-1.547	-2.913*	-2.866

*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}=-2.93 and t_{NL2}=-3.40, 10% critical values t_{NL}=-1.92, t_{NL1}=-2.66 and t_{NL2}=-3.13*

4.2. Half-lives

The half-lives from the ADF regressions for all samples were also computed (Table 3). The UK has the lowest number of months for mean reversion, concerning all periods, except from the post-euro period, where Sweden has the lowest half-life of a deviation from PPP.

Except from that, Sweden is the only country for which the half-life is reduced after the introduction of the euro. All other countries experience an increase in the half-lives when comparing the periods before and after the single currency.

On the other hand, with the exception of Austria, Greece and Ireland, half-lives are reduced during the period after the treaty of Maastricht, as compared to the period before. This is not a surprise as the last two countries face lately considerable fiscal difficulties[3]. However, only in the case of Ireland it seems that the half-life is increased after 1992. The mean is lower in the period after 1992, while higher in the period after 1999. This finding is in line with the literature (for instance Gadea and Gracia, 2009). The effect of the Maastricht treaty and the subsequent criteria seem to have a more significant effect as countries made an attempt to reduce inflation in order to participate in the single currency.

Table 2B. KSS nonlinear unit root test

Sample	**1973-1991**			**1992-2009**		
Country	t_{NL}	t_{NL1}	t_{NL2}	t_{NL}	t_{NL1}	t_{NL2}
Austria	-0.878	-1.176	-1.344	-0.180	-2.317	-1.935
Belgium	-0.426	-1.500	-1.358	-0.061	-1.653	-1.995
Denmark	-0.796	-1.166	-1.314	-0.299	-2.350	-1.981
Finland	-1.216	-1.495	-1.537	-0.133	-1.613	-2.285
France	-0.641	-1.430	-1.292	-0.189	-1.525	-1.811
Germany	-0.907	-1.343	-1.243	-0.829	-1.831	-2.014
Greece	-0.690	-1.341	-1.473	-0.291	-1.553	-1.714
Ireland	-0.573	-1.446	-1.788	-1.200	-1.795	-1.719
Italy	-0.617	-1.074	-1.128	0.259	-2.935**	-2.667
Luxembourg	-0.315	-1.561	-1.380	-0.104	-1.608	-1.960
Netherlands	-0.942	-1.454	-1.381	-0.787	-1.766	-1.930
Portugal	-0.715	-0.815	-1.046	-0.170	-1.838	-2.192
Spain	-1.158	-0.855	-0.933	0.114	-2.541	-2.226
Sweden	-0.613	-1.568	-0.818	0.338	-1.708	-2.443
UK	-0.504	-2.070	-2.062	-1.924*	-3.635**	-3.099

[3] See for instance what the President of the ECB says here : http://www.ecb.int/press/pressconf/2010/html/is100204.en.html

*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}=-2.93 and t_{NL2}=-3.40, 10% critical values t_{NL}=-1.92, t_{NL1}=-2.66 and t_{NL2}=-3.13*

Table 2C. KSS nonlinear unit root test

Sample	**1973-1998**			**1999-2009**		
Country	t_{NL}	t_{NL1}	t_{NL2}	t_{NL}	t_{NL1}	t_{NL2}
Austria	-0.724	-1.520	-1.714	-0.355	-1.637	-1.244
Belgium	-0.203	-1.725	-1.575	-0.362	-1.233	-1.497
Denmark	-0.660	-1.406	-1.569	-0.478	-1.666	-1.370
Finland	-0.660	-2.349	-2.366	-0.407	-0.944	-1.214
France	-0.463	-1.710	-1.562	-0.391	-1.109	-1.301
Germany	-1.009	-1.628	-1.521	-0.724	-1.239	-1.384
Greece	-0.534	-1.526	-1.671	-0.488	-1.320	-1.437
Ireland	-1.537	-1.911	-2.427	-0.488	-1.440	-1.310
Italy	-0.066	-2.221	-2.324	-0.327	-1.456	-1.259
Luxembourg	-0.102	-1.793	-1.601	-0.413	-1.218	-1.492
Netherlands	-1.006	-1.680	-1.602	-0.731	-1.361	-1.490
Portugal	-0.521	-1.090	-1.371	-0.447	-1.242	-1.475
Spain	-0.521	-1.452	-1.600	-0.542	-1.564	-1.254
Sweden	0.026	-2.699*	-1.896	-0.040	-0.949	-0.972
UK	-1.192	-2.592	-2.573	-1.082	-1.548	-1.096

*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}=-2.93 and t_{NL2}=-3.40, 10% critical values t_{NL}=-1.92, t_{NL1}=-2.66 and t_{NL2}=-3.13*

Table 3. Half-lives

Country	1973-2009	1973-1991	1992-2009	1973-1998	1999-2009
Austria	31	30	31	28	39
Belgium	41	47	31	39	44
Denmark	33	38	26	31	38
Finland	36	32	20	26	32
France	32	34	29	28	37
Germany	33	35	30	31	33
Greece	44	38	39	34	69
Ireland	33	28	38	20	70
Italy	35	71	21	31	46
Luxembourg	41	46	33	39	47
Netherlands	31	32	29	28	42
Portugal	48	44	34	40	55
Spain	43	80	29	38	66
Sweden	56	72	19	44	20
UK	22	29	12	21	30
Mean	37.27	43.73	28.07	31.87	44.53
Median	35	38	29	31	42
Variance	69.50	288.50	54.35	49.84	218.98

4.3. Panel tests

The results of the panel tests are shown in Table 4. Table 4A presents the results for the whole panel (15 countries), while Table 4B for the 12 Eurozone countries, excluding Denmark, Sweden and the UK, since the three countries do not participate in the Eurozone.

In both panels we see that there is evidence in favour of PPP, according to the IPS and the PES tests. In particular, both tests reject the null of a unit root in all series for the whole period, showing evidence in favour of PPP during the past 36 years (in a sense reject the no PPP null for the whole sample for both the 15 and the 12 countries).

However, according to the IPS test, the treaty of Maastricht in 1992 changes the relationship, rejecting the PPP hypothesis in both subperiods. When cross-sectional dependence is taken into account, that is according to the PES test, the outcome is reversed in favour of PPP in the post-Maastricht period, only when all 15 countries are considered. In the case of the Eurozone countries, though, the unit root null cannot be rejected either before, or after the Maastricht treaty (marginally for the second subperiod).

When we consider the introduction of the euro as a breakpoint both the IPS and the PES tests provide evidence for PPP only in the pre-euro period in both panels. There is no support for PPP after the introduction of the single currency in the two panels by both tests. For the 15 countries there is evidence of stationarity in the period after the Maastricht treaty by the PES test. The latter does not hold for the 12 countries.

Overall, the evidence from the panel unit root tests are in favour of PPP for the whole sample, as well as for the period before the single currency, for both the 15 and the 12 countries, while after the Maastricht treaty for the 15 countries only. Interestingly, evidence against PPP emerges after the introduction of the single currency.

As far as the panel stationarity tests are concerned, the PPP hypothesis is rejected by the HAD test and when cross-sectional dependence is taken into account, that is when the HAK test is applied. Thus, the null hypothesis of stationarity is rejected by both tests in all subperiods for both panels.

Table 4A. Panel unit root and stationarity tests (15 countries)

Sample	1973-2009	1973-1991	1992-2009	1973-1998	1999-2009
IPS					
$\bar{t}_{NT}$	-2.045**	-1.295	-1.787	-1.910**	-0.939
$W_{\bar{t}}$	-2.321**	1.070	-1.155	-1.707**	2.678
	(0.010)	(0.857)	(0.123)	(0.043)	(0.996)
PES					
CIPS	-2.482**	-1.952	-2.194*	-2.262**	-0.878
HAD					
Z	9.347**	7.811**	7.464**	7.383**	23.381**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
HAK					
Z_A	31.882**	27.700**	22.744**	17.905**	9.172**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: The optimal lag length is based on SIC. IPS, PES, HAD and HAK denote the Im, Pesaran and Shin (2003), the Pesaran (2007), the Hadri (2000) and the Hadri and Kurozumi (2008) tests respectively. Corresponding *p-values in parentheses, **, * indicate rejection of the null hypothesis at 5% and 10% significance levels, respectively, 5% critical values:* $\overline{t}_{NT}$ *=-1.89, CIPS=-2.25, 10% critical values* $\overline{t}_{NT}$ *=-1.81, CIPS=-2.15*

Table 4B. Panel unit root and stationarity tests (12 countries - excluding Denmark, Sweden, UK)

Sample	1973-2009	1973-1991	1992-2009	1973-1998	1999-2009
IPS					
$\overline{t}_{NT}$	-2.027**	-1.301	-1.650	-1.911*	-0.887
$W_{\overline{t}}$	-1.999**	0.935	-0.477	-1.532*	2.606
	(0.022)	(0.825)	(0.316)	(0.062)	(0.995)
PES					
CIPS	-2.607**	-1.841	-2.039	-2.239**	-1.638
HAD					
Z	7.038**	7.379**	6.248**	6.914**	21.755**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
HAK					
Z_A	34.305**	33.000**	30.382**	22.262**	19.479**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

*Notes: The optimal lag length is based on SIC. IPS, PES, HAD and HAK denote the Im, Pesaran and Shin (2003), the Pesaran (2007), the Hadri (2000) and the Hadri and Kurozumi (2008) tests respectively. Corresponding p-values in parentheses, **, * indicate rejection of the null hypothesis at 5% and 10% significance levels, respectively, 5% critical values:* $\overline{t}_{NT}$ *=-1.93, CIPS=-2.32, 10% critical values* $\overline{t}_{NT}$ *=-1.85, CIPS=-2.21*

5. Conclusions

This 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 the Purchasing Power Parity. In particular, the real exchange rates of 15 European countries, Eurozone members as well as others, vis a vis the US dollar, are tested for mean reverting behaviour. Univariate, as well as panel unit root and stationarity tests are employed.

Linear and nonlinear unit root tests reject the PPP overall, with the exception of the UK, that nevertheless does not participate in the single currency. Half-lives, though, were considerably reduced after the Maastricht treaty. For the period after the introduction of the single currency the highest half-lives were observed. In the time series dimension the Maastricht treaty seems to have a more significant effect than the single currency for the PPP.

Panel stationarity tests reject the parity even when cross-section dependence is taken into account. The panel unit root tests provide evidence in favour of PPP for the whole sample, the period before the single currency and limited after the Maastricht treaty. The introduction of the single currency has weakened the evidence in favour of the parity.

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Appendix

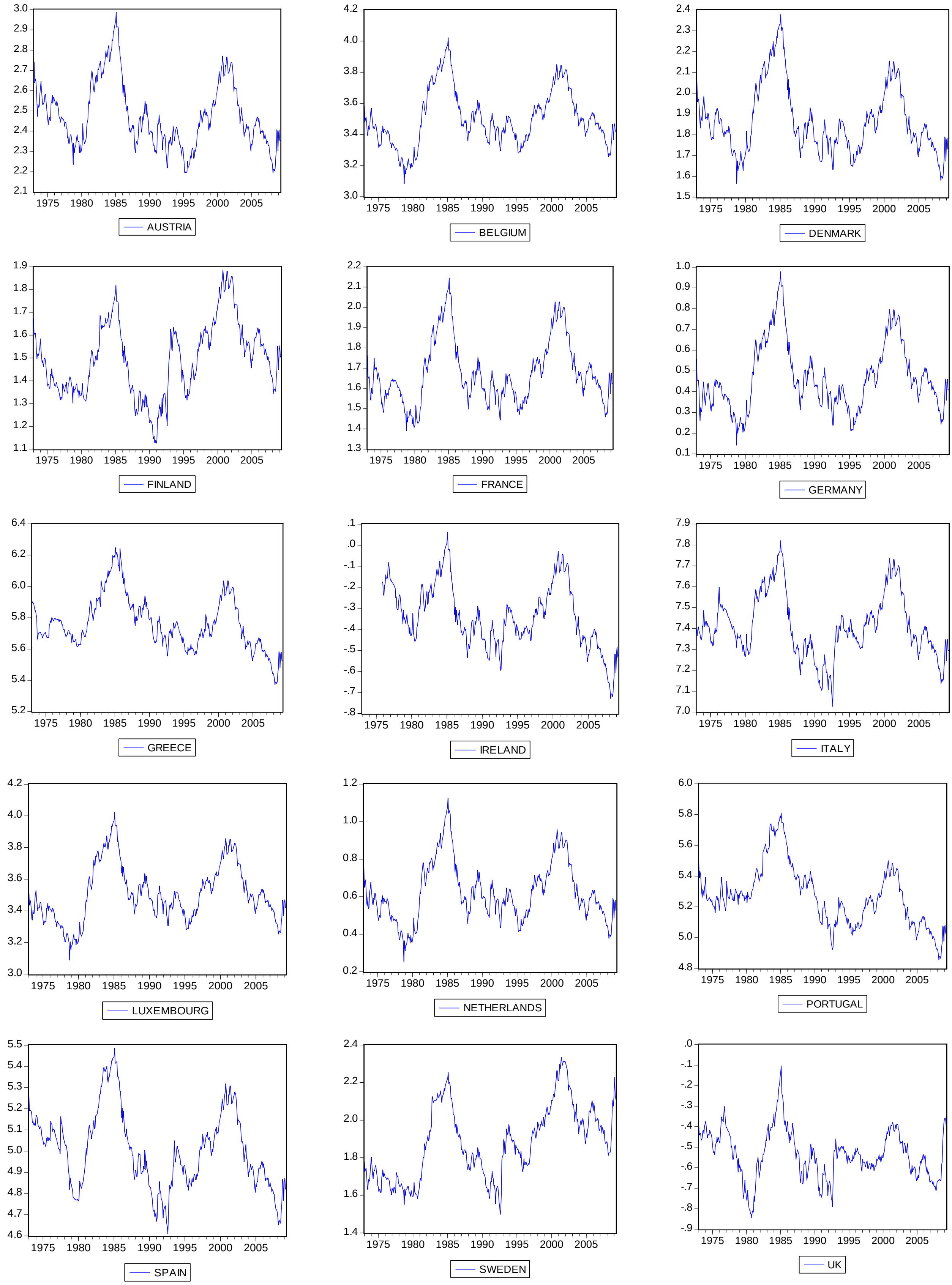

Figure 1. Real exchange rates relative to US dollar

Table A1. 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