# Purchasing power parity:
# an empirical study of three EMU countries

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## Abstract

We apply Purchasing Power Parity (PPP) theory to the analysis of long-run equilibrium in the foreign exchange market. We study the case of Portugal vis-à-vis Germany and Spain, and the case of Spain vis-à-vis Germany, in the period 1960-1990. The empirical analysis was based on unit-root testing (using ADF tests) and Johansen's methodology for the study of co-integration. We worked with linear long-run relationships based exclusively on PPP, as well as with long-run relations that also allowed for the effect of interest rates. In a situation in which PPP does not hold, one could think that on account of some "natural reason" agents believe that, as time goes by, the dominant currency, which is also the reference currency of the EMS (the German Mark), will appreciate. We concluded, on the contrary, that the weaker currencies were the ones that with the passing of time appreciated in real terms. The fact that PPP theory was applied to two southern European countries deserves a special mention, because it may serve as an example for other countries that come to be in a position similar to that of Portugal and Spain before their adhered to the European Union.

*Keywords*: Purchasing Power Parity, Unit Roots, EMU, Economic Integration and Co-integration

*JEL Classification*: F31, F41, C32, G15, C51

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## I – INTRODUCTION

Little more than 25 years after the move to a generalised system of floating exchange rates, PPP theory is one the most important tools in international macroeconomics[1]. PPP is frequently employed in international comparisons of real variables. It supports the determination of the long-run equilibrium real exchange rate and, thus, allows us to analyse the evolution of the relative purchasing power in two countries. However, initially, most empirical papers were not favourable to PPP, e.g. Frenkel (1981), Branson (1981) and Adler and Lehman (1983). A number of causes are usually mentioned to justify the empirical rejection of PPP.

On one hand, several studies are based on short time series, frequently with samples beginning after 1973. Bearing in mind that most studies referred to the US Dollar, Papell (1998) suggests that the empirical rejection of PPP may also be explained by the considerable appreciation and depreciation of the Dollar during the 1980s. Fortunately, in recent times, the availability of longer time series, comparable across countries, has increased noticeably.

On the other hand, neither goods markets nor capital markets are perfectly competitive and functioning unrestricted. Several institutional factors contribute to this: transaction costs, price discrimination policies, capital controls, trade barriers, differences in assets' risk and liquidity, different ways of constructing price indices, etc.. If these are not taken into account when specifying the model, deviations relative to the PPP condition may arise. Besides, we may also point out to the lack of formal econometric methods to study PPP, which limits its usefulness in analysis. Fortunately, with the development of unit root tests and co-integration theory this problem is significantly reduced.

Our study aims at applying PPP theory to the analysis of long-run equilibrium in the foreign exchange market. The empirical work covers the period 1960-1999. Thus, we study periods of fixed and of floating exchange rates. We use annual, quarterly and monthly data for Portugal, Spain and Germany. The choice of two of the least developed countries in the European Union is justified on three accounts. First, there is the fact that these economies had been relatively closed to capital movements. Secondly, their currencies are not important in international markets. Third, they currently

[1] Excellent surveys are provided in Froot and Rogoff (1994), MacDonald (1995) and Rogoff (1996).

have developed financial markets, increasingly integrated in the world economy. The choice of Germany is related to the central role played by this country in the European Monetary System.

The application of PPP theory to time series data is based on unit root testing, using the ADF test, and co-integration analysis following the methodology proposed in Johansen (1995).

This paper is structured as follows. Section II presents definitions, basic concepts and theoretical structures, and critically reviews the underlying hypotheses. Section III presents the data and their treatment. Section IV tests the series for unit roots and graphs the relationships found in the study. Section V establishes the existence of a set of co-integrating relations and analyses the long-run behaviour of the series. Finally, section VI gives some clues for future research and concludes the paper.

## II. DEFINITIONS AND BASIC CONCEPTS

The connection between exchange rates and prices that underlies PPP doctrine is one of the oldest and most controversial in exchange rate theory. Its origin dates back to the so-called Salamanca School in the XVI[th] century. It arises in the context of the large inflows of precious metals from America. Interest in this theory is renewed in the XIX[th] century, during the debate on the writings of famous economists such as David Ricardo, Stuart Mill and Alfred Marshall. PPP gained prominence again in the 1922, when the empirical work of the Swedish economist Gustav Cassel[2] was published. The PPP theory has been widely used since the collapse of the Gold Standard during World War I[3].

PPP theory says that in the long-run the domestic and the foreign price levels are equal when they are measured in the same currency. As is generally accepted, this relation results directly from the “Law of One Price” at the international level. Assuming that all goods are tradable, zero transport costs, no barriers to trade, perfect homogeneity of domestic and foreign goods, and (usually) perfect competition, this Law says that free trade must lead to equal prices across countries[4]. In this context, for any good *i*, we have:

$$P_t\ (i) = P_t^*\ (i)\,.\,E_t \qquad (1)$$

[2] Cassel, Gustav (1922), Money and foreign exchange after 1914, MacMillan, New York.
[3] See Frenkel (1981), Rogoff (1996) and Olloqui and Rivero (2000). For a more detailed analysis of the origins of PPP theory, see Frenkel (1978).
[4] See Isard (1977), Richardson (1978), Ardeni and Lubian (1991), Froot et al. (1995) or Rogoff (1996).

where $P_t(i)$ is the price of *good i* in terms of domestic currency in period t, $P^*_t(i)$ is the analogous price in foreign currency, and $E_t$ is the price of one unit of foreign currency in terms of domestic currency in period t. The simple arbitrage-in-the-goods-market argument underlying the "Law of One Price" has in fact given rise to a number of derivations of PPP, which is formulated in one of two alternative ways: absolute PPP and relative PPP.

The *absolute version of PPP* may be presented in the following manner:

$$P_t\ (CPI) = P_t^*\ (CPI)\,.\,E_t \qquad (2)$$

where CPI stands for the basket of goods employed in the construction of a consumer price index. In its absolute version, PPP implies that one unit of currency, after conversion, should purchase the same basket of goods both at home and abroad. Naturally, even if the "Law of One Price" holds, we are not assured that condition (2) holds, unless both countries consume identical baskets of goods[5].

With the goal of allowing for the existence of a constant price differential between the two baskets of goods, the empirical literature has also tested the *relative version of PPP*. Taking logs and defining the variables as rates of change, relative PPP may easily be obtained from expression (2):

$$\Delta p_t\ (CPI) = \Delta p_t^*\ (CPI) + \Delta e_t \qquad (3)$$

where lower cases denote the log of the original variables. Thus, the relative version of PPP requires movements in the relative price levels to be offset, in the same period, by movements in the exchange rate.

We can also obtain the definition of the real exchange rate (R)[6] from expression (2):

$$R = \frac{E\,.\,P*}{P} \qquad (4)$$

According to PPP, in the long-run the real exchange rate should equal one, so that, given enough time for price movements to be transmitted to the exchange rate, domestic and foreign prices are identical when expressed in terms of the same currency[7].

[5] See Abuaf and Jorion (1990), Froot and Rogoff (1994) MacDonald (1995) and Rogoff (1996).
[6] To simplify the notation, we now write P, $P^*$ and E instead of $P_t$(CPI), $P^*_t$(CPI) and $E_t$, respectively.
[7] Obviously, we assume that there is a short-run adjustment mechanism in the exchange market, which is essential to reach to long-run equilibrium. Many studies show that short-run deviations from PPP subsist 3 to 5 years on average, and they may become cumulative and persistent. See, e.g., Adler and Lehmann (1983) or Rogoff (1996). Wei and Parley (1995) contend that the existence of this phenomenon reflects the volatility of the nominal exchange rate, while being also related to transport costs. They also point out that free trade areas such as EEC and EFTA do not appear to significantly reduce deviations from PPP compared to other OECD countries. See also Froot et al. (1995) and Bayoumi and MacDonald (1998).

However, the construction of the price indices does not usually assign the same weight to each good, nor is the quality of those goods the same in different countries. Besides, recent theories of international trade are based on differentiation, either on the demand side (in which case differentiation could come from the diversity of consumer tastes, income levels, the “search for difference” or from the availability of information) or on the supply side (in which producers differentiate goods through quality in order to gain market share or to prevent new competitor to enter the market). These theories imply added difficulties for the construction of comparable price indices[8].

Thus, there is widespread agreement that the long-run equilibrium level of the real exchange rate, assumed to be the one implied by PPP, is not always correct, but may obtained by including a constant K that depends on the base year of the price indices, i.e.:

$$R = \frac{E \, . \, P^*}{P \, . \, K} \qquad (4')$$

or, taking logs,

$$r = e + p^* - p - k \qquad (4'')$$

The value of K is determined by a set of factors that affect in different ways different countries and thus prevent domestic prices to equal foreign prices after converting to the same unit of account[9].

One of the factors that affect the value of K is the policy-makers commitment to fight inflation. Deviations from PPP may also originate in a change of the international specialisation of countries, namely through the development of activities that are relatively more capital intensive. This may accentuate or blur productivity differentials[10]. Also, a change in domestic production costs caused by the discovery of new oil sources, e.g. in the North Sea, may lead to deviations from PPP. In fact, when the economy expands, the real exchange rate may appreciate in such a way that it may jeopardise efforts to industrialise and diversify the country’s structure of production[11].

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[8] See Linder (1961), Grubel and Lloyd (1975), Lancaster (1980) and Balassa (1986). Duarte (1997) reviews this literature.

[9] See Edison (1987), Taylor (1996), Fernández (1998) and Chinn (1999).

[10] Cunha and Machado (1993a) emphasize the part played by public expenditure in the evolution of the real exchange rate. Stein et al. (1995) develop an alternative approach (NATREX models) that explains real exchange rate movements as a function of the weight of the external debt, of capital intensity, technological progress and factor productivity.

[11] This paradoxical phenomenon has been termed, in the economics literature, the *Dutch Disease*. See, e.g., Murphy (1994), who describes the short-run macroeconomic effects of the discovery of oil sources in Colombia. Koutassila (1999) analyses the negative consequences of the same event in Congo and Cameroon. See Eismont and Kuralbaeva (1999) for the Russian case.

Burstein, Neves and Rebelo (2000) emphasise the role of the distribution sector in the dynamics of the real exchange rate. According to them, during a stabilisation process based on the real exchange rate (e.g. Argentina), production costs end up being a small part of consumer prices. The most significant costs seem to be in fact distribution costs, and this may explain deviations from PPP.

In all of these cases, not taking account of the change in K may result in a rejection of the theory of PPP. However, even if we take that into account, deviations from PPP may occur as a result of the fact that what determines K is a function of other elements.

Empirical papers on the issue of determining the equilibrium long-run value of the real exchange rate implicitly use the relative version of PPP. But some authors, such as Edison (1987), Ardeni and Lubian (1991), MacDonald (1995) or Botas and Sousa (1995), consider still another *unrestricted version of PPP*, which may be expressed by means of a price function:

$$P = b \,.\, E^{a1} \,.\, (P^*)^{a2} \qquad (5)$$

After taking logs, we obtain:

$$p = a_0 + a_1 \,.\, e + a_2 \,.\, p^* \qquad \text{com } a_0 = \ln b \qquad (6)$$

This is the version most used in co-integration tests (following the Engle-Granger procedure[12]), though its purpose is "simply" to test for the existence of a common trend in the variables. Notice that if $\alpha_0=0$, $\alpha_2=1$ (symmetry) and $\alpha_1=\alpha_2=1$ (proportionality), we obtain the absolute version of PPP.

In this paper we first tested PPP by examining the time-series properties of the real exchange rate, given by:

$$r = e + p^* - p \qquad (7)$$

To study co-integration we employed the maximum likelihood approach presented in Johansen (1995)[13].

[12] Engle, R. F. and J. Granger (1987), "Co-integration and error correction: representation, estimation and testing", *Econometrica*, 55, pp. 251-276.
[13] Most of the computations were carried out using PcGive 9.0 and PcFiml 9.0. See Hendry and Doornik (1996) for a description of PcGive 9.0, and Doornik and Hendry (1997) for a description of PcFiml 9.0.

## III. DATA

We used annual (A), quarterly (Q) and monthly (M) data, spanning the period 1960-1999[14]. In the case of prices (Consumer Price Index and GDP Deflator) and exchange rates we used either the last observation in the period (LV), the last average value (LAV), or the period's average (PA)[15].

Most of the data come from OECD publications; in general precedence was given to the most recent ones[16]. We aimed at building the longest possible time series (for the sample size to be reasonable) and this made it necessary to conciliate recent and older data sets for Spain and Germany.

In tests of PPP we initially used nominal bilateral exchange rates (E) for the Escudo (ES), the Peseta (PTA) and the German Mark (DM) against the US Dollar (USD) in the process of the computation of the nominal bilateral exchange rates of the Escudo against the German Mark (EESDM), the Escudo against the Peseta (EESPTA), and the Peseta against the German Mark (EPTADM). As indicators for the price level we employed the Consumer Price Index (CPI, monthly data) and the GDP deflator (GDPD, quarterly and annual data). The introduction of this last price index was motivated by the fact that the GDP deflator gives more relevance to tradable goods, which should lead to more robust empirical results concerning the rejection/acceptance of PPP[17].

Another alternative could be to use an index of the prices of exportable goods. However, as Chinn (1998:4) points out, it is likely that the composition of the baskets of exportable goods differs across countries even more than the corresponding CPI basket. In this context, we opted not to employ this kind of index. Thus, using two different price indices, we were able to compute two alternative series for the real exchange rate (R), which is the starting point of our applied study of PPP.

We took logs of the variables and computed indices based in 1990.

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[14] Hakkio and Rush (1990) suggest that we gain information by using high frequency data (monthly and quarterly), which may increase the power of tests. For an alternative view see Ardeni and Lubian (1991) or MacDonald (1995). Kim (1990) reviews the most important results from studies employing data with different frequencies.

[15] The last observation in the period (LV), in the case of annual data, is obtained from the last monthly or quarterly observation in each year, according to whether the original data is monthly or quarterly; in the case of quarterly data, the value comes from the last observation in each quarter. In a similar way, for annual time series, the period's average (PA) is the average of the twelve monthly observations or of the four quarterly observations. In the case of quarterly time series, it is the average of the three observations in each quarter. The last average value (LAV) is computed only for annual series, and equals the average of the three observations in the last quarter of each year.

[16] Estima (www.estima.com) *OECD Main Economic Indicators*. To build the Portuguese time series we also used data from Instituto Nacional de Estatística and Banco de Portugal.

[17] See Edison (1987). Engel (1996) disaggregates price indices into tradable goods indices and non-tradable goods indices. This purports to take into account the existence of stationary and non-stationary components in the real exchange rate. See also Fisher and Park (1991) and Burtein, Neves and Rebelo (2000).

## IV. UNIT ROOT TESTS

For PPP to be confirmed empirically, real exchange rates computed in the way described by equation 7 must be stationary. We employed Augmented Dickey-Fuller tests to study stationarity. The null hypothesis is the non-stationarity of the series, i.e. the existence of a unit root. We accept the null hypothesis if the t-statistic is less than the critical value and we reject it when it is greater. In the last case, we conclude that the series is stationary, i.e. it does not have a unit root.

To implement the ADF test we had to specify the number of lags required to eliminated serial correlation in the errors. To this end, we used tested the significance of individual coefficients, as well as of sets of coefficients. Selection proceeded from the largest to the smallest lag. This procedure was meant to provide a sort of “econometric prudence rule” in the sense that it we thought it to be less misleading to over-parameterise rather than exclude relevant lags. The longest lag was set to thirteen, eight, or five, according to whether the data was monthly, quarterly or annual. When no lag was selected, the Dickey-Fuller test was used and auto-correlation was tested by means of the Durbin-Watson statistic.

The results from the unit root tests (Table 1) generally point to two conclusions.

On one hand, the tests could not reject the hypothesis of a non-stationary real exchange rate between Portugal and Germany (cases 1.1 to 1.9), between Spain and Germany (cases 1.10 to 1.18) and between Portugal and Spain (cases 1.19 to 1.27).

# Table 1: Stationarity Tests for the Real Exchange Rate (PPP)

| Variable | | Period | Critical Value 5% | Critical Value 1% | Lag | t-adf / DF | t-value constant | t-value trend | Stationary |
|---|---|---|---|---|---|---|---|---|---|
| **RCPIESDMM** | S + C + T | 1960:01 ; 1999:07 | -3.421 | -3.982 | **10** | **-3.603*** | **3.583** | **-3.234** | StC* ; **StT*** |
| (1.1) | - | | - | - | - | - | - | - | - |
| **RCPIESDMQLV** | S + C + T | 1960:01 ; 1999:02 | -3.44 | -4.02 | **3** | **-3.655*** | **3.657** | **-3.238** | StC* ; **StT*** |
| (1.2) | - | | - | - | - | - | - | - | - |
| **RCPIESDMQPA** | S + C + T | 1960:01 ; 1999:02 | -3.44 | -4.02 | **4** | **-4.146**** | **4.13** | **-3.59** | StC** ; **StT**** |
| (1.3) | - | | - | - | - | - | - | - | - |
| **RCPIESDMALV** | T + C | 1960:01 ; 1998:01 | -3.535 | -4.224 | **1** | **-4.261**** | **4.25** | **-3.481** | StC** ; **StT**** |
| (1.4) | - | | - | - | - | - | - | - | - |
| **RCPIESDMALAV** | T + C | 1960:01 ; 1998:01 | -3.535 | -4.224 | **1** | **-4.155*** | **4.145** | **-3.441** | StC* ; **StT*** |
| (1.5) | - | | - | - | - | - | - | - | - |
| **RCPIESDMAPA** | T + C | 1960:01 ; 1998:01 | -3.535 | -4.224 | **1** | **-4.509**** | **4.496** | **-3.803** | StC** ; **StT**** |
| (1.6) | - | | - | - | - | - | - | - | - |
| **RGDPDESDMQLV** | S + C + T | 1970:01 ; 1998:04 | -3.45 | -4.042 | **3** | **-2.237** | **2.356** | **-2.186** | **NSt** |
| (1.7) | - | | - | - | - | - | - | - | - |
| **RGDPDESDMQPA** | S + C + T | 1970:01 ; 1998:04 | -3.45 | -4.042 | **3** | **-2.297** | **2.447** | **-2.138** | **NSt** |
| (1.8) | - | | - | - | - | - | - | - | - |
| **RGDPDESDMAPA** | T + C | 1960:01 ; 1998:01 | -3.539 | -4.232 | 2 | -1.076 | 1.136 | -1.407 | NSt |
| (1.9) | C | | -2.945 | -3.623 | **2** | **-0.9539** | 0.941 | - | **NSt** |
| **RCPIPTADMM** | S + C + T | 1960:01 ; 1999:07 | -3.421 | -3.982 | 1 | -2.655 | 2.712 | -1.632 | NSt |
| (1.10) | S + C | | -2.868 | -3.446 | **1** | **-2.117** | **2.217** | - | **NSt** |
| **RCPIPTADMQLV** | S + C + T | 1960:01 ; 1999:02 | -3.439 | -4.019 | 0 | -2.404 | 2.427 | -1.419 | NSt |
| (1.11) | S + C | | -2.88 | -3.473 | **0** | **-1.973** | **2.028** | - | **NSt** |
| **RCPIPTADMQPA** | S + C + T | 1960:01 ; 1999:02 | -3.439 | -4.019 | 1 | -2.567 | 2.552 | -1.516 | NSt |
| (1.12) | S + C | | -2.88 | -3.473 | **1** | **-2.11** | **2.111** | - | **NSt** |
| **RCPIPTADMALV** | T + C | 1960:01 ; 1998:01 | -3.531 | -4.216 | 0 | -2.493 | 2.465 | -1.471 | NSt |
| (1.13) | C | | -2.94 | -3.612 | **0** | **-2.047** | **2.031** | - | **NSt** |
| **RCPIPTADMALAV** | T + C | 1960:01 ; 1998:01 | -3.531 | -4.216 | 0 | -2.288 | 2.258 | -1.267 | NSt |
| (1.14) | C | | -2.94 | -3.612 | **0** | **-1.971** | 1.955 | - | **NSt** |
| **RCPIPTADMAPA** | T + C | 1960:01 ; 1998:01 | -3.535 | -4.224 | 1 | -3.052 | 3.012 | -1.768 | NSt |
| (1.15) | C | | -2.94 | -3.612 | **0** | **-1.845** | 1.827 | - | **NSt** |
| **RGDPDPTADMQLV** | S + C + T | 1970:01 ; 1999:01 | -3.449 | -4.039 | **0** | **-2.688** | **2.694** | **-2.227** | **NSt** |
| (1.16) | S + C | | - | - | - | - | - | - | - |
| **RGDPDPTADMQPA** | S + C + T | 1970:01 ; 1999:01 | -3.449 | -4.039 | **0** | **-2.432** | **2.428** | **-1.987** | **NSt** |
| (1.17) | S + C | | - | - | - | - | - | - | - |
| **RGDPDPTADMAPA** | T + C | 1970:01 ; 1998:01 | -3.622 | -4.417 | **5** | **-3.34** | **3.315** | **-3.087** | **NSt** |
| (1.18) | C | | - | - | - | - | - | - | - |
| **RCPIESPTAM** | S + C + T | 1960:01 ; 1999:07 | -3.421 | -3.982 | 12 | -2.286 | 0.357 | -0.657 | NSt |
| (1.19) | S + C | | -2.868 | -3.447 | **12** | **-2.271** | 0.087 | - | **NSt** |
| **RCPIESPTAQLV** | S + C + T | 1960:01 ; 1999:02 | -3.44 | -4.02 | 3 | -1.959 | 1.261 | -0.793 | NSt |
| (1.20) | S + C | | -2.88 | -3.474 | **3** | **-1.952** | 0.99 | - | **NSt** |
| **RCPIESPTAQPA** | S + C + T | 1960:01 ; 1999:02 | -3.44 | -4.02 | 3 | -2.208 | 1.502 | -0.747 | NSt |
| (1.21) | S + C | | -2.88 | -3.474 | 3 | **-2.2** | 1.308 | - | **NSt** |
| **RCPIESPTAALV** | T + C | 1960:01 ; 1998:01 | -3.531 | -4.216 | 0 | -1.957 | 1.811 | -0.784 | NSt |
| (1.22) | C | | -2.94 | -3.612 | 0 | -1.979 | 1.701 | | NSt |
| | C | | -2.942 | -3.617 | **1** | **-2.818** | **2.503** | - | **NSt** |
| **RCPIESPTAALAV** | T + C | 1960:01 ; 1998:01 | -3.531 | -4.216 | 0 | -1.86 | 1.767 | -0.789 | NSt |
| (1.23) | C | | -2.94 | -3.612 | **0** | **-1.899** | 1.634 | - | **NSt** |
| **RCPIESPTAAPA** | T + C | 1960:01 ; 1998:01 | -3.535 | -4.224 | 1 | -2.86 | 2.375 | -0.522 | NSt |
| (1.24) | C | | -2.942 | -3.617 | **1** | **-2.927** | **2.613** | - | **NSt** |
| **RGDPDESPTAQLV** | S + C + T | 1970:01 ; 1998:04 | -3.449 | -4.04 | 0 | -1.493 | 1.815 | -1.146 | NSt |
| (1.25) | S + C | | -2.887 | -3.488 | **0** | **-1.812** | 1.47 | - | **NSt** |
| **RGDPDESPTAQPA** | S + C + T | 1970:01 ; 1998:04 | -3.449 | -4.04 | 0 | -1.345 | 2.147 | -1.296 | NSt |
| (1.26) | S + C | | -2.887 | -3.489 | **3** | **-1.913** | 1.279 | - | **NSt** |
| **RGDPDESPTAAPA** | T + C | 1970:01 ; 1998:01 | -3.58 | -4.323 | 0 | -1.136 | 2.244 | -1.687 | NSt |
| (1.27) | C | | -2.971 | -3.685 | **0** | **-1.692** | 1.533 | - | **NSt** |

**Note 1:** Values in **bold** were retained for our later analysis. Notation: S=Seasonality; C=Constant; T=Trend; NSt=Non-stationary; St=Stationary; Z=Statistically insignificant. We considered the constant and the trend not to be significant when the corresponding statistic was less than 1.96 in absolute value.

**Note 2:** (*) and (**) mean rejection of the null hypothesis at the 5% and the 1% level, respectively.

**Example of interpretation**: the real exchange rate, computed using the Consumer Price Index, between the Escudo and the German Mark, at annual frequency – last observation in the period (RCPIESDMALV) –, is trend stationary, the trend being significant at the 1% critical level (StT**).

Therefore, we accepted the hypothesis that there is a unit root, which indicates the existence of long-run disequilibria in the foreign exchange market. In effect, none of the ADF tests in Table 1 favoured constant mean stationarity, which means that if a shock occurs, deviations will persist and there is no tendency to return to the equilibrium value.

On the other hand, the tests pointed to the trend stationarity of some series, namely of the real exchange rate between Portugal and Germany computed using the CPI (cases 1.1 to 1.6).

**Figures 1 to 6: Real Exchange Rate (Portugal vs. Germany)**

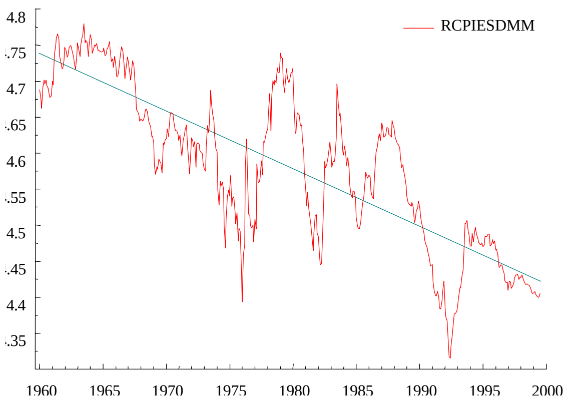


Figure 1

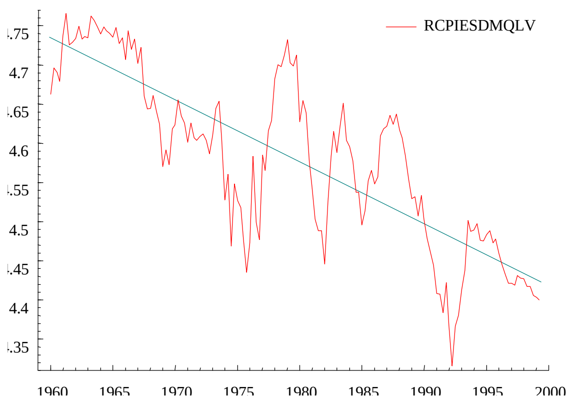


Figure 2

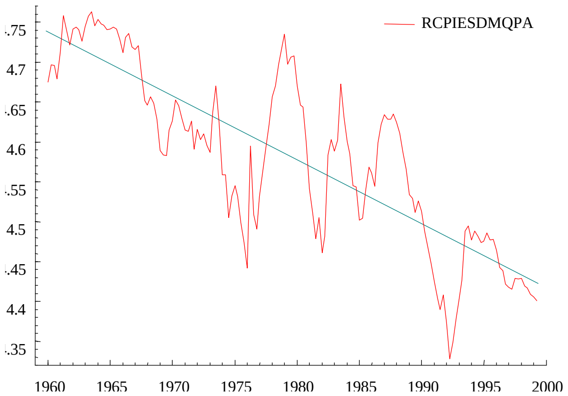


Figure 3

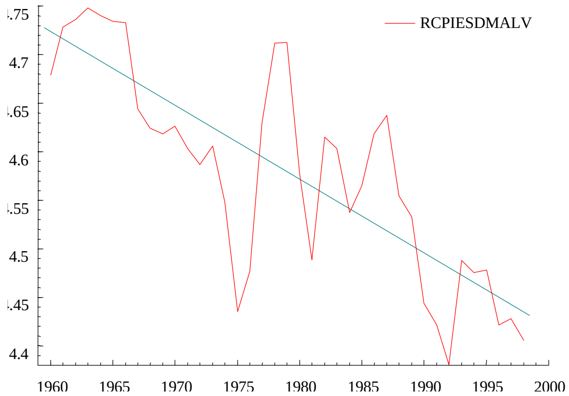


Figure 4

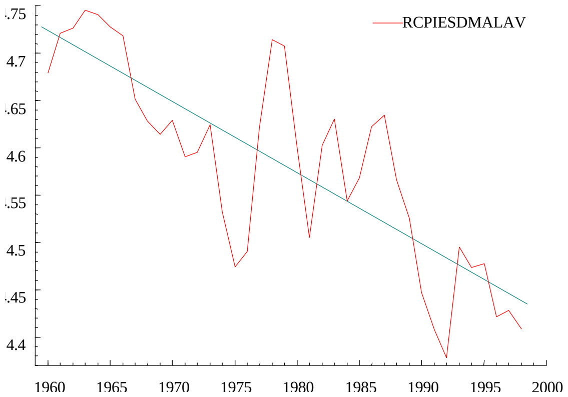


Figure 5

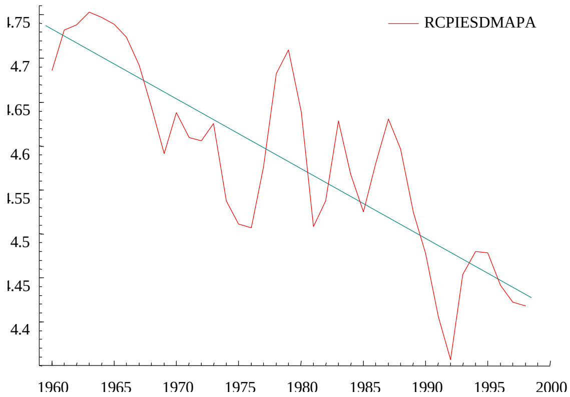


Figure 6

Figures 1 to 6 reveal that there is "mean reversion" to a trend, thus corroborating the tests. Actually, disturbances to the real exchange rates caused, for instance, by devaluations of the Escudo, did not persist. Instead the series returned to the trend values[18].

A more detailed analysis of the unit root tests shows that:

i) Contrary to what is sometimes suggested, use of annual, quarterly or monthly data did not significantly affect our results. The stationarity results were robust to the frequency of the data.

ii) Although it gives more weight to tradable goods, use of the GDP deflator did not lead to more satisfactory results. Though we concluded that the real exchange rate series were non-stationary, they were trend stationary only when they were computed using the Consumer Price Index, which is contrary to our initial expectations. However, as Chinn (1998:4) observes, if consumption goods become more alike across the countries that produce them or resale them, then the Consumer Price Index may give a more adequate measure of the price level and thus of the real exchange rate. This is probably what happened in the case of Portugal and Germany, since trade between them has been growing in importance, especially at the intra-industry level.

iii) In a situation in which PPP does not hold, one could think that on account of some "natural reason" agents believe that, as time goes by, the dominant currency, which is also the reference currency of the EMS (the German Mark), will appreciate. We concluded, on the contrary, that the weaker currencies and, especially, the Portuguese Escudo, which are not traditionally used in the international commercial relations, were the ones that with the passing of time appreciated in real terms.

Though the overall results are not so clear in the case of Spain, the Spanish Peseta has also appreciated in real terms relative to the German Mark, especially between 1987 and 1997[19]. Notice also that the Portuguese and the Spanish economies share the same geographical area, their specialisation is overlapping in certain goods, and they compete with one another in other markets.

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[18] In fact, the trend was for the Escudo to appreciate in real terms. We will return to this result later on.
[19] See Cunha and Machado (1993b). Canzoneri et al. (1998) notice that productivity growth in Germany is higher than in other EC countries. This may justify the price differentials favourable to Germany and thus the real appreciation of currencies such as the Peseta, the Lira, the Escudo, or the Belgian Franc. See also Olloqui and Rivero (1999).

Therefore, the depreciation of one of the currencies may drag the other one. This "domino effect" may have caused some of the devaluations of the Escudo that followed devaluations of the Peseta[20].

Going back to Figures 1 to 6, they show that, passed the instability period subsequent to the oil shocks, the great period of real appreciation of the Escudo began in 1986, the same year Portugal and Spain joined the EEC. This tendency for the Escudo to appreciate in real terms became stronger over the following years. From the viewpoint of economic policy in most EMS countries, this process was characterised by the choice of the same primary strategic goal: low inflation.

Given its tradition of inflation aversion, Germany has played since then the role of country of reference in Europe. The other countries, such as Portugal, try to make their price levels to converge to those of Germany. In the Portuguese case, the option for price stability was mandatory because of its desire to participate in the third stage of EMU. In this context it is not surprising to observe the tendency for the inflation levels in both countries to come closer, as a result of the decrease in price growth in Portugal. However, in spite of this behaviour, the inflation differential has systematically been unfavourable to Portugal. Taken together with an insufficient nominal depreciation of the Escudo against the Mark, this lead to the tendency for the Escudo to appreciate in real terms. In fact, not even the devaluations of the Escudo of 6%, 6.5%, and 3.5%, in late 1992, 1993 and 1995, were enough to invert this tendency.

These results beg the questions: Why is it that a small economy like Portugal, with a weak currency, did not suffer strong speculative attacks? Why was the nominal devaluation of the Escudo not big enough to stop its real appreciation? After all, we must not forget that a similar phenomenon occurred in other countries, not only Asian but also from Latin America, like Mexico and Argentina, and lead these economies into serious financial crises.

It appears unquestionable that some of the factors mentioned above as responsible for changes in the K term have also helped both the real appreciation of the Escudo and the absence of subsequent speculative attacks. In effect, a major contributor for the fact that Portugal did not endure a crisis like the ones in these countries may well have been the process of integration of the Portuguese economy

[20] Loureiro (1998: 73-130) provides a good chronology of events.

in the European Community, which coincided with the real appreciation of the Escudo. This process of integration allowed Portugal to benefit from the credibility and stability associated to the tacit acceptance of the anti-inflation stance of the Bundesbank's monetary policy and from the pegging of the Escudo to the German Mark. Thus, under the "protection" of both the Exchange Rate Mechanism and the European Union, Portugal managed to escape the effects of potential speculative attacks, i.e. to prevent abrupt falls in foreign exchange reserves that would result from devaluation expectations towards the Escudo, even after the elimination in late 1992 of the last restrictions on capital mobility. In the sequence of this process, Portugal was equally successful in achieving the primary goal of price stability, which was explicitly upheld by the Government.

The Portuguese case may serve as an example to other countries that get involved in an integration process similar to that of Portugal and Spain and that wish to prevent problems related to the appreciation of their currencies in real terms. If they do not, they will be exposed to the eventuality of a financial crisis following speculative attacks against their currencies, as in the cases of several Southeast Asian and Latin American countries in the late 90s. Faced with this possibility, as Cooper (1999) suggests, small countries have no alternative but to join the large dominant monetary zones, even though that means relinquishing their freedom to set monetary and exchange rate policies.

We have finished our analysis of the unit root tests. We proceed to obtain co-integration relations (co-integrating vectors): this is the next step in our study of long-run equilibrium in the foreign exchange market.

## V. CO-INTEGRATION

A necessary step in this part of the analysis is the determination of the order of integration of the variables involved in the PPP condition. If one variable was found to be I(2), we would try and combine it with another one such that the resulting variable would be I(1). For example, in the case of the series RCPIESDMQLV, we found that the nominal exchange rate (e) is I(1) and that both the domestic price (p) and the foreign price ($p^*$) are I(2). However, when the price levels were combined in ($p - p^*$), we obtained an I(1) series. Based on this information, we moved on to co-integration analysis[21]. Thus we employed in a complementary way two methodologies: stationarity analysis (unit root tests) and co-integration analysis.

Our aim is to investigate whether there is a linear combination between the nominal exchange rate and prices that is stationary in the long-run. We wish to find a long-run relation (co-integrating vector) that describes the connection between the variables.

To estimate the co-integrating relations we applied Sören Johansen's maximum likelihood method. Following this procedure, we initially specified a system with the variables suggested by theory, for which purpose we only required that at least two of those variables be I(1)[22].

The way in which I(2) variables were linearly combined to generate I(1) variables was fundamental in this process. Even so, sometimes we could not advance to co-integration analysis because we could not find those I(1) linear combinations. This was the case of the series for real exchange rate between Portugal and Spain when they were constructed using GDPD. In other cases we studied co-integration using the I(2) series differenced. One such case is the that of the series RCPIPTADMQLV, for which initially the nominal exchange rate (e) was I(1) and the domestic (p) and foreign (p*) prices were I(2). After observing that (p–p*) was also I(2), co-integration analysis was applied to the first differences (de, dp and dp*), because these variables were I(0), I(1) and I(1), respectively.

To specify the system we also needed to define the nature of the variables to be included. In the first stage of our research, we considered the nominal exchange rate, the domestic price and the foreign price to be endogenous, as theory suggests. These variables were always assumed to belong to the co-integration space. In the second stage we introduced additional variables in the analysis, both endogenous and exogenous. An example of an endogenous variable added is the domestic interest rate (i), which was included in the co-integration space. An example of an exogenous variable added is the foreign interest rate (i*), which was inside and outside the co-integration space. The constant (C) and the trend (T) received a special treatment in each of the cases above: they were sometimes included

[21] Given the volume of information involved, we do not present all the results from this preliminary study in the paper. However, that information may be requested via e-mail to: portugal@fe.uc.pt.

[22] The others could be I(0). See Johansen (1995). See also Hansen and Juselius (1995). Marques (1998) and Andrade (1999) give some examples.

and sometimes excluded from our analysis. When they were included, the constant was both inside and outside the co-integration space, whereas the trend was always assumed to be inside the co-integration space. Having identified the variables to be included in the system and their status, we proceed to select the number of lags required for the errors to be serially uncorrelated[23].

Using the trace and *l max* (maximum eigenvalue) test statistics and a 95% confidence interval, acceptance/rejection of the null hypothesis was equivalent to acceptance/rejection of the number of vectors indicated by the order of co-integration being tested[24].

The existence of error auto-correlation was assessed equation by equation. If auto-correlation were not rejected, we would choose a higher number lags. If this did not eliminate auto-correlation, we would assess auto-correlation for the complete system by means of a multivariate test. If auto-correlation were not detected, co-integration analysis would proceed with the selection of the number of co-integrating vectors[25]. We would then test (using Wald tests) whether the coefficients in the co-integrating vectors met the requirements for PPP to be valid[26].

The main results obtained using the methodology described above are shown in Table 2.

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[23] We did not add any lags to the exogenous variables. See Doornik and Hendry (1997).

[24] In practice, this means we accept the null hypothesis if the test statistics are less than the respective critical value. We reject the null hypothesis otherwise. However, if the null hypothesis is accepted when the order of co-integration is greater than zero, the interpretation is that we found one or more co-integrating vectors – there is no guarantee that those vectors accord to the theory.

[25] In practice, this means we accept the null hypothesis if the test statistics are less than the respective critical value. We reject the null hypothesis otherwise. However, if the null hypothesis is accepted when the order of co-integration is greater than zero, the interpretation is that we found one or more co-integrating vectors – there is no guarantee that those vectors accord to the theory.

[26] If the tests reveal the existence of two co-integrating vectors, we should continue imposing only one restriction. This will be applied initially at the second order of co-integration level and only afterwards at the level of the first order of co-integration. If the Chi-square statistic rises above 5% in the course of the process, then two co-integrating vectors will have been found. If three or more co-integrating vectors are being tested, the procedure will be similar.

# Table 2: Co-integration Analysis

| Serie (case) | Endogenous vs. Exogenous Variables | Const. | Trend | Error Auto-Correlation (chi^2) | Lags. End. | CO-INTEGRATION VECTOR | General Restriction (LR-Test Chi^2) |
|---|---|---|---|---|---|---|---|
| RCPIESDMM | e; (p - p*) | U | T | 12.78[0.385] ; 17.35[0.136] | 15 | | 13.43[0.0002]** |
| (2.1) | " | - | - | 18.12[0.112] ; 10.82[0.544] | 72 | 1ª: 1.e –1.(p – p*) | 2.46[0.116] |
| RCPIESDMQLV | e; (p – p*) | U | T | 4.63[0.327] ; 8.43[0.077] | 4 | 1ª: 1.e – 1.(p – p*) + 0.0021279.Trend | 2.51[0.113] |
| (2.2) | " | U | T=0 | 4.63[0.327] ; 8.43[0.077] | 4 | | 17.96[0.0001]** |
| RCPIESDMQPA | e; (p – p*) | U | T | 8.81[0.065] ; 3.55[0.469] | 4 | 1ª: 1.e – 1.(p – p*) + 0.0021911.Trend | 2.58[0.1077] |
| (2.3) | " | - | T | | | | |
| RCPIESDMALV | de; dp; dp* | U | - | 2.34[0.31] ; 4.74[0.09] ; 3.61[0.16] | 3 | 1ª: 1.de – 1.dp + 1.dp* | 4.59[0.1005] |
| (2.4) | " | C | T | | | | |
| RCPIESDMALAV | de; dp; dp* | U | T | 2.02[0.36] ; 0.82[0.66] ; 5.92[0.05] | 2 | 1ª: 1.de – 1.dp + 1.dp* | 3.27[0.194] |
| (2.5) | " | C=0 | T | | | | |
| RCPIESDMAPA | de; dp; dp* | U | - | 5.79[0.05] ; 2.56[0.27] ; 0.24[0.88] | 2 | 1ª: 1.de – 1.dp + 1.dp* | 1.19[0.5509] |
| (2.6) | " | U | T=0 | Test Multivariate: 22.549[0.2085] | 2 | 1ª: 1.de – 1.dp + 1.dp* + 0.000.Trend | 1.30[0.7286] |
| RGDPDESDMQLV | p*, (e – p) | - | - | Test Multivariate: 24.001[0.0895] | 1 | | 13.195[0.003]** |
| (2.7) | p*, (e – p); i; i* | U | - | Test Multivariate: 45.553[0.1325] | 1 | 1ª: 1.p* + 1.(e – p) – 2.595.i + 5.629.i* | 0.00505[0.9433] |
| RGDPDESDMQPA | p*, (e – p) | C | - | 2.33[0.674] ; 8.14[0.086] | 5 | | 10.01[0.0016]** |
| (2.8) | p*, (e – p); i; i* | U | - | Test Multivariate: 47.038[0.1030] | 2 | 1ª: 1.p* + 1.(e – p) – 2.618.i + 6.850.i* | 1.5297[0.2162] |
| RGDPDESDMAPA | p*, (e – p) | - | - | 0.44[0.8005] ; 4.513[0.104] | 3 | 1ª: 1.p* + 1.(e – p) | 0.00366[0.9517] |
| (2.9) | " | C=0 | - | 1.74[0.417] ; 3.94[0.139] | 4 | 1ª: 1.p* + 1.(e – p) – 0.000.Constant | 0.531[0.7665] |
| | | | | | | | |
| RCPIPTADMM | e; (p - p*) | - | T=0 | | | | |
| (2.10) | e; (p - p*); (i – i*)U | U | T | 19.529[0.076] ; 13.988[0.3015] | 17 | 1ª: 1.e – 1.(p –p*) – 0.0035468.Trend | 0.01305[0.9090] |
| RCPIPTADMQLV | de; dp; dp* | U | - | 4.67[0.32] ; 4.94[0.29] ; 6.91[0.14] | 5 | 1ª: 1.de – 1.dp + 1.dp* | 2.6562[0.2650] |
| (2.11) | " | C | - | 4.67[0.32] ; 4.94[0.29] ; 6.91[0.14] | 5 | 1ª: 1.de – 1.dp + 1.dp* + 0.0023.Const | 2.6379[0.2674] |
| RCPIPTADMQPA | de; dp; dp* | U | - | 4.42[0.35] ; 9.48[0.05] ; 8.46[0.07] | 4 | 2ª ; L1: 1.de – 1.dp + 1.dp* | 0.48272[0.4872] |
| (2.12) | " | " | " | " | " | - 0.0565.de + 0.5499.dp – 1.2557.dp* | " |
| | " | " | " | " | " | 2ª ; L2: - 1.08.de + 0.49.dp + 0.34.dp* | " |
| | " | " | " | " | " | 1.de – 1.dp + 1.dp* | " |
| | " | " | " | " | " | 1ª: 1.de – 1.dp + 1.dp* | 5.4938[0.0641] |
| | " | C=0 | T=0 | | | | |
| RCPIPTADMALV | de; dp; dp* | U | - | Test Multivariate: 25.308[0.1167] | 1 | 2ª; L1: 1.de – 1.dp + 1.dp* | 0.74108[0.3893] |
| (2.13) | " | " | " | " | " | -0.0699.de + 0.4746.dp – 1.3039.dp* | " |
| | " | " | " | " | " | 2ª ; L2: -1.19.de + 0.75.dp + 0.14.dp* | " |
| | " | " | " | " | " | 1.de – 1.dp + 1.dp* | " |
| | " | " | " | " | " | 1ª: 1.de – 1.dp + 1.dp* | 1.9463[0.3779] |
| | " | U | T=0 | Test Multivariate: 27.694[0.0669] | 1 | 1ª: 1.de – 1.dp + 1.dp* + 0.000.Trend | 2.1084[0.5502] |
| RCPIPTADMALAV | de; dp; dp* | U | T | 3.95[0.13] ; 2.06[0.35] ; 4.69[0.09] | 4 | | 14.38[0.0008]** |
| (2.14) | " | _ | _ | 1.62[0.44] ; 1.06[0.58] ; 3.10[0.21] | 3 | 2ª ; L1: 1.de – 1.dp + 1.dp* | 0.84395[0.3583] |
| | " | " | " | " | " | 0.16091.de – 0.6771.dp + 1.5441.dp* | " |
| | " | " | " | " | " | 2ª ; L2: 1.04.de – 0.32.dp – 0.88.dp* | " |
| | " | " | " | " | " | 1.de – 1.dp + 1.dp* | " |
| | " | " | " | " | " | 1ª: | 6.482[0.0391]* |
| RCPIPTADMAPA | de; dp; dp* | U | - | 3.81[0.14] ; 3.27[0.19] ; 3.21[0.20] | 2 | | 13.63[0.0011]** |
| (2.15) | de; dp; dp*; i; i* | C | - | 4.1[0.12];3.4[0.1];3.6[0.1];2.1[0.3] | 1 | 2ª ; L1: 1.de – 1.dp + 1.dp* - 0.331.i - | 2.3699[0.1237] |
| | | | | | | - 0.026253.Constant + 0.39326.i* | |
| | " | " | " | " | " | 0.025.de – 0.2614.dp + 1.2356.dp* + | " |
| | | | | | | 0.192.i + 1.014.Constant – 1.1584.i* | |
| RGDPDPTADMQLV | e; p; p* | U | T=0 | 5.27[0.26] ; 7.36[0.11] ; 1[0.9098] | 2 | 1ª: 1.e – 1.p +1.p* - 0.000.Trend | 6.7751[0.0794] |
| (2.16) | " | - | - | 6.24[0.18] ; 6.25[0.18] ; 0.75[0.94] | 2 | | 22.77[0.0000]** |
| RGDPDPTADMQPA | e; p; p* | U | T=0 | 8.25[0.08] ; 7.27[0.12] ; 0.81[0.93] | 2 | 1ª: 1.e – 1.p +1.p* - 0.000.Trend | 7.2422[0.0646] |
| (2.17) | " | C | - | 8.25[0.08] ; 7.59[0.10] ; 0.80[0.93] | 2 | | 5.0528[0.0246]* |
| RGDPDPTADMAPA | e; p; p* | U | T=0 | Test Multivariate: 22.498[0.2106] | 2 | 2ª ; L1: 1.e – 1.p* + 0.000.Trend | 2.0585[0.3573] |
| (2.18) | " | " | " | " | " | -0.8.e + 0.3.p + 0.5.p* + 0.0002.Trend | " |
| | " | " | " | " | " | 2ª ; L2: 0.2.e + 0.1.p – 1.0.p*- 0.0002.T | " |
| | " | " | " | " | " | 1.e – 1.p +1.p* - 0.000.Trend | " |
| | " | " | " | " | " | 1ª: | 8.7853[0.0323]* |
| | " | C | - | Test Multivariate: 27.977[0.0624] | 3 | | 9.837[0.0073]** |
| | | | | | | | |
| RCPIESPTAM | e; (p – p*) | U | T | 11.545[0.4829] ; 11.636[0.4754] | 21 | | 11.23[0.0008]** |
| (2.19) | " | C | - | 12.121[0.4360] ; 8.8852[0.7127] | 76 | 1ª: 1.e – 1.(p – p*) – 0.12715.Constant | 2.4176[0.1200] |
| RCPIESPTAQLV | e; (p – p*) | U | - | 7.0085[0.1354] ; 2.5027[0.6441] | 23 | 1ª: 1.e – 1.(p – p*) | 2.9292[0.0870] |
| (2.20) | " | U | T=0 | 1.7308[0.7851] ; 7.5161[0.1110] | 8 | | 12.92[0.0016]** |
| RCPIESPTAQPA | e; (p – p*) | U | - | 8.0144[0.0911] ; 1.2555[0.8689] | 23 | 1ª: 1.e – 1.(p – p*) | 3.3121[0.0688] |
| (2.21) | " | - | T | | | | |
| RCPIESPTAALV | de; dp; dp* | C | T | | | | |
| (2.22) | " | - | - | Test Multivariate: 26.069[0.0982] | 2 | 1ª: 1.de – 1.dp + 1.dp* | 5.934[0.0515] |
| RCPIESPTAALAV | de; dp; dp* | - | - | 1.10[0.57] ; 1.40[0.49] ; 2.18[0.33] | 2 | 1ª: 1.de – 1.dp + 1.dp* | 4.8636[0.0879] |
| (2.23) | " | C | - | 0.01[0.99] ; 1.006[0.60] ; 1.9[0.38] | 2 | | 10.58[0.0050]** |
| RCPIESPTAAPA | de; dp; dp* | U | - | 0.84[0.65] ; 2.66[0.26] ; 1.76[0.41] | 1 | | 6.5789[0.0373]* |
| (2.24) | " | - | - | 0.73[0.69] ; 2.07[0.35] ; 0.92[0.62] | 1 | 1ª: 1.de – 1.dp + 1.dp* | 4.0045[0.1350] |

**Note 1**: For each series (case), only two of the alternatives investigated are presented. However, we attempted to publicise in some way all the peculiarities encountered in the results.

**Note 2**: Notation: U=Unrestricted Constant (outside the co-integration space); C= Unrestricted Constant (inside the co-integration space); C=0=Constant restricted to be zero (inside the co-integration space); T=Unrestricted Trend (inside the co-integration space); T=0=Trend restricted to be zero (inside the co-integration space); -=Constant and Trend excluded from the analysis.

Several conclusions may be drawn from that Table.

On one hand, regardless of the series' frequency we were able to find at least one co-integrating vector respecting PPP in most cases. Exceptions are two instances between Portugal and Germany (cases 2.2 and 2.3) and one between Spain and Germany (case 2.10). In these cases the long-run relation was trend stationary. Though unit root tests did not reject non-stationarity for the real exchange rate, through co-integration analysis we obtained linear long-run relations compatible with PPP theory. In certain cases this was related with the fact that auto-correlation was tested with the multivariate test; otherwise co-integration relations that matched PPP could not be have been found.

On the other hand, note that the previous results depend on the variables included in the system to be estimated. Actually, had we only considered the variables suggested by PPP theory, the Wald test would have rejected the required restriction in four of the cases studied. Two between Portugal and Germany (cases 2.7 and 2.8) and two between Spain and Germany (cases 2.10 e 2.15). However, when we included the countries interest rates as explanatory variables for the long-run errors, we concluded that that situation was no longer possible.

Testing PPP including interest rates in the analysis was especially interesting in cases 2.7, 2.8 and 2.15. In these cases, the corresponding co-integrating vector, besides matching PPP, exhibited a negative relation between the nominal exchange rate and the domestic interest rate, and a positive relation between the nominal exchange rate and the foreign interest rate. In the context of perfect capital mobility, these long-run relations would also accord to the mechanism by which an increase (reduction) in the domestic interest rate relative to the foreign interest rate would lead to an appreciation (depreciation) of the domestic currency. In case 2.10, although interest rates were included in the analysis, the long-run relation was only stationary around a trend.

## VI. CONCLUSION

This purpose of our study was to use Purchasing Power Parity theory to analyse of the behaviour of the exchange rate in three EMU countries in the period 1960-1999.

Unit-root based tests of PPP did not reject the hypothesis of non-stationarity of the real exchange rate, which is a symptom of the long-run persistence of disequilibria in the foreign exchange market. The results also showed that some real exchange rate series were trend stationary, leading us to believe that there is a mean reversion phenomenon around a trend. This outcome is particularly important if we think that, in a situation in which PPP does not hold, agents believe, on account of some “natural reason”, that as time goes by the dominant currency in the EMS (the German Mark) will appreciate. We concluded, on the contrary, that the weaker currencies — especially the Portuguese Escudo — were the ones that with the passing of time appreciated in real terms.

The fact that the Portuguese economy was in the process of integrating the EC when the strongest real appreciation of the Escudo took place, may have allowed Portugal to benefit from the credibility and stability that resulted from accepting the anti-inflation stance of Germany’s monetary policy and from pegging the Escudo to the Mark. Thus the Portuguese economy avoided the negative effects of possible speculative attacks against the Escudo. As we mentioned before, the process of integration of Portugal in the EC may serve as an example to other small economies in the sense that they will have an interest in joining on of the dominant monetary zones.

Using Johansen’s co-integration methodology, we observed that in most cases we could find at least one co-integrating vector matching PPP. In three cases, the results depended on using the countries’ interest rates to explain the deviations from the long-run relation implied by PPP theory.

However, the application of PPP theory should not be “confined” to the search for long-run relations: it should also lead to the study of short-run dynamics. Therefore, in future research the construction of models with an error-correction mechanism should be considered, especially if our aim is to estimate also short-run adjustment coefficients, i.e. to find more concrete explanations for those situations in which deviations from theory occur through the incorporation of the long-term adjustment errors.

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