Exchange Rate Mean Reversion within a Target Zone: Evidence from a Country on the Periphery of the ERM

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Abstract

The aim of this study is to assess to what extent the Portuguese participation in the European Monetary System has been characterized by mean reverting behaviour, as predicted by the exchange rate target zone model developed by Krugman (1991). For this purpose, a new class of mean reversion tests is introduced. The empirical analysis of mean reversion in the Portuguese exchange rate shows that most of the traditional unit root and stationarity tests point to the nonstationarity of the exchange rate within the band. However, using a set of variance-ratio tests, it was possible to detect the presence of a martingale difference sequence. This suggests that the Portuguese foreign exchange market has functioned efficiently, allowing us to conclude that the adoption of an exchange rate target zone regime has contributed decisively to the creation of the macroeconomic stability conditions necessary for the participation of Portugal in the euro area.

JEL Classification: C32, C51, F31, F41, G15.
Key Words: Martingale difference sequence, mean reversion, stationarity, target zones and unit roots.

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1. Introduction

Exchange rate mean reversion within the band is one of the main predictions of the target zones literature, since it is expected that the exchange rate is stationary around the central parity. If a floating band for the exchange rate is credible, this should be borne out by a strong mean reverting behaviour within the band conducive to a degree of stability of the exchange rate that is present neither under a free floating exchange rate regime nor even in a conventional managed floating system.

Although exchange rate mean reversion is widely referred to in the literature (see, e.g. Krugman (1991), Svensson (1992, 1993), Rose and Svensson (1994)), and usually taken as a natural property of an exchange rate target zone regime, only a small number of studies have been devoted to the analysis of its empirical validity. Most of this work has been based almost exclusively on standard Augmented Dickey-Fuller (ADF) unit root tests and focused especially on the most stable and credible bands, ignoring completely the currencies on the periphery of the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS)[1]. In our study we attempt to overcome this important insufficiency in the target zone literature.

For this purpose, we studied the stationarity of the Portuguese escudo against the Deutschmark in the context of the participation of the Portuguese currency in the ERM of the EMS, based not only on the traditional unit root and stationarity tests (ADF, KPSS, Perron and Lanne tests), but also on a set of variance-ratio tests (Hamilton 1994; Maddala and Kim 1999; Marques 1998; Andrade 2004). The aim with this second set of tests was to analyse the effects of a unit shock on the exchange rate series over time (Cochrane test). If the shock is neutralised the exchange rate displays a mean reverting behaviour within the band. We also tried to ascertain whether the foreign exchange market could still work efficiently (Wright test) if there is no mean reversion. To accomplish this, we analysed the existence of a martingale difference sequence in the exchange rate series.

The paper is structured as follows. Section 2 presents the theoretical approach based on the target zone model developed by Krugman (1991). Section 3 explores the existence of mean reverting behaviour in the exchange rate within the band of the Portuguese escudo against the Deutschmark. Finally, Section 4 draws some conclusions.

[1] Exceptions include the work by Nieuwland, Verschoor and Wolff (1994) and Anthony and MacDonald (1998, 1999).

2. Exchange Rate Mean Reversion within a Target Zone: A Theoretical Approach

According to the basic target zone model proposed by Krugman (1991), the behaviour of the exchange rate within the band depends on an aggregate fundamental and its expected rate of change, as can be described by the following equation:

$$s(t) = f(t) + \alpha \, E_t\left[ds(t)\right] \; / \, dt \, , \qquad \forall t \text{ and } \alpha > 0 \, , \tag{1}$$

where *s(t)* is the log of the nominal exchange rate at time *t*, *f(t)* is the fundamental at time *t*, α is the absolute value of the semi-elasticity of the exchange rate with respect to its expected rate of change and E_t is the conditional expectations operator on the available information at time *t*, according to the rational expectations hypothesis.

The fundamental is the sum of two components,

$$f(t) = m(t) + v(t) \, , \tag{2}$$

the domestic money supply, *m(t)*, and a term representing a composite money demand shock, usually referred to in the literature on target zones as “velocity”, *v(t)*. The model assumes that “velocity” is an exogenous stochastic process, whereas the money supply is a stochastic process controlled by the monetary authorities. The question is then how the presence of a credible floating band may affect the behaviour of the exchange rate.

In the absence of any intervention, a situation common in a free floating regime, it is assumed that the money supply *m(t)* is kept constant. As a consequence, the fundamental is simply equal to “velocity”, *f(t) = v(t)*. It is thus assumed that “velocity” follows a Brownian motion with drift μ and instantaneous standard deviation σ:

$$dv(t) = \mu \, dt + \sigma \, dz(t) \, , \ \mu \text{ and } \sigma \text{ positive parameters and } v(0) > 0 \, , \tag{3}$$

where *z(t)* is a Wiener process with $E_t\left[dz(t)\right] = 0$ and $E_t\left[\left(dz(t)\right)^2\right] = dt$, that is, *f(t)* is the equivalent of a continuous random walk (Merton 1992; Campbell, Lo and Mackinlay 1997; Maddala and Kim 1999; Demange and Rocher 2005).

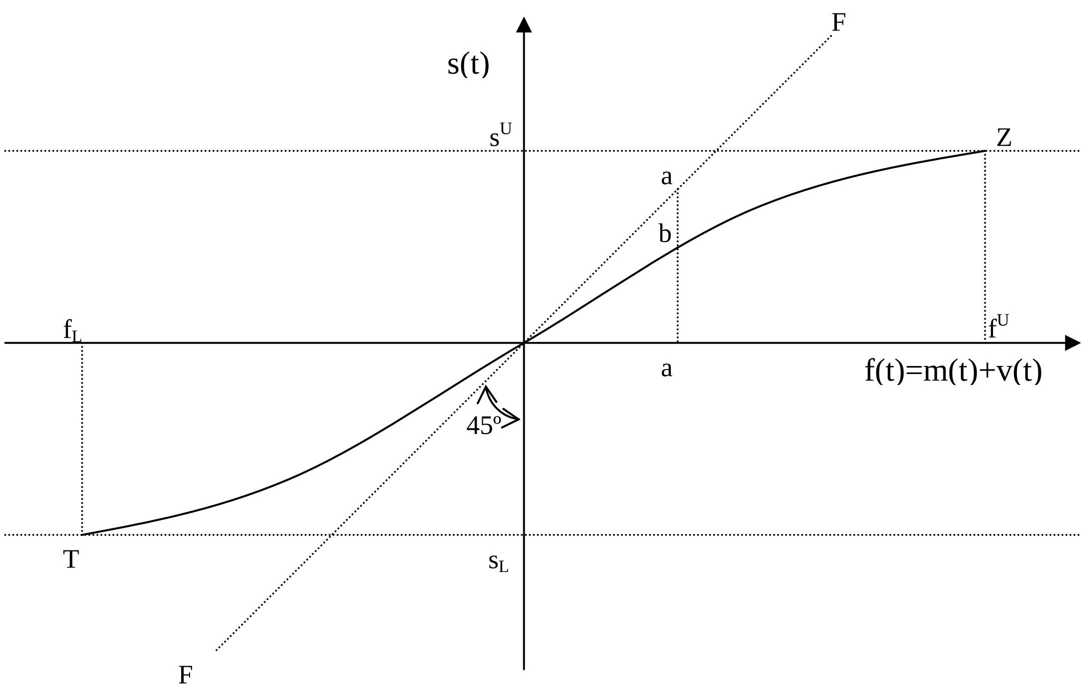
This assumption implies that the exchange rate under a free floating regime is also a Brownian motion. Therefore, changes in the fundamental will translate into equal changes in the exchange rate, *ds(t)=df(t)*.

In a target zone, it is assumed that the intervention rule is based on a specific floating band for the fundamental, $f_L \le f(t) \le f^U$, and that, if necessary, the fundamental will be regulated to remain within the band. This implies that the fundamental follows a regulated Brownian motion with constant drift and instantaneous standard deviation[2]:

$$df(t) = \mu\, dt + \sigma\, dz(t) + dL(t) - dU(t), \qquad (4)$$

where $L(t)$ and $U(t)$ are the lower and upper regulators, defined as continuous and increasing functions of t, so that $dL(t)$ represents increases in the money supply, positive only if $f(t)=f_L$, and $dU(t)$ represents decreases in the money supply, positive if $f(t)=f^U$. Under these circumstances the exchange rate function establishes a non-linear relationship between the exchange rate and its fundamental, as illustrated in Figure 1.

Figure 1: Exchange Rate in a Perfectly Credible Target Zone



The straight-line FF represents the equilibrium exchange rate in the free floating case. A shock in $v(t)$ leads to a proportional change in $f(t)$ and $s(t)$. The exchange rate target zone function is tangent to the edges of its floating band, where $s_L=s(f_L)$ and $s^U=s(f^U)$, represented by the curve TZ, non-linear, and S-shape, respectively.

[2] Harrison (1985) and Karatzas and Shreve (1997) provide a formal presentation of these processes.

The behaviour of the exchange rate in a target zone with perfect credibility leads to two main results. First, the slope of the curve TZ is always less than one. This feature is called the "honeymoon effect", a reference by Krugman (1987: 19) to a "target zone honeymoon". The exchange rate function thus appears less sensitive to changes in the fundamental than the corresponding free floating exchange rate. Moreover, the part of the adjustment supported by the exchange rate in a target zone is not constant, but decreases as the exchange rate moves away from the central parity. The "honeymoon effect" thus implies that a perfectly credible target zone is inherently stabilising[3].

Second, the curve TZ becomes flatter, reaching a zero slope at the edges of the band. At the edges of the target zone, the exchange rate function is tangential to the horizontal dashed lines that represent the edges of the exchange rate band. This result is known as a "smooth pasting" condition.

These results imply that the exchange rate within the band displays mean reversion. This mean reversion is an important general property of exchange rates in the context of a target zone because it is expected that the exchange rates are stationary around the central parity.

In this context the expected mean reversion of the exchange rate around the central parity gives the monetary authorities some autonomy in the execution of the monetary policy. Acting on the position of the exchange rate within the band, the monetary authorities would be able to control the level of the interest rate. This autonomy would be the main reason for the adoption of a target zone regime. Indeed, we can find here the main difference between a free floating regime and a target zone. In a free floating regime, the exchange rate is responsible for the whole adjustment process following a monetary shock. In a target zone, the exchange rate and interest rates "share" that responsibility (Duarte, Andrade and Duarte 2008).

[3] Returning to Figure 1, if we consider that a positive random shock in *v(t)* increases the fundamental from the origin to point *a*, under a free floating regime the exchange rate increases by the same amount. However, in a target zone, agents recognize that there is a high probability of a future contraction in the money supply. Thus, agents expect the future appreciation of the exchange rate. This results in an equilibrium exchange rate that is less than *a*, at point *b*.

3. Exchange Rate Mean Reversion: Evidence from the Portuguese Case

The framework of the Portuguese monetary and foreign exchange policy changed on April 6 1992 when the Portuguese escudo joined the ERM of the EMS. This was made possible by the better convergence of the Portuguese inflation rate to the European Union's average level and, in particular, to Germany (Duarte 2009). The central parity was fixed at 178.735 and 86.9393 escudos against the ECU and the Deutschmark, respectively, and the Portuguese escudo was allowed to fluctuate within a band of ±6%.

From that date onwards, there was a formal commitment to keep the Portuguese escudo within the band, the credibility of the disinflation policy increased and thus facilitated the pursuit of the price stability goal. This foreign exchange policy course was maintained until the end of 1998, in spite of the disturbances that affected the EMS. Table 1 summarizes these events, allowing us to identify the main features of the Portuguese exchange rate target zone with the Deutschmark as the reference currency.

Table 1: Bands for the Portuguese Target Zone

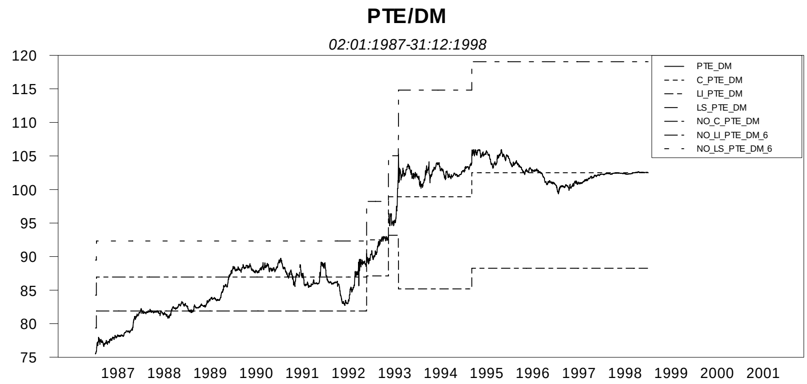
Period / Date	Band	PTE/DM		
		Lower Edge	**Central Parity**	**Upper Edge**
6 April 1992	±6%	81.9	86.9393	92.336
23 November 1992	±6%	87.108	92.488	98.232
13 May 1993	±6%	93.197	98.9177	105.042
2 August 1993	±15%	85.179	98.9177	114.811
6 March 1995	±15%	88.277	102.505	119.033

Source: Banco de Portugal.

In Figure 2 we depict the behaviour of the Portuguese escudo exchange rate against the Deutschmark as part of the PTE/DM band[4]. Besides the target zone period, we simulated, from January 2 1987 to April 5 1992, an unofficial band of ±6%, with an unofficial central parity (No_C_PTE_DM) and unofficial intervention edges (No_LI_PTE_DM_6 and No_LS_PTE_DM_6) equal to those adopted when the PTE joined the ERM of the EMS[5].

[4] See Appendix I for a description of the data used.
[5] See Appendix II for a complete list of variables and their description.

Figure 2: The Behaviour of the PTE/DM Exchange Rate



Source: Banco de Portugal.

As we can see, the PTE/DM exchange rate had been relatively stable since the beginning of the 1990s. This was the result of the pegging of the Portuguese escudo to the Deutschmark, which allowed the Portuguese currency to benefit from the credibility, stability and discipline associated with the tacit acceptance of the anti-inflationary stance of the Bundesbank's monetary policy.

Concentrating on the target zone period, from April 6 1992 to December 31 1998, it is possible to confirm that after joining the ERM the Portuguese escudo registered a significant nominal appreciation and an almost immediate decline to a value near the lower edge of its band. After the bands were widened, the exchange rate again stabilised, but now within the implicit band of ±6%.

Under these circumstances, we began to study the stationarity feature of the exchange rate within the band using the most common unit root tests: the Augmented Dickey-Fuller, usually known as ADF tests (Augmented DF), due to the presence of lagged terms of the dependent variable in the equation to be estimated of the Dickey-Fuller (DF) test, which is intended to correct for the presence of autocorrelation in the errors[6].

The variable to be studied is the difference between the nominal exchange rate and its central parity (position of the exchange rate within the band).

The number of lags to be used to avoid the autocorrelation problem in the errors was chosen through an LM autocorrelation test. We start with a more general ADF model that includes constant and trend, although we know that when there are no positive or negative persistent deviations the constant is equal to zero. In the cases where we cannot exclude the null hypothesis of a trend we use only the constant, but if

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[6] Statistics $t_{\rho=1}$ and $N.(\hat{\rho}-1)$, where N is the number of observations. See Dickey and Fuller (1979), Phillips (1987) and Phillips and Perron (1988). Andrade (2004) presents a survey of the literature.

that is not statistically different from zero, then we have a model with no trend and no constant.

Table 2 shows the results of the ADF tests for the PTE/DM exchange rate deviation against the central parity (DC_PTE/DM).

Table 2: Augmented Dickey-Fuller Unit Root Tests

Regime	**Lags (LM Test)**	**Deterministic Variable**	**t_{ADF} Test** $t_{\rho=1}$	**Z_{ADF} Test** $N.(\hat{\rho}-1)$
1	3	—	-2.27**	-10.22**
2	0	T	-2.87	-6.82
3	0	T	-2.69	-14.43
4	0	C	-2.84**	-4.70**
5	0	—	-2.25**	-5.28
6	2	—	-1.57	-4.91
7	2	T	-2.30	-10.77
8	1	—	-0.97	-2.35
9	2	T	-3.06	-13.19
10	*1*	*T*	*-2.26*	*-9.76*
11	*0*	—	*-2.55***	*-10.97***

Note 1: As usual, the notation (*), (**) and (***) represents the rejection of the null hypothesis at a significance level of 10%, 5% and 1%, respectively. H0= Null Hypothesis of presence of unit root.
Note 2: C= With Constant; T= With Trend; — = Without Constant and without Trend.
Suggested reading: In regime 4, which covers the period between the second and the third realignment of the Portuguese escudo against the Deutschmark, the LM test indicates that there is no need to use any lag to avoid the autocorrelation problem in the errors. In both ADF tests, the PTE/DM exchange rate deviation against the central parity (DC_PTE/DM) is stationary around a constant statistically different from zero for a significance level of 5%.

As we can see, for the whole period of participation of the Portuguese escudo in the ERM (regime 1), the t_{ADF} and Z_{ADF} tests both accept the stationarity of the exchange rate deviation against the central parity for a significance level of 5%. This strong evidence of mean reversion in the exchange rate within the band is certainly linked to the numerous intra-marginal interventions by the Portuguese monetary authorities.

Particularly interesting is the mean reverting behaviour during the period when the Portuguese escudo was pegged to the Deutschmark (regime 11). The pegging of the escudo to the reference currency of the EMS imposed an ambitious goal of disinflation on the Portuguese economy. This resulted in the adoption of a nominal stabilisation policy for the escudo that had positive reflections noted in increased credibility, strengthened by the reduction in inflationary expectations. As a result of this strategy the Portuguese escudo has maintained a high degree of stability. Therefore, it is not surprising that in the period under analysis the ADF tests reject the null hypothesis of presence of a unit root, suggesting the stationarity of the exchange rate for a significance level of 5%.

It is still possible to observe mean reverting behaviour in the exchange rate within the band in the periods prior to Portugal joining the European Monetary Union (EMU), regimes 4 and 5, although in the latter case the results are not so clear. Despite the t_{ADF} test rejection of the presence of a unit root for a significance level of 5%, thus leading to conclude for the stationarity of the exchange rate within the band, the Z_{ADF} test does not show a consistent result in the direction of mean reverting behaviour, in the sense that it is not possible to exclude the null hypothesis of a unit root. However, it is important to note that regimes 4 and 5 correspond to a large part of the wide band period, when it might be considered that the force of reversion represented by the central parity would be less strong. The empirical confirmation of mean reverting behaviour in the exchange rate within the band may thus be related to the lessening of speculation against the Portuguese currency. Although there could be short-run imbalances, the foreign exchange market worked in a credible way. This situation was associated with the expectation of adopting the European single currency[7].

It was not possible to empirically confirm the presence of mean reverting behaviour in the PTE/DM exchange rate within the band for the remaining exchange rate regimes. Both ADF tests do not reject the null hypothesis of presence of a unit root. This result may be justified by the fact that the majority of the cases analysed are associated with the presence of a trend in the form of a deterministic variable. Let's not forget the initial appreciation of the Portuguese escudo and its almost immediate decline to a value near the lower edge of its floating band after joining the ERM. The constraints on capital mobility during this early stage may also help to understand the lower degree of stability in the exchange rate within the band and some inefficiency in the functioning of the foreign exchange market.

Besides finding periods of nonstationarity in the exchange rate, alternating with periods of stationarity, the ADF tests detected strong mean reversion in the exchange rate within the band throughout the target zone period, thus reflecting the high degree of confidence of economic agents as to the ability of the Portuguese monetary authorities to intervene, if necessary, to defend the band of the escudo.

[7] The rejection of the stationarity of the exchange rate within the band for the whole of the wide band period (regime 7) may be related to the initial presence of strong disturbances in the foreign exchange market following the monetary crisis that struck the EMS. Once the disruptive effects are eliminated, it is easy to understand the empirical confirmation of mean reverting behaviour in the exchange rate during much of the wide band period, as suggested by the results of the ADF tests for regimes 4 and 5.

The results of the KPSS stationarity test[8] show a completely different picture. It was impossible to find mean reverting behaviour in the exchange rate within the band, in any of the exchange rate regimes tested. This may indicate that our conclusions about the mean reversion property of the exchange rate within the band may be dependent not only on the period considered, as became clear from the results of the ADF tests, but also on the type of tests used[9].

The test proposed by Denis Kwiatkowski; Peter Phillis; Peter Schmidt and Yong Shin, known by the initials of its authors, KPSS, takes stationarity as the null hypothesis (Kwiatkowski, Phillips, Schmidt and Shin 1992). The non-exclusion of the null hypothesis, conditional on the level of information available for the variable, therefore leads us to accept the stationarity characteristic of the series involved. In the KPSS test, we used the lags truncation parameter given by $l = Int\left(4 \times \sqrt[4]{T/100}\right)$, where T is the total number of observations (Lutkepohl 2004). Table 3 summarises the results of the KPSS test.

Table 3: KPSS Stationarity Test

Regime	Parameter l	η_μ Test	η_τ Test
1	8	2.81	2.15
2	4	2.14	0.52
3	4	1.74	0.16*
4	5	2.32	0.67
5	7	5.46	2.42
6	5	0.51*	0.47
7	7	12.17	1.95
8	4	1.75	0.29
9	7	5.35	1.69
10	*7*	*9.94*	*0.89*
11	*4*	*0.77*	*0.17**

Note 1: The notation (***), (**) and (*) represents the non rejection of the null hypothesis at a significance level of 10%, 5% and 1%, respectively. H0= Null Hypothesis of stationarity.
Note 2: η_μ= KPSS statistic to a process around a constant; η_τ= KPSS statistic to a process with constant and around a trend.
Suggested reading: In regime 1, which covers the whole target zone period, we use eight lags for the parameter *l*. In both KPSS tests, the stationarity of the PTE/DM exchange rate deviation against the central parity (DC_PTE/DM) is rejected.

As we can see, in none of the eleven exchange rate regimes considered was it possible to accept the stationarity characteristic of the PTE/DM exchange rate within its

[8] For the non rejection of stationarity we consider a middle exigency criterion of 5%.
[9] For an analysis of the problems associated with the use of different types of tests in the study of the mean reverting behaviour of the exchange rates see MacDonald (1995), Froot and Rogoff (1995) and Anthony and MacDonald (1998).

floating band; so, if any shock happens, the disturbances caused in the exchange rate last for some time. Although the graphical analysis of the series (see Figure 2) suggested the existence of stationarity in some cases, the fact is that the results of the KPSS test do not show a mean reverting behaviour in the exchange rate of the Portuguese escudo against the Deutschmark.

Following these results we analysed the stationarity characteristic of the exchange rate within the band in the presence of a structural break in the series. For this purpose, we carried out the unit root tests both with the structural break of Phillips-Perron and in accordance with the proposals made by Lanne, Lutkepohl and Saikkonen (2002).

The purpose of the Phillips-Perron test is to examine the existence of a unit root in variables with deterministic trends, assuming as null hypothesis the presence of a unit root (Perron 1989; Perron 1997). The test tried to answer the problem of having series that are stationary around a trend, but suffer a shock, leading us to conclude, for the whole period, that they have a unit root - and obviously incorrect conclusion (Andrade 2004).

The way to solve the problem is to determine endogenously the period when the shock occurred (date of break in the series). To do this we must have an idea of the shock's consequences, i.e., the type of structural break. Three different types of structural change are usually identified, known as the IO1 model, IO2 model and AO model. In the first case, we test a change in the interception at the moment of the break. In the second case, we test a change in both the interception and the slope. Finally, the third structural break hypothesis considers a model to be estimated with a change in the slope without discontinuity in the trend curve.

The method of endogenous determination of the period of break coincides with the research principle of the period that led to the value of $t_{\alpha=1}$ minimum[10]. The coefficient α is the coefficient of the lagged term of the variable analysed. Since the test is intended to consider the hypothesis that a series apparently with a unit root is, in fact, stationary, the test is very robust in terms of excluding that hypothesis of a unit root. The Phillips-Perron test therefore allows us to analyse whether a series is stationary around a trend, even in the presence of a structural break. Of course, in the cases where this is confirmed, the existence of mean reverting behaviour will always be excluded. The series will only be stationary around a trend with a structural break.

[10] For an analysis of the appropriate distributions, to each of the ways to detect the structural break endogenously, and applied to $t_{\alpha=1}$, see Perron (1997: 362-3).

Neither the IO1 nor the IO2 models allowed the detection of the presence of any structural break in the exchange rate series. It was only possible to detect the existence of structural breaks by using an AO type model. The problem of autocorrelation in the errors continued to be controlled for using an LM test.

Table 4 summarises the results of the Phillips-Perron unit root tests with a structural break for the PTE/DM exchange rate.

Table 4: Phillips-Perron Unit Root Tests with Structural Break

Regime	**Lags (LM test)**	**Model (IO1; IO2; AO)**	**Date of Break**	**$t_{\alpha=1}$ Test**
2	0	AO	21 May 1992	-3.38
3	0	AO	15 January1993	-3.1
7	2	AO	21 April 1997	-3.28
9	2	AO	18 August 1997	-3.21
10	*5*	*AO*	*19 November 1987*	*-2.28*

Note 1: As usual, the notation (*), (**) and (***) represents the rejection of the null hypothesis at a significance level of 10%, 5% and 1%, respectively. H0= Null Hypothesis of presence of a unit root.
Note 2: In terms of exchange rate regimes analysed, we considered only the cases where the ADF test confirmed that there was a trend.
Suggested reading: In regime 7, which covers the wide band period, the use of an AO model shows the existence of a structural break at the date 21 April 1997. According to the LM test, the use of two lags corrects the autocorrelation problem in the errors. In this situation, the Phillips-Perron test shows that the PTE/DM exchange rate deviation against the central parity (DC_PTE/DM) is nonstationary around a trend with structural break. Neither of the other two models (IO1 and IO2) allows detection of the existence of a structural break in the series.

From the inspection of Table 4, for the five exchange rate regimes in which the existence of a deterministic trend in the exchange rate deviation against the central parity was confirmed, the value of *t* associated with alpha equal to unit ($t_{\alpha=1}$) did not allow the rejection of the null hypothesis of presence of a unit root in any of the cases analysed, thus suggesting the nonstationarity of the variable around a trend with structural break.

The unit root tests of Lanne, Lutkepohl and Saikkonen (LLS) also allows to analyse the stationarity characteristic of the series in the presence of structural breaks, considering for the purpose four possible models of structural changes in the variables (Impulse Dummy, Shift, Exponential Shift and Rational Shift)[11]. The null hypothesis is the presence of a unit root. The dynamic equation is obtained using the Schwarz criterion for the choice of the number of lags in accordance with the exclusion of first order autocorrelation in the errors. Table 5 summarises the results of the LLS test.

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[11] See Lanne, Lutkepohl and Saikkonen (2002), Saikkonen and Lutkepohl (2002), Lanne, Lutkepohl and Saikkonen (2003). The specification used does not include a trend.

Table 5: Lanne, Lutkepohl and Saikkonen Unit Root Tests with Structural Break

Regime	Model	Data of Break	Lags (Schwarz Criterion)	LLS Test
1	*Impulse Dummy*	13 May 1993	2	-2.37
	Shift	23 November 1992	2	-1.82
	Exponential Shift	23 November 1992	2	-1.86
	Rational Shift	23 November 1992	2	-1.91
2	*Impulse Dummy*	6 October 1992	2	-2.34
	Shift	19 August 1992	2	-2.48
	Exponential Shift	19 August 1992	2	-2.52
	Rational Shift	19 August 1992	2	-2.52
3	*Impulse Dummy*	31 December 1992	2	-2.34
	Shift	28 January 1993	2	-2.43
	Exponential Shift	28 January 1993	2	- - -
	Rational Shift	28 January 1993	2	-2.38
4	*Impulse Dummy*	2 August 1993	2	-2.30
	Shift	3 August 1993	2	-1.91
	Exponential Shift	3 August 1993	2	-1.85
	Rational Shift	3 August 1993	2	-1.85
5	*Impulse Dummy*	2 June 1995	2	-2.38
	Shift	22 September 1995	2	-2.38
	Exponential Shift	22 September 1995	2	- - -
	Rational Shift	22 September 1995	2	-2.35
6	*Impulse Dummy*	13 May 1993	2	-2.32
	Shift	23 November 1992	2	-1.85
	Exponential Shift	23 November 1992	2	-1.86
	Rational Shift	23 November 1992	2	-1.91
7	*Impulse Dummy*	6 March 1995	2	-2.33
	Shift	6 March 1995	2	-2.31
	Exponential Shift	6 March 1995	2	- - -
	Rational Shift	6 March 1995	2	-2.23
8	*Impulse Dummy*	20 November 1992	2	-2.38
	Shift	23 November 1992	2	-1.82
	Exponential Shift	23 November 1992	2	- - -
	Rational Shift	23 November 1992	2	-1.76
9	*Impulse Dummy*	13 May 1993	2	-2.38
	Shift	13 May 1993	2	-1.80
	Exponential Shift	13 May 1993	2	- - -
	Rational Shift	13 May 1993	2	-1.99
10	*Impulse Dummy*	*12 January 1987*	*2*	*-2.37*
	Shift	*28 January 1987*	*2*	*-2.25*
	Exponential Shift	*28 January 1987*	*2*	*-2.25*
	Rational Shift	*28 January 1987*	*2*	*-2.36*
11	*Impulse Dummy*	*28 February 1991*	*2*	*-2.38*
	Shift	*28 February 1991*	*2*	*-2.21*
	Exponential Shift	*28 February 1991*	*2*	- - -
	Rational Shift	*28 February 1991*	*2*	*-2.15*

Note 1: As usual, the notation (*), (**) and (***) represents the rejection of the null hypothesis at a significance level of 10%, 5% and 1%, respectively. H0= Null Hypothesis of presence of a unit root.
Note 2: "- - -", means that it was not possible to implement the test for numerical implementation reasons.
Suggested reading: In regime 6, which covers the wide band period, the use of an Impulse Dummy model detects the existence of a structural break at the date of 13 May 1993. According to the Schwarz criterion, the use of two lags corrects the autocorrelation problem in the errors. In this situation, the Lanne, Lutkepohl and Saikkonen (LLS) test shows that the PTE/DM exchange rate deviation against the central parity (DC_PTE/DM) is nonstationary with a structural break. None of the other three models can detect the existence of mean reversion when there is a structural break in the series.

As we can see, for the eleven foreign exchange regimes analysed it was not possible to accept the presence of mean reverting behaviour in the exchange rate within the band in the presence of a structural break in the series. Whatever the type of break detection model used, the LLS tests never rejected the null hypothesis of presence of a unit root, showing the nonstationarity of the variable for all the sub-periods considered.

To conclude our study, we also implemented a set of stationarity variance-ratio tests based on the analysis by Cochrane (1988) and Campbell and Mankiw (1987), and also in accordance with the corrections proposed by Wright (2000) in respect to the conventional variance-ratio tests used by Lo and Mackinlay (1988) and Poterba and Summers (1988).

The stationarity test of Cochrane and Campbell is used under the hypothesis of an AR1 process. With this test, if a variable is stationary, or stationary around a trend, then the J(K) statistic of Cochrane and Campbell obtained from the variance-ratio will tend to zero (Cochrane 1988; Campbell and Mankiw 1987). The purpose of the test is further, to see if there is mean reverting behaviour by studying the persistence over time of a unit shock on the variable. In our case, we tried to analyse the effects of an innovation of 1% on the exchange rate over 5, 10 and 30 days periods.

The results are not very different from those found in Anthony and MacDonald (1998) for exchange rates that include only the currencies on the periphery of the ERM of the EMS, clearly pointing to the rejection of the mean reversion property of the exchange rate within the band, as can be seen in Table 6.

In none of the exchange rate regimes does the value of the J(K) statistic of Cochrane and Campbell obtained from the variance-ratio tend to zero, so the exchange rate does not show mean reverting behaviour. In none of the eleven cases examined was the unit shock produced in the exchange rate eliminated with the passage of time. The innovation has permanent effects, as shown by the very high values record by A_1. In some cases, it is observed that even when only 5 days have gone by after the existence of the innovation on the variable, its effects are explosive. This situation occurs, for example, in regime 2, where, in the wake of a shock of 1% on the exchange rate, its effects are amplified to 1.08%; 1.21% and 1.45% after 5, 10 and 30 days, respectively.

Table 6: Stationarity Test of Cochrane and Campbell

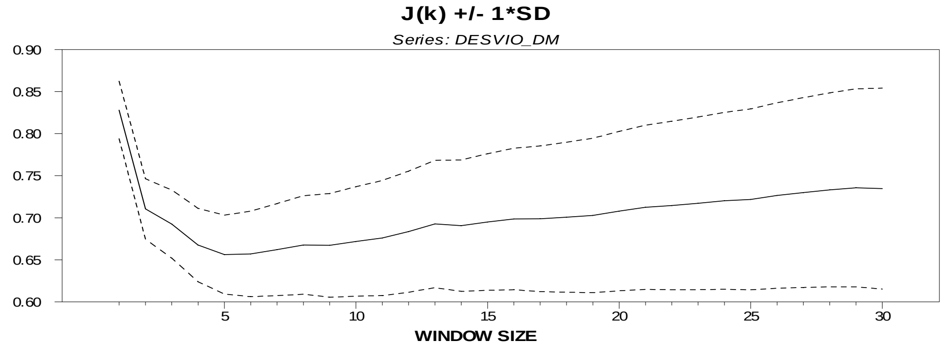
Regime	K	J(K)	A_1
1	5	0.66	0.82
	10	0.67	0.83
	30	0.73	0.87
2	5	1.17	1.08
	10	1.47	1.21
	30	2.10	1.45
3	5	0.75	0.87
	10	0.59	0.77
	30	0.48	0.69
4	5	0.78	0.88
	10	0.85	0.92
	30	1.10	1.05
5	5	1.02	1.01
	10	1.00	1.00
	30	1.02	1.01
6	5	0.62	0.81
	10	0.61	0.80
	30	0.67	0.84
7	5	0.74	0.87
	10	0.70	0.84
	30	0.64	0.81
8	5	0.77	0.89
	10	0.76	0.88
	30	0.81	0.91
9	5	0.62	0.80
	10	0.63	0.80
	30	0.72	0.86
10	*5*	*0.74*	*0.86*
	10	*0.66*	*0.82*
	30	*0.75*	*0.87*
11	*5*	*1.16*	*1.08*
	10	*1.16*	*1.08*
	30	*0.91*	*0.96*

Note 1: The stationarity test of Cochrane and Campbell is used in the hypothesis of an AR1 process.
Note 2: The meaning of the notation used is: K= Number of observations after the data in analysis; J(K)= statistic of Cochrane and Campbell obtained from the variance-ratio; A_1= Value of permanence of a unit shock in the series DC_PTE/DM.
Suggested reading: In regime 4, which covers the period between the second and the third realignment of the Portuguese escudo against the Deutschmark, the J(K) statistic of Cochrane and Campbell obtained from the variance-ratio never tends to zero, so the PTE/DM exchange rate deviation against the central parity (DC_PTE/DM) does not display a mean reverting behaviour. After 5 days of existence of a unit shock on the variable, its effects still persist, with a value of 0.88. Following 10 days its impact increases to about 92% of the initial value, clearly pointing to the persistence of the shock over time. The reaction to the shock becomes explosive 30 days after the initial impulse.

These results can be regarded as empirical non-confirmation of the mean reversion properties of the exchange rate within the band.

Figure 3 represents the behaviour of the J(K) statistic of Cochrane and Campbell in the context of the variance-ratio for the target zone period[12].

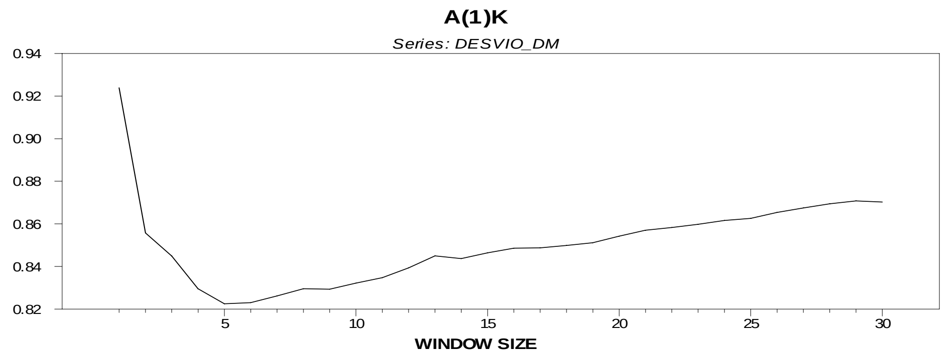
Figure 3: Behaviour of the J(K) Statistic of Cochrane and Campbell in the Context of the Variance-Ratio (Regime 1)



As can be observed, the value of the J(K) statistic does not tend to zero as time goes by, so the PTE/DM exchange rate does not show mean reverting behaviour within its floating band. But, despite the fact that the J(K) statistic does not tend to zero, the analysis of the lower standard deviation of the exchange rate shows that there was some stability in the series within a given period of time (after 5 days), in spite of the non-existence of mean reversion.

The effects of a unit shock on the exchange rate over time for the target zone period (regime 1) are illustrated in Figure 4[13].

Figure 4: Temporal Permanence of a Unit Shock in the Context of the Cochrane and Campbell Test (Regime 1)



[12] See Figure 5 in Appendix III for an analysis in terms of the eleven exchange rate regimes used.
[13] For all exchange rate regimes considered see Figure 6 in Appendix III.

As can be seen, after 5 days of the existence of a unit shock in the PTE/DM exchange rate, its effects still persist, with a value of 0.82. After 30 days its impact increases to 87% of the initial value, clearly bearing out the permanence of the effects of the shock on the exchange rate, so the variable does not exhibit mean reverting behaviour.

The variance-ratio stationarity tests proposed by Wright (2000) admit as null hypothesis the existence of a martingale difference sequence.

The aim of our study is to see if, despite the non-existence of exchange rate mean reversion within the band, the foreign exchange market may nonetheless operate efficiently over time, thus achieving a stabilising process in the exchange rate in spite of the absence of mean reverting behaviour. According to those tests, for this to be possible there should be a martingale difference sequence in the exchange rate series:

$$E[s(t) \mid I(t-1)] - E[s(t-1) \mid I(t-2)] = 0, \qquad (5)$$

i.e., the expected value of the exchange rate in period *t*, given the information on period *t-1*, minus the expected value of the exchange rate at *t-1*, given the information for period *t-2*, should be equal to zero. This means that there is no information gain in the foreign exchange market to be exploited by the agents. Thus, over time (5, 10 and 30 days), any economic agent is able to predict positive (depreciations) or negative (appreciations) differences in the exchange rate. The variable thus exhibits the behaviour of an efficient foreign exchange market. When we cannot accept the hypothesis that there is a martingale difference sequence in the exchange rate, it can be said that economic agents anticipate positive (negative) differences in the dynamics of the exchange rate, so the foreign exchange market does not operate efficiently.

Table 7 summarizes the essential results of the application of variance-ratio tests in accordance with the proposals of Jonathan Wright.

Table 7: Variance-Ratio Stationarity Tests in Accordance with the Corrections Proposed by Wright

Regime	K	M_1 Test	M_2 Test	R_1 Test	R_2 Test	S_1 Test
1	5	-2.70***	-0.89	1.03	0.09	1.23
	10	-1.74*	-0.65	1.87*	0.92	1.77*
	30	-0.10	-0.05	3.18***	2.15**	3.23***
2	5	0.30	0.04	0.58	0.56	0.57
	10	0.79	0.13	1.67*	1.50	1.47
	30	0.49	0.10	1.42	1.08	2.37**
3	5	-1.32	-0.10	-0.67	-0.97	-0.67
	10	-1.40	-0.12	-0.92	-1.17	-0.86
	30	-1.18	-0.13	-0.97	-1.10	-0.80
4	5	-1.91*	-0.63	-0.34	-0.79	1.10
	10	-1.21	-0.46	-0.16	-0.32	1.33
	30	-0.17	-0.08	1.09	0.88	2.20**
5	5	-0.07	-0.004	0.95	0.48	0.74
	10	-0.18	-0.01	1.60	0.85	0.93
	30	-0.17	-0.01	2.33**	1.22	1.95*
6	5	-1.54	-0.55	-0.34	-0.70	0.06
	10	-1.47	-0.60	0.07	-0.39	0.39
	30	-1.47	-0.73	-0.16	-0.56	0.84
7	5	-2.83***	-0.36	1.11	-0.03	1.25
	10	-2.53**	-0.37	1.70*	0.43	1.64
	30	-1.47	-0.26	2.94***	1.67*	2.81***
8	5	-1.32	-0.28	0.05	-0.34	0.33
	10	-0.63	-0.15	1.20	0.71	1.19
	30	-0.37	-0.11	1.08	0.62	2.10**
9	5	-2.30**	-0.64	1.09	0.14	*1.17*
	10	-1.75*	-0.56	1.41	0.34	*1.41*
	30	-0.13	-0.05	2.81***	1.79*	*2.70****
10	*5*	*-0.48*	*-0.05*	*-0.78*	*-0.80*	*-1.16*
	10	*-0.53*	*-0.06*	*-0.68*	*-0.79*	*-0.66*
	30	*0.16*	*0.02*	*0.28*	*0.15*	*-0.02*
11	*5*	*0.22*	*0.05*	*0.69*	*0.65*	*1.29*
	10	*0.17*	*0.04*	*1.55*	*1.28*	*1.91**
	30	*-0.80*	*-0.24*	*0.44*	*0.11*	*1.03*

Note 1: As usual, the notation (*), (**) and (***) represents the rejection of the null hypothesis at a significance level of 10%, 5% and 1%, respectively. H0= Null Hypothesis of existence of a martingale difference sequence.

Note 2: K is the number of observations after the date of analysis.

Suggested reading: In regime 6, which covers the narrow band period, any of the five variance-ratio tests shows the existence of a martingale difference sequence. There is no information gain in the market to be explored by the agents. Over time (5, 10 and 30 days) any economic agent is able to predict positive/negative differences in the PTE/DM exchange rate. The variable exhibits the behaviour of an efficient market.

We used five types of tests. The first two (M_1 and M_2 tests) are conventional variance-ratio tests in line with the work of Lo and Mackinlay (1988). The M_1 test is a variance-ratio test without correction for conditional heteroscedasticity, while the M_2 test is based on the variance-ratio but with correction for conditional heteroscedasticity. The remaining tests (R_1, R_2 and S_1) are based on the corrections introduced by Wright. The R_1 and R_2 tests take into account the order of the time series to test the null hypothesis of existence of a martingale difference sequence in the series. These are non-parametric tests. The R_1 test is based on a linear transformation of the order to obtain a new series with zero mean and variance equal to 1. The R_2 test is based on the inverse of the Normal distribution and has zero mean and variance of approximately equal to 1. Finally, the S_1 variance-ratio test is based on the signal of the series, assuming that the series has the normal characteristics of I.I.D., with zero mean and variance equal to 1, which according to Wright (2000) should make the test more exact, even in the presence of conditional heteroscedasticity.

As we can see, in most of the exchange rate regimes the five variance-ratio tests show the existence of a martingale difference sequence in the PTE/DM exchange rate series. The results are not so clear for the whole target zone period (regime 1), with some tests leading to the exclusion of the null hypothesis of existence of a martingale difference sequence, and others allowing its acceptance, but it is nonetheless possible to find periods of clear operational efficiency in the foreign exchange market. One such period is the period between the first and the second realignment of the Portuguese escudo against the Deutschmark (regime 3).

Comparison of the different tests confirms the greater power of the R_1, R_2 and S_1 tests in the rejection of the null hypothesis of existence of a martingale difference sequence, particularly in the two periods of free capital mobility and the wide band. The results of the M_2 test always show the non-existence of a gain of information in foreign exchange market to be explored by the agents, allowing us to conclude that, despite the absence of mean reversion, no significant changes (depreciations or appreciations) were detected in the exchange rate.

Particularly interesting are the results for the period prior to the participation of Portugal in the EMU (regime 5), a fact that can be explained by the expected adoption of the single currency. According to the conventional variance-ratio tests, the exchange rate always exhibits the behaviour associated with an efficient foreign exchange market. The R_1 and S_1 tests point in the same direction, although they exclude the hypothesis of existence of a martingale difference sequence after 30 days. On the other hand, the R_2 test detects that throughout the whole period considered (5, 10 and 30 days) no economic agent had the capacity to foresee positive (negative) differences in the exchange rate. This clearly supports the hypothesis that a stabilising process in the exchange rate within the band was achieved. This situation could not have occurred without the liberalisation of capital movements and the modernisation of the financial system, both of which were fundamental to the creation of the macroeconomic stability conditions necessary to the transition from an exchange rate target zone regime to a single currency system.

4. Conclusion

Portugal joined the ERM on 6 April 1992, adopting a floating band for the Portuguese escudo of ±6%. Joining the exchange rate mechanism changed the framework for both monetary and exchange rate policy. Even though the pegging of the Portuguese escudo to the Deutschmark was already a reality largely incorporated by the markets, the fact that there was a formal commitment by the Portuguese monetary authorities to maintain the evolution of the Portuguese escudo within a pre-established floating band increased the credibility of the disinflation policy, thus facilitating the achievement of the main objective of price stability. Without such a decision it would have been very difficult to fulfil the necessary conditions for Portugal's inclusion in the euro area.

Based on the participation of Portugal in the ERM, this study tried to analyse one of the main predictions of the literature on target zones, according to which the existence of a credible floating band should lead to an exchange rate mean reverting behaviour within the band.

The study of the stationarity of the exchange rate showed that although the majority of the traditional unit root and stationarity tests point to the non-existence of mean reverting behaviour of the exchange rate within the band for most of the exchange rate regimes considered, it was nonetheless possible to detect the presence of a martingale difference sequence using a set of variance-ratio tests. This situation indicates that the Portuguese foreign exchange market has operated efficiently, allowing the exchange rate to stabilise within the band. The adoption of an exchange rate target zone regime thus contributed decisively to the creation of the macroeconomic stability conditions necessary for the participation of Portugal in the euro area.

The integration process of the Portuguese economy should therefore be used as an example by other small open economies on the periphery of the European Union, since they may benefit from participating in one of the dominant monetary areas. Otherwise they will be more exposed to speculative attacks, leading, especially, to the real appreciation of their currencies. But eight years on from the establishment of the EMU, winner members have to implement real, solid convergence policies. Overvalued currencies can be fatal for new members.

Acknowledgments

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Appendix I – The Data

We used daily time series data in an attempt to cover the period from January 2, 1987 to December 31, 1998, which gives a total of 3130 potential observations. The observations corresponding to holidays and weekends were left out of the sample. In addition to the period when a target zone was officially functioning, between April 6 1992 and December 31 1998, we extended the analysis to the period when Portugal adopted a crawling peg and a managed floating system, with the Portuguese escudo pegged to the Deutschmark.

The exchange rate data was taken from the Banco de Portugal (Long Series: Monetary and Financial Statistics of the Banco de Portugal). We used nominal exchange rates of the Portuguese escudo against the Deutschmark (PTE/DM). This exchange rate is computed by the Banco de Portugal as the average daily currency price. Unless otherwise stated all the series have been transformed into natural logarithms. In order to maximize the number of available observations, we were forced to extrapolate missing values whenever there were breaks in the series. The missing values were computed using an extrapolation method based on an AR1 process with trend. The empirical analysis was applied to different sub-periods, also known as exchange rate regimes. We considered eleven exchange rate regimes:

Table 8: Exchange Rate Regimes Description

Regime	Dates (Sub-periods)	Description	Potential Number of Observations
1	06:04:1992-31:12:1998	Whole Period in the ERM of the EMS	1759
2	06:04:1992-22:11:1992	Membership of the ERM - 1st Realignment	165
3	23:11:1992-12:05:1993	1st Realignment - 2nd Realignment	123
4	13:05:1993-05:03:1995	2nd Realignment - 3rd Realignment	472
5	06:03:1995-31:12:1998	3rd Realignment- EMU membership	999
6	06:04:1992-01:08:1993	Narrow band Period	345
7	02:08:1993-31:12:1998	Wide band Period	1414
8	06:04:1992-15:12:1992	Restrictions on Capital Mobility	182
9	16:12:1992-31:12:1998	Free Capital Mobility	1577
10	*02:01:1987-30:09:1990*	*Portuguese Escudo Crawling Peg*	*976*
11	*01:10:1990-05:04:1992*	*Pegging of the PTE to the DM*	*395*

The five observations immediately before and after the realignments and the date corresponding to the enlargement of the bands were excluded from the sample, in all the analyses, in order to avoid bias. Most results were obtained using RATS 6.2, PcGive 10, and Jmulti 4.1[14].

[14] See www.estima.com, for RATS 6.2, Hendry and Doornik (2001), for PcGive 10, and Lutkepohl and Kratzig (2004), for Jmulti 4.1 (www.jmulti.de).

Appendix II – Variables Used in the Empirical Analysis

PTE/DM = PTE_DM: Nominal exchange rate of the Portuguese escudo against the Deutschmark

C_PTE_DM: Official central parity of the Portuguese escudo against the Deutschmark

LI_PTE_DM: Official lower edge for the PTE/DM

LS_PTE_DM: Official upper edge for the PTE/DM

No_C_PTE_DM: Unofficial central parity of the Portuguese escudo against the Deutschmark

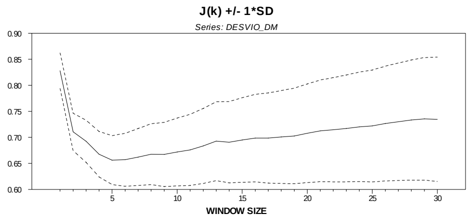
No_LI_PTE_DM_6: Unofficial lower edge for the PTE/DM and an unofficial exchange rate band of ±6%

No_LS_PTE_DM_6: Unofficial upper edge for the PTE/DM and an unofficial exchange rate band of ±6%

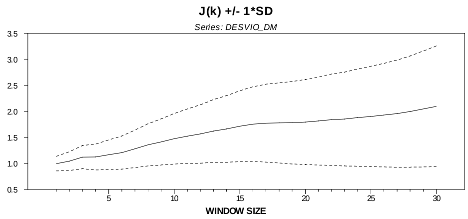
DC_PTE/DM: PTE/DM exchange rate deviation against the central parity between the two currencies (in logs)

Appendix III – Figures

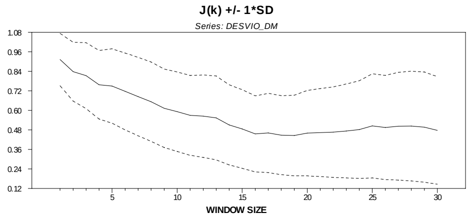
Figure 5: Behaviour of the J(K) Statistic of Cochrane and Campbell in the Context of the Variance-Ratio (Regimes 1 to 11)



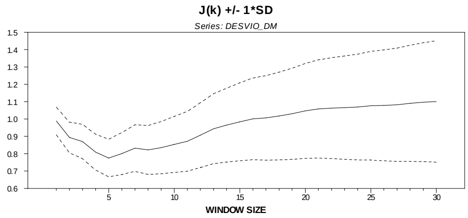
Regime 1



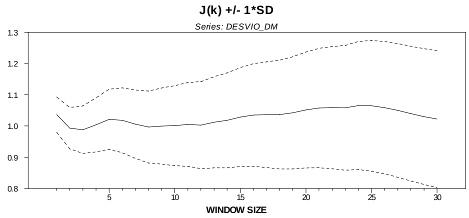
Regime 2



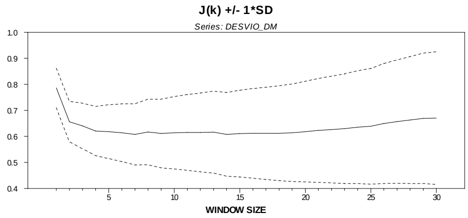
Regime 3



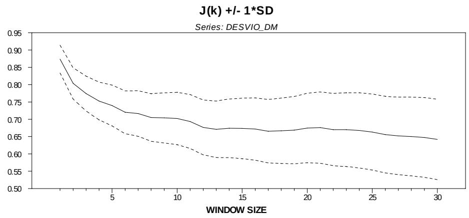
Regime 4



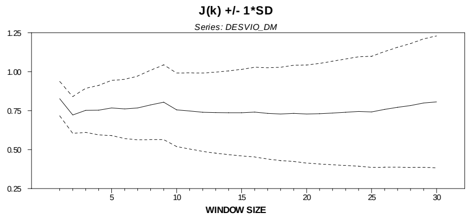
Regime 5



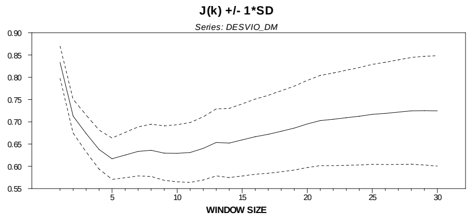
Regime 6



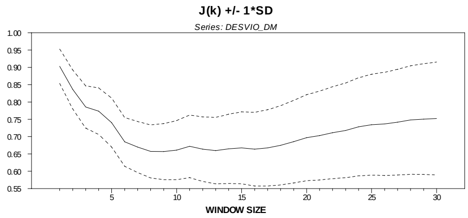
Regime 7



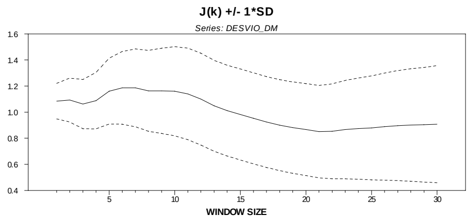
Regime 8



Regime 9

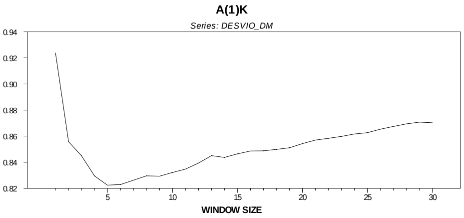


Regime 10

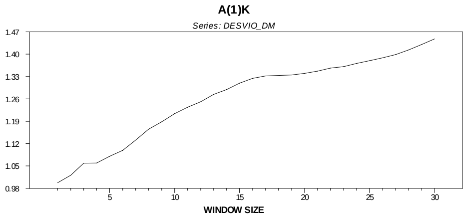


Regime 11

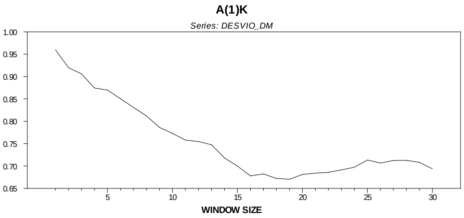
Figure 6: Temporal Permanence of a Unit Shock in the Context of the Cochrane and Campbell Test (Regimes 1 to 11)



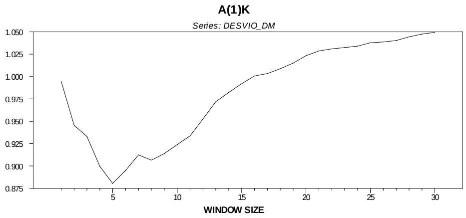
Regime 1



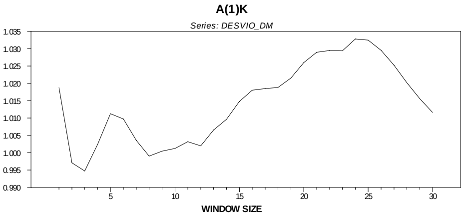
Regime 2



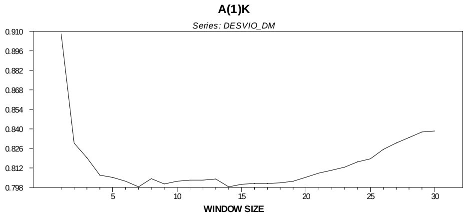
Regime 3



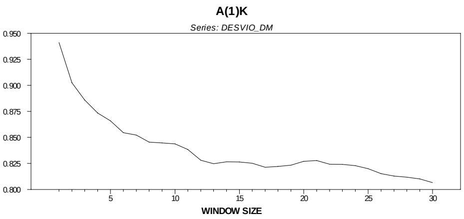
Regime 4



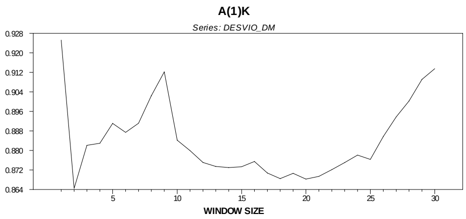
Regime 5



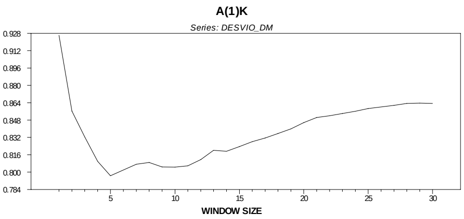
Regime 6



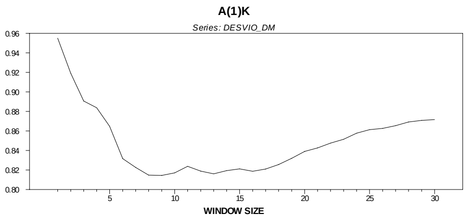
Regime 7



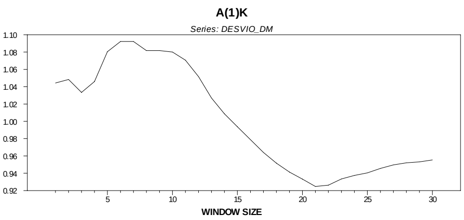
Regime 8



Regime 9



Regime 10



Regime 11