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Exchange Rate and Interest Rate Distribution and Volatility under the Portuguese Target Zone

Summary: The aim of this study is to analyse the exchange rate and interest rate distribution and volatility under the participation of the Portuguese economy in the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS) based on some of the main predictions of the target zone literature. Portugal adopted this exchange rate target zone from April 6 1992 until December 31 1998. During this period, the exchange rate distribution reveals that the majority of the observations lie close to the central parity, thus rejecting one of the key predictions of the Paul Krugman (1991) model. The analysis of the data also shows that exchange rate volatility tended to increase as the exchange rate approached the edges of the band, contrary to the predictions of the basic model. Interest rate differential volatility, on the other hand, seemed to behave in line with theoretical predictions. This suggests an increase in the credibility of monetary policy, allowing us to conclude that the adoption of a target zone has contributed decisively to the creation of the macroeconomic stability conditions necessary for the participation in the European Monetary Union (EMU). The Portuguese integration process should therefore be considered as an example to be followed by other small open economies in transition to the euro area.

Key words: Exchange rate stability, EMS, Volatility and target zones.

JEL: C32, C51, F31, F41, G15.

The target zones are one of the exchange rates regimes that have been more often used throughout history, from the classical gold standard until the current exchange rate arrangement in the ERM II of the European Union. However, the traditional debate concerning the choice of appropriate exchange rate regime has neglected this fact, focusing its attention on the choice between fixed or flexible exchange rates (Jeffrey Frankel 1999; Stanley Fischer 2001; Guillermo Calvo and Carmen Reinhart 2002; Reinhart and Kenneth Rogoff 2004; Eduardo Levy-Yeyati and Federico Sturzenegger 2005).

The functioning of the ERM of the EMS remains one of the best examples of a target zone regime. From March 13th, 1979 the majority of the currencies fluctuated within a band of ±2.25% built around a central parity reference. The exchange rates could float more or less freely within an exchange rate band, committing the respective central banks to intervene whenever the target zone was threatened.

After some initial theoretical research on exchange rate target zones, with major contributions from Robert McKinnon (1984), John Williamson (1985), Williamson and Marcus Miller (1987) and Bernard Dumas (1989), the literature on the sub-

ject has known a revival with the introduction by Paul Krugman (1991) of the first model of a nominal exchange rate target zone in continuum time with rational expectations, using the structure of regulated Brownian motion. Details of this literature can be found in Lars Svensson (1992), Antoine Magnier (1992), Giuseppe Bertola (1994), Peter Garber and Svensson (1995), Fabrice Pansard (1997), Bernd Kempa and Michael Nelles (1999), Marco Tronzano, Zacharias Psaradakis, and Martin Sola (2003) and Jarko Fidrmuc and Roman Horváth (2008).

The basic target zone model has quite interesting implications for the behaviour of the exchange rate and the interest rate differential. The model predicts that the statistical distribution of the exchange rate must be U-shaped or bimodal, with a greater number of observations lying close to the edges of the band. However, if the macroeconomic fundamental variable (the interest rate differential) is heavily concentrated around the mean (zero), then the exchange rate observations would not necessarily have a greater number of observations lying close to the edges of the band. But, for the period under analysis, the interest rate differential followed a negative trend. Additionally, the basic target zone model predicts that the exchange rate is much less variable the closer it is to the edges of the band and that there is a negative relationship between the exchange rate and the interest rate differential. Therefore, we should find evidence of a trade-off between the volatility of the exchange rate and the volatility of the interest rate differential. These predictions can be tested against real world data in order to confirm the validity of the model and the credibility of the bands. Credibility is considered in the sense of a reduced number of exchange rate realignments and not in the usual sense of no change in the central parity.

However, although the former model leads to interesting predictions regarding exchange and interest rate dynamics these were rejected by empirical analyses of data. Examples can be found in Robert Flood, Andrew Rose, and Donald Mathieson (1991), Svensson (1991a, b), Frankel and Steven Phillips (1992), Hans Lindberg and Paul Soderlind (1994), Mustapha Baghli (2004) and Jesús López and Hugo Mendizábal (2007), just to name a few.

This paper analyses the Portuguese exchange rate target zone under the participation of the Portuguese escudo in the ERM of the EMS. Our main aim is to study the behaviour and volatility of exchange and interest rates based on the predictions of the first generation of target zones models. Our contribution to the literature stems from the fact that we are analysing a currency belonging to the system periphery, while most previous work has focused on the Nordic countries and on fluctuation bands of the ERM considered to be more stable and credible. The adoption by Portugal of an exchange rate target zone regime confirmed that a small open economy can also conduct successfully a policy aimed at stabilising the behaviour of the exchange rate and of the interest rate. In effect, even during the most turbulent phases of the ERM, Portugal did not abandoned the EMS and respected the edges of the previous floating band of ±6%, when others countries violated the discipline of the ERM. This process should therefore be used as an example by other small open economies in transition to the euro area. They may benefit from participating in one of the dominant monetary areas, otherwise they will be more exposed to speculative attacks, especially in the case of real appreciation of their currencies.

The paper is structured as follows. In section 1 we examine the functioning of the Portuguese exchange rate target zone during the participation of the Portuguese escudo in the ERM. Section 2 is dedicated to the theoretical analysis of exchange rate and interest rate distributions and volatility under an exchange rate target zone regime. In section 3 we describe the data. Section 4 presents the empirical results for the Portuguese target zone. Finally, in section 5 we conclude.

1. The Portuguese Exchange Rate Target Zone

On April 6 1992, the framework of the Portuguese monetary and foreign exchange policy changed when the Portuguese escudo joined the ERM of the EMS. This was made possible by the better convergence of the Portuguese inflation rate with the EU's average level and, in particular, with the values recorded by Germany. The central parity was fixed at 178.735 and 86.9393 escudos for the ECU and for the Deutschmark, respectively, and the Portuguese escudo was allowed to fluctuate within a band of ±6%.

As there was a formal commitment to keep the Portuguese escudo within the band from this date, the credibility of the disinflation policy increased, facilitating 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 while the Deutschmark was the reference currency.

Table 1 Bands for the Portuguese Target Zone (PTE/DM)

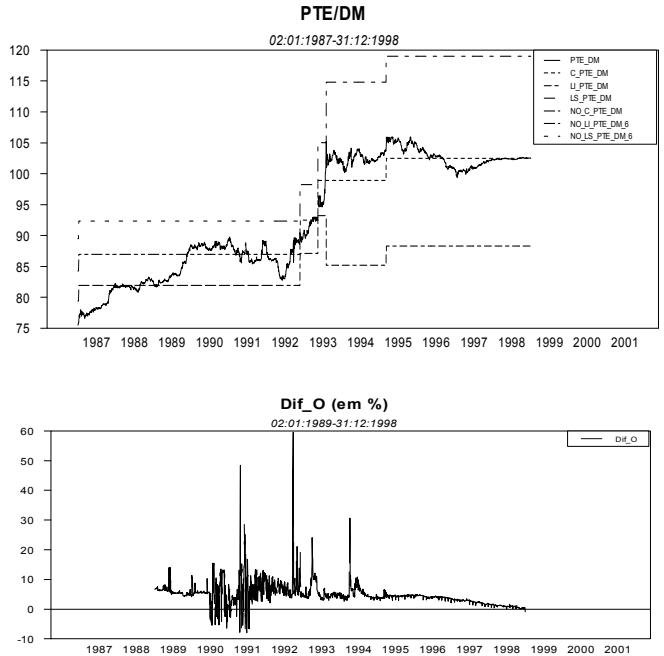
Period / Date	Band	PTE/DM [a]		
		Lower Edge [b]	Central Parity	Upper Edge [b]
6 April 1992 [c]	±6%	81.900	86.9393	92.336
23 November 1992 [d]	±6%	87.108	92.4880	98.232
13 May 1993 [e]	±6%	93.197	98.9177	105.042
2 August 1993 [f]	±15%	85.179	98.9177	114.811
6 March 1995 [g]	±15%	88.277	102.505	119.033

Note:
(a) Portuguese escudos necessary to buy one Deutschmark.
(b) The lower (upper) edge represents the maximum appreciation (depreciation) permitted to the Portuguese escudo against the Deutschmark.
(c) Membership of the Portuguese escudo of the ERM of the EMS with a bandwidth of ±6%.
(d) Realignment in the EMS with devaluation of 6% of the Spanish's peseta and the Portuguese escudo.
(e) Realignment in the EMS with devaluation of 8% of the Spanish's peseta and 6.5% of the Portuguese escudo.
(f) Enlargement of the bands of the ERM to ±15%, with the exception of the guilder/deutschmark exchange rate that maintained the ±2.25% band.
(g) Realignment in the EMS with devaluation of 7% of the Spanish's peseta and 3.5% of the Portuguese escudo.

Source: Banco de Portugal, Annual Reports.

In Figure 1 we depict the behaviour of the Portuguese escudo exchange rate against the Deutschmark and the evolution of the overnight interest rate differential between Portugal and Germany (Dif_O) as part of the PTE/DM band. 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 that adopted on joining[1].



Source: Banco de Portugal, Annual Reports.

Figure 1 PTE/DM Exchange Rate and Overnight Interest Rate Differential

Figure 1 shows that 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, 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. Furthermore, everything seems to indicate that the realignments were anticipated, given the high interest rate differential before the realignments. After the widening of the bands, the exchange rate again stabilises, but now within the implicit band of ±6%.

The effectiveness of the nominal stabilisation policy of the escudo allowed the Portuguese economy to substantially reduce inflation deviation against Germany. From 1992 onwards there was a gradual disinflation process in Portugal, expressed

[1] See Appendix 1 for a complete list of variables and their description.

on a continuous decline in the inflation rate which coincided with the participation of the Portuguese escudo in the exchange rate target zone.

2. Distribution and Volatility under an Exchange Rate Target Zone

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:

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

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 expectations operator conditional 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 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" follow a Brownian motion with drift μ and standard deviation (volatility) σ:

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

where *z(t)* is a Wiener process with $E_t[dz(t)] = 0$ and $E_t\left[(dz(t))^2\right] = dt$, that is, *f(t)* is the continuous-time equivalent of a random walk (G. S. Maddala and In-Moo Kim 1999; Gabrielle Demange and Jean-Charles 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)*.

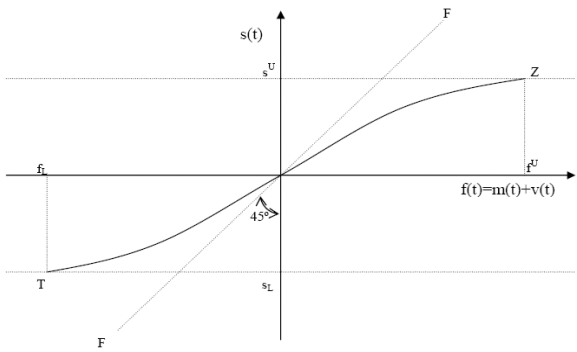
In a target zone, it is assumed that the intervention rule is based on a specific floating band for the fundamental, $f_L \le f(t) \le f^U$, and that, if necessary, the fundamental will be regulated to remain within the band. This implies that the fundamental follows a regulated Brownian motion with constant drift μ and standard deviation σ (Michael Harrison 1985; Ioannis Karatzas and Steven Shreve 1997):

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

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 only if $f(t)=f^U$. It is thus necessary to assume that the probability distribution of the interventions is determined by the current level of the fundamental, $s(t) = s\big(f(t)\big)$, so that the exchange rate function in a target zone will be flat at the edges of the fundamental band and tangent to the edges of the exchange rate band:

$$s'(f_L) = s'(f^U) = 0\,. \tag{5}$$

Under these circumstances, the exchange rate function establishes a non-linear relationship between the exchange rate and its fundamental, as illustrated in Figure 2.



Source: Krugman (1991) and Bertola and Caballero (1992).

Figure 2 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)*. According to equation (5), 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 curves TZ, non-linear, and S-shape, respectively.

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, p. 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[2]. The expectations concerning the monetary authorities' interventions when the

[2] Mark Taylor and Matteo Iannizzotto (2001) conclude that the non-linearity predicted by the basic model is in reality present, but applies only near the edges of band.

exchange rate is near the edges of the band stabilise the exchange rate behaviour. The "honeymoon effect" thus implies that a perfectly credible target zone is inherently stabilizing.

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 band. This result, represented by equation (5), is known as "smooth pasting" conditions, which correspond to the continuity conditions for the solution of the basic model. This means that under the assumption of rational agents, their expectations about future values of the exchange rate change only if the expected values for the fundamentals change, so that if this does not happen, they think today as they have thought yesterday. Given these conditions, the model predicts that the statistical distribution of the exchange rate must be U-shaped or bimodal.

We analysed the asymptotic distribution of the exchange rate within the band based on Harrison (1985), Svensson (1991a) and Bertola and Ricardo Caballero (1992). Since the exchange rate function, *s(f)*, is strictly increasing and invertible only on the interior of the band, the asymptotic density function, $\varphi^s(s)$, is given by:

$$\varphi^s(s) = \frac{\varphi^f\left(f(s)\right)}{\left|s'\left(f(s)\right)\right|}, \tag{6}$$

for $s_L < s < s^U$, where *f(s)* denotes the inverse of *s(f)*. Since the fundamental is uniformly distributed, the exchange rate will change slowly near the edges of the band.

Moreover, the model implies that the exchange rate will be much less variable near the edges of the band. The variability of *s(t)* is directly proportional to the slope of the curve TZ:

$$V(t)\left[ds(t)\right] = \left[s'\left(f(t)\right)\sigma\right]^2 dt, \tag{7}$$

where *V(t)[ds(t)]* is the conditional variance of the changes in the exchange rate. The variability of the exchange rate thus reaches a maximum at the centre of the exchange rate band and decreases as the exchange rate gets closer to the edges of the band.

The basic model has also implications for the behaviour of the interest rate differential that emphasize the special features of the adjustment process in a target zone following a monetary shock. Since under a target zone $s'\left(f(t)\right) < 1$, it follows that the interest rate differential will be decreasing in the fundamental, $\delta'\left(f(t)\right) < 0$. Furthermore, recalling that the exchange rate is an increasing function of the fundamental, the basic model implies a negative deterministic relationship between the exchange rate and the interest rate differential.

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. In a target zone, the exchange rate and interest rates "share" that responsibility between them[3]. The volatility spillover from the exchange rate to the interest rates can be analysed through the variability of the interest rate differential.

[3] However, in the target zone regime the substitution between stability and police autonomy remains modest. See Michael Bordo and Ronald MacDonald (2005) and Fidrmuc and Horváth (2008).

Letting $\delta(t)$ denote the interest rate differential, the variability of the interest rate differential is computed using Ito's lemma:

$$d\delta(t) = \frac{\delta(f(t))}{\alpha}dt + \delta'(f(t))\sigma dz(t), \tag{8}$$

where $[\delta'(f(t))\sigma]^2 dt$ represents the conditional variance of the changes in the interest rate. It follows that the interest rate differential's volatility is minimum at the centre of the band and increases near the edges of the band, replacing here the exchange rate as the main variable in the adjustment process. There is thus a trade-off between the variability of the exchange rate and the variability of the interest rate differential (Svensson 1991a, 1994; Ching-chong Lai, Chung-rou Fang, and Juin-jen Chang 2008).

3. Data Description

We used time series data with daily frequency 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 a period in which Portugal adopted a crawling peg and a managed floating system, when the Portuguese escudo was pegged to the Deutschmark.

The exchange rate and interest rates data was taken from the Banco de Portugal (Long Series: Monetary and Financial Statistics of the Banco de Portugal) and the Bundesbank (Bundesbank Time Series Database). We used nominal exchange rates of the Portuguese escudo against the Deutschmark (PTE/DM). Interest rate data is available from January 2, 1989 and is measured as the average of the daily transactions held in the Money Market. Since we used daily data, we chose overnight interest rates and interest rates with a maturity of 28 to 32 days. Based on the examination of the evolution of the interest rates over time, we left out the outliers, defined as observations with values higher than 25% of the arithmetic average of the previous thirty observations relative to the observation under analysis. This methodology made the analysis of the volatility of the series feasible.

Unless otherwise stated, all the series have been transformed into natural logarithms. In the case of the interest rates, we used the natural logarithm of 1 plus the interest rate (%), divided by 100. In order to maximize the number of available observations, we were forced to extrapolate missing values whenever there were breaks in the series. The breaks occurred mainly in the Portuguese Money Market interest rates series with a maturity of 28 to 32 days. To compute the missing values, we used an extrapolation method based on an AR1 process with trend. The empirical analysis was applied to different sub-periods. We considered eleven sub-periods in accordance with political, economic and institutional events as described in Table 2.

Table 2 Sub-periods for the Empirical Analysis

Sub-periods	Dates	Description	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 (± 6%)	345
7	02:08:1993-31:12:1998	Wide band Period (± 15%)	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*
10´	*02:01:1989-30:09:1990*	*Portuguese Escudo Crawling Peg*	*455*
11	*01:10:1990-05:04:1992*	*Pegging of the PTE to the DM*	*395*

Note: Sub-period 10´presents a smaller number of observations since the interest rates database only contains 455 observations. When the analysis focused on the exchange rate we used the sample corresponding to sub-period 10. When the analysis concerned both the exchange rate and the interest rates we used sample 10´.

Source: Banco de Portugal, Annual Reports.

The five observations before and after the realignments and the date corresponding to the enlargement of the bands were excluded from the sample. This was to avoid biases in the analysis. Most results were obtained using RATS 6.2, PcGive 10, and Jmulti 4.1 (David Hendry and Jurgen Doornik 2001; Helmut Lutkepohl and Marcus Kratzig 2004).

4. Empirical Analysis under the Portuguese Target Zone

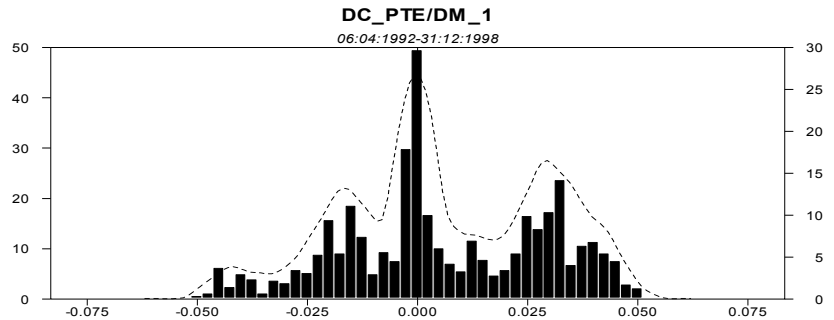
In this section we analyse the density distribution of the exchange rate as well as the distribution of this variable in specific intervals of exchange rate variation for the eleven sub-periods considered in our study. Next we proceed to examine the exchange rate and the interest rates differential volatility in each interval of the distributions[4].

Figure 3 shows the frequency distribution and the Kernel estimation of the PTE/DM exchange rate function for sub-period 1 (whole period in the ERM of the EMS).

We used the Epanechnikov kernel function[5] for the analysis of the density distribution of the exchange rate. As we can see from the inspection of Figure 3, most of the observations of the PTE/DM exchange rate often lie close to the central parity. Despite the nominal exchange rate stabilization process, enabled by the participation of the Portuguese escudo in an exchange rate target zone regime, the U-shaped or bimodal density of the exchange rate is not clear from the simple inspection of the data distribution (see Figure A.1 in Appendix 2).

[4] As we have eleven sub-periods, in order to simplify our presentation in the main part of the text, we only analyse the results for the whole period of participation in the ERM of the EMS (sub-period 1). The graphical results for all the sub-periods are presented in Appendix 2.

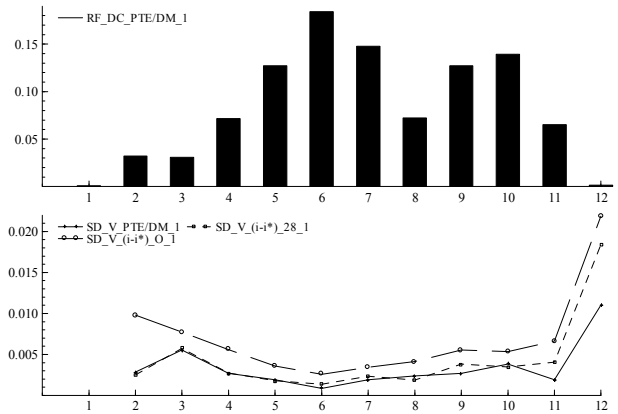
[5] RATS uses the Normal distribution as Kernel. See Adrian Pagan and Aman Ullah (1999). We prefer Epanechnikov to avoid the long tails associated to the Normal.



Note: The left axis concerns the histogram, and the right axis corresponds to the Kernel estimation.

Source: Banco de Portugal, Annual Reports.

Figure 3 Frequency Distribution and Kernel Estimation of the Probability Density Function (PTE/DM, Sub-period 1)



Note 1: For a description of the variables see Appendix 1.

Note 2: In the horizontal axis, "1" corresponds to the interval of exchange rate variation [-5.85%, -5%[; "2 "to [-5%, -4%[; "3" to [-4%, -3%[; "4" to [-3%, -2%[; "5" to [-2%, -1%[; "6" to [-1%, 0%[; "7" to [0%, +1%[; "8" to [+1%, +2%[; "9" to [+2%, +3%[; "10" to [+3%, +4%[; "11" to [+4%, +5%[and "12" to [+5%, +6.18%].

Source: Banco de Portugal, Annual Reports.

Figure 4 Exchange Rate and Interest Rate Distribution and Volatility (PTE/DM, Sub-period 1)

We also evaluated the distribution of the exchange rate series in specific intervals of exchange rate variation of identical width (first part of Figure 4). From this analysis, we proceeded to study the exchange rate and the interest rates volatility in each interval used in the histograms (second part of Figure 4). For this, we considered twelve intervals in the ±6% fluctuation band.

As can be seen from Figure 4 (first part), most of the observations lie close to the central parity for the whole target zone period, thus rejecting once again the U-shaped density of the exchange rate[6].

The analysis of the histograms (see first part of Figure A.2 in Appendix 2) also allowed us to conclude that only in the period immediately after the Portuguese escudo joined the ERM (sub-periods 2 and 8) were there a larger number of observations lying close to the limits of the band, although this is not very pronounced near the upper edge. The autonomy in monetary policy making as well as in exchange rate policies, possibly due to the maintenance of capital movement restrictions, explains the stability of the exchange rate near the edges of the band.

For the remaining sub-periods, the U-shape in the distribution of the PTE/DM exchange rate is clearly rejected by the analysis of the histograms. Table 3 summarizes the fundamental nature of these results based on the relative frequencies of exchange rate distribution in each of the twelve intervals of the band.

Table 3 Relative Frequency of PTE/DM Exchange Rate Observations in Twelve Intervals of the Band

Sub-periods	Lower Edge [(a)]	Centre of the Band [(b)]	Upper Edge [(c)]	Distribution
1	13.50	53.17	33.33	∩
2	48.18	33.58	18.24	⎩; ∪
3	46.67	53.33	0	—
4	9.44	6.78	83.78	⎭
5	6.42	77.74	15.84	∩
6	53.31	37.28	9.41	⎩
7	4.58	57.03	38.39	∩
8	50.33	31.79	17.88	⎩; ∪
9	9.56	55.45	34.99	∩
10´	*49.61*	*48.31*	*2.08*	—
11	*0*	*94.71*	*5.29*	∩

Note 1: (a) Sum of the relative frequencies of the intervals 1 to 4 (%).
(b) Sum of the relative frequencies of the intervals 5 to 8 (%).
(c) Sum of the relative frequencies of the intervals 9 to 12 (%).

Note 2: ∪= bi-modal or U-shaped distribution (larger number of observations near the edges of the band); ∩= uni-modal or unshaped distribution (larger number of observations near the centre of the band); ⎩= uni-modal distribution in the form of "U cut to the right" (larger number of observations near the lower edge of the band); ⎭= uni-modal distribution in the form of "U cut to the left" (larger number of observations near the upper edge of the band); — = Undetermined distribution.

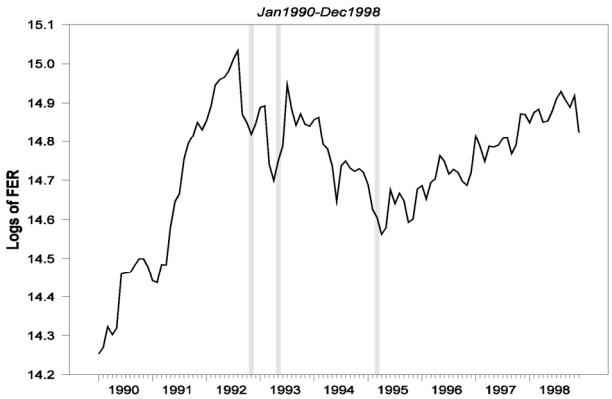
Source: Banco de Portugal, Annual Reports.

The results are not very different from those in Flood, Rose, and Mathieson (1991), Bertola and Caballero (1992), Magnier (1992), Lindberg and Soderlind (1994), Christopher Cornell (2003), Christian Bauer, Paul De Grauwe, and Stefan Reitz (2008) and Fidrmuc and Horváth (2008) for the case of the fluctuation bands of the countries of the centre of the EMS, transition countries, and for the Swedish uni-

[6] At the second part of Figure 4 we represent the exchange rate and interest rate differential volatility considered in the histogram. See Figure A.2 in Appendix 2.

lateral target zone. This lack of conformity with theoretical predictions, instead of indicating the uselessness of the bands, is due to the monetary authorities credibility expressed by current intra-marginal interventions, which were frequent during the period under analysis. Since the intra-marginal interventions limit the amount of time spent by the exchange rates near the edges of the band, their occurrence take the exchange rates close to the central parity, thus contributing decisively to the rejection of the first prediction of the model[7].

Figure 5 presents the monthly evolution of the foreign exchange reserves held by the Portuguese monetary authorities from January 1990 to December 1998. Its evolution allows the frequency of intra-marginal interventions to be evaluated and also helps to understand how the Portuguese authorities managed to stabilize the behaviour of the Portuguese escudo within the band, even during the periods of disturbance in the ERM.



Note 1: The vertical shadows concern to the data of the realignments of the central parity of the Portuguese Escudo.
Note 2: Logs of FER represents the logarithms of the foreign exchange reserves of the Portuguese monetary authorities, excluding gold.

Source: Banco de Portugal, Statistical Bulletins.

Figure 5 Monthly Evolution of the Foreign Exchange Reserves

As can be seen, during the periods of greater instability in the EMS, when the central parity of the Portuguese escudo was realigned, there was a fairly significant reduction in the foreign exchange reserves held by the Portuguese monetary authorities. A few months after the beginning of the participation of the Portuguese escudo in the exchange rate mechanism, the Portuguese central bank began to lose quite substantial amounts of foreign exchange reserves. The realignment on November 23 1992 only temporarily relieved the pressure on the Portuguese currency, with the foreign exchange reserves again declining in March and April 1993. The realignment of the following month introduced some stability to the foreign exchange market. In

[7] Our conclusions must be smoothed by the fact that we only used as a fundamental the interest rate differential and by the theoretical unrealistic hypothesis of a Brownian movement for fundamentals.

an attempt to defend the original central parity with which the Portuguese escudo joined the exchange rate target zone of the EMS, and afterwards the parity adopted in November 1992, the Banco de Portugal lost in little more than six months around 28% of the foreign exchange reserves it held in late August 1992.

The foreign currency sales helped to cope with the speculative attacks on the Portuguese currency. We can also see that the foreign exchange reserves were restored in the periods immediately following the realignment. The change of central parity relieved the pressure on existing foreign exchange reserves, avoiding their total depletion. By using these two ways it was possible to keep the exchange rate in the target zone regime and, more importantly, close to the central parity. This analysis makes it is possible to explain the results lack of conformity with the predictions of the literature[8].

On the other hand, the fact that the Portuguese escudo floated within a wide band of ±6% implied a lower probability that the edges of the target zone would be reached. If a narrow band of ±2.25% had been adopted, the exchange rates would certainly have remained near the boundaries of the target zone more often.

However, the proximity of the exchange rates to the edges of the band should not be regarded by itself as a measure of lack of credibility, as it may simply indicate that the target zone is being tested by the agents operating in the market. It is also important to analyse the volatility of the exchange rate as it gets closer to the edges of the band. According to Flood, Rose, and Mathieson (1991), Krugman (1991), Svensson (1991a, b), Bertola and Caballero (1992), Baghli (2004), and López and Mendizábal (2007), evidence of lower volatility near the edges of the band is an indicator of credibility. In most of the sub-periods analysed, the PTE/DM exchange rate volatility tends to increase as the exchange rate approaches the edges of the band, particularly the upper edge, contrary to theoretical predictions (see Tables 4a and 4b). However, this lack of conformity with the predictions of the basic model should not be interpreted as indicating the lack of credibility of the Portuguese escudo floating band. It is important to remember that the escudo very rarely approached the edges of the band, where the existence of less volatility in the exchange rate should be more obvious.

Tables 4a and 4b summarizes exchange rate and interest rate volatility using descriptive indicators for the twelve intervals of the floating band.

The exchange rate volatility analysis also confirms that the realignments are preceded by periods of above average volatility, largely as a result of speculative attacks and fear of a sudden depreciation in the currency value. The periods immediately after the realignments, however, are characterized by below-average exchange rate volatility, due to the fact that the weak competitive position of the currency has been restored.

[8] See Tronzano, Psaradakis, and Sola (2003).

Table 4a Exchange Rate and Interest Rate Volatility

Sub-period	Exchange Rate (a)				Interest Rate Differential; Overnight (b)			
	Minimum		Maximum		Minimum		Maximum	
	Standard Deviation	Intervals	Standard Deviation	Intervals	Standard Deviation	Intervals	Standard Deviation	Intervals
1	0.08625	I_6	1.09932	I_{12}	0.25811	I_6	2.18513	I_{12}
2	0.18888	I_2	0.97383	I_8	0.60932	I_8	1.23089	I_9
3	0.21328	I_7	0.33621	I_5	0.72791	I_6	0.90201	I_3
4	0.19052	I_{11}	1.09932	I_{12}	0.18562	I_2	2.18513	I_{12}
5	0.04594	I_6	0.19801	I_{10}	0.12508	I_5	0.55742	I_{10}
6	0.27716	I_6	0.98555	I_{10}	0.64246	I_8	1.20590	I_9
7	0.04594	I_6	0.26696	I_{10}	0.12508	I_5	0.66388	I_{11}
8	0.18888	I_2	0.98555	I_{10}	0.67213	I_7	1.20590	I_9
9	0.08625	I_6	1.09932	I_{12}	0.18562	I_2	2.18513	I_{12}
10´	*0.11178*	I_3	*0.19476*	I_4	*0.18979*	I_3	*1.86544*	I_7
11	*0.15781*	I_6	*1.03457*	I_{10}	*0.78696*	I_{10}	*3.24793*	I_7

Note 1: (a) Standard deviation of the variations of the PTE/DM exchange rate in each interval considered in the histogram; (b) Standard deviation of the variations of the overnight interest rate differential in each interval considered in the histogram; (c) Standard deviation of the variations of the interest rate differential with a maturity of 28 to 32 days in each interval considered in the histogram.

Note 2: I_j with j= 1, 2, 3,..., 12= intervals of the exchange rate band; ∪= Minimum volatility in the centre of the band (intervals I_5, I_6, I_7, I_8) and increasing near the edges of the band (intervals I_1, I_2, I_3, I_4, I_9, I_{10}, I_{11}, I_{12}); ∩= Maximum volatility in the centre of the band and decreasing near the edges of the band; ⟨= Increasing volatility near the lower edge of the band (intervals I_1, I_2, I_3, I_4); ⟩= Decreasing volatility near the lower edge of the band; ⟩= Increasing volatility near the upper edge of the band (intervals I_9, I_{10}, I_{11}, I_{12}); ⟨= Decreasing volatility near the upper edge of the band; — = Volatility with undefined behaviour.

Source: Banco de Portugal, Annual Reports.

Table 4b Exchange Rate and Interest Rate Volatility (cont.)

Sub-period	Interest Rate Differential Maturity of 28 to 32 days (c)				Volatility		
	Minimum		Maximum		Exchange Rate (a)	Interest Rate (b) Overnight	Interest Rate (c) 28 days
	Standard Deviation	Intervals	Standard Deviation	Intervals			
1	0.13531	I_6	1.83876	I_{12}	∪	∪	∪
2	0.17470	I_3	0.76075	I_9	∩	∪	—
3	0.18404	I_5	0.75829	I_3	—	—	∪
4	0.16953	I_5	1.83876	I_{12}	—	⟩	⟩
5	0.08756	I_6	0.31187	I_{10}	∪	⟩	∪
6	0.15438	I_8	0.74500	I_9	—	∪	—
7	0.08756	I_6	0.40474	I_{11}	∪	⟩	⟩
8	0.14730	I_8	0.74500	I_9	—	∪	—
9	0.13531	I_6	1.83876	I_{12}	∪	⟩	⟩
10´	*0.13282*	I_9	*0.74216*	I_7	—	∩	∩
11	*0.26865*	I_6	*0.90948*	I_8	⟩	⟨	—

Source: Banco de Portugal, Annual Reports.

We also observe that the interest rate differential volatility seems to behave in accordance with the implications of the theory. In effect, interest rate volatility increases as the exchange rate approaches the edges of the band. Furthermore, the results of this analysis allow us to conclude that at least in one case (sub-period 2) there is a trade-off between the exchange rate volatility and the overnight interest rate differential volatility. Possible explanations for this situation are the modernisation of the banking and financial system, and the progress made in terms of disinflation policy, which allowed the interest rate to serve as an alternative variable to the exchange rate in the adjustment process following a monetary shock, thereby facilitating the pursuit of the main objective of price stability. In this context, the participation of the Portuguese escudo in a target zone was crucial to create the conditions of stability, credibility, and confidence, necessary for the adoption of the single currency.

5. Conclusion

In this study we have analysed the participation of the Portuguese escudo in the ERM of the EMS according to the literature on target zones. Our main aim was to study the behaviour and volatility of exchange and interest rates based on the predictions of the first generation of target zones models. The contribution to the literature stems from the fact that we considered a currency from the system's periphery, while most previous work has focused on the Nordic countries and on fluctuation bands of the ERM considered as more stable and credible.

The empirical results do not support the theoretical predictions of the basic target zone model, but this does not mean that the participation in a target zone did not have a stabilizing effect upon the exchange rate behaviour.

The analysis of the distribution of the exchange rate has confirmed that most of the observations tended to lie near the central parity, thus rejecting the U-shaped distribution implied by the theory. The basic target zone model assumes that monetary interventions are only carried out at the edges of the band, i.e. are marginal interventions, when actually the functioning of the ERM of the EMS was characterised by frequent intra-marginal interventions. The non confirmation of this basic assumption can explain our empirical results. For most of the sub-periods, volatility tended to increase as the exchange rate approached the edges of the band, contrary to the predictions of the basic model. Interest rate differential volatility, on the other hand, seemed to behave in line with theoretical predictions that imply that the interest rate volatility is minimal at the centre of the band and increases near the edges of the band, replacing in this situation the exchange rate as the main variable in the adjustment process following a monetary shock.

This is particularly interesting given the presence of a negative trend in the interest rate differential which, instead of representing inefficient actions in the foreign exchange market, reveals the high degree of macroeconomic stability achieved in the Portuguese economy. The downward path eventually reflects the increased credibility of the conduct of monetary policy, allowing the continued pursuit of exchange rate stability, in the context of the ultimate objective of price stability.

The exchange rate target zone regime adopted by Portugal confirms that a small open economy in the periphery can also conduct a successful stabilising policy

of the exchange rate and the interest rate, even during times of turbulence in the EMS. In effect, even during the most turbulent phases, Portugal did not abandon the EMS and also maintained the target of ±6% band.

The monetary integration process of the Portuguese economy should therefore be used as an example by other small open economies in the sense that they may benefit from adopting an intermediate exchange rate regime like a target zone as a strategy for a "smooth" transition to a more extreme exchange rate regime as the EMU, otherwise they will be more exposed to speculative attacks, especially in the case of real appreciation of their currencies.

References

Baghli, Mustapha. 2004. "Modelling the FF/MM Rate by Threshold Cointegration Analysis." *Applied Economics*, 36(6): 533-548.

Banco de Portugal. 1990, 1992, 1993, 1995, 1997, 1999. *Annual Report*. Lisboa: Banco de Portugal.

Banco de Portugal. 1992, 1994, 1996, 1999. *Statistical Bulletin*, *December*. Lisboa: Banco de Portugal.

Barbosa, António, and José Machado. 1996. "O Custo da Desinflação Portuguesa: Uma Nota." *Boletim Económico*, 9(1): 47-50.

Bauer, Christian, Paul De Grauwe, and Stefan Reitz. 2008. "Exchange Rate Dynamics in a Target Zone – a Heterogeneous Expectations Approach." *Journal of Economic Dynamics and Control*, 33(2): 329-344.

Bertola, Giuseppe. 1994. "Continuous-Time Models of Exchange Rates and Intervention." In *The Handbook of International Macroeconomics*, ed. Frederick Ploeg, 251-298. Oxford: Blackwell Economics.

Bertola, Giuseppe, and Ricardo Caballero. 1992. "Target Zones and Realignments." *American Economic Review*, 82(3): 520-536.

Bordo, Michael, and Ronald MacDonald. 2005. "Interest Rate Interactions in the Classical Gold Standard, 1880-1914: Was there Any Monetary Independence?" *Journal of Monetary Economics*, 52(1): 307-327.

Calvo, Guillermo, and Carmen Reinhart. 2002. "Fear of Floating." *Quarterly Journal of Economics,* 127(2): 379-408.

Cornell, Christopher. 2003. "Target Zones, Reserves Crises, and Inverted S-Curves." *Journal of International Financial Markets Institutions & Money*, 13(4): 313-323.

Demange, Gabrielle, and Jean-Charles Rocher. 2005. *Méthodes mathématiques de la finance.* 3rd Edition. Paris: Economics.

Dumas, Bernard. 1989. "Pricing Physical Assets Internationally: A Non-Linear Heteroscedastic Process for Equilibrium Real Exchange Rates." University of Pennsylvania Working Paper 25.

Fidrmuc, Jarko, and Roman Horváth. 2008. "Volatility of Exchange Rates in Selected New EU Members: Evidence from Daily Data." *Economic Systems*, 32(1): 103-118.

Fischer, Stanley. 2001. "Exchange Rate Regimes: Is the Bipolar View Correct?" *Journal of Economic Perspectives*, 15(2): 3-24.

Flood, Robert, Andrew Rose, and Donald Mathieson. 1991. "An Empirical Exploration of Exchange Rate Target Zones." IMF Working Paper 91/15.

Frankel, Jeffrey. 1999. *No Single Currency Regime is Right for All Countries or at All Times*. Princeton: Princeton University Press.

Frankel, Jeffrey, and Steven Phillips. 1992. "The European Monetary System: Credible at Last." *Oxford Papers*, 44(4): 791-816.

Garber, Peter, and Lars Svensson. 1995. "The Operation and Collapse of Fixed Exchange Rate Regimes." In *Handbook of International Economics*, ed. Gene M. Grossman and Kenneth Rogoff, 1865-1911. Amsterdam: Elsevier.

Harrison, Michael. 1985. *Brownian Motion and Stochastic Flow Systems*. New York: John Wileys & Sons.

Hendry, David, and Jurgen Doornik. 2001. *Empirical Econometric Modelling Using PcGive 10*. London: Timberlake Consultants.

Karatzas, Ioannis, and Steven Shreve. 1997. *Brownian Motion and Stochastic Calculus*. 2nd Edition. New York: Springer-Verlag.

Kempa, Bernd, and Michael Nelles. 1999. "Theory of Exchange Rate Target Zones." *Journal of Economic Surveys,* 13(2): 173-210.

Krugman, Paul. 1987. "Trigger Strategies and Price Dynamics in Equity and Foreign Exchange Markets." NBER Working Paper 2459.

Krugman, Paul. 1991. "Target Zones and Exchange Rate Dynamics." *The Quarterly Journal of Economics*, 116(3): 669-682.

Lai, Ching-chong, Chung-rou Fang, and Juin-jen Chang. 2008. "Volatility Trade-offs in Exchange Rate Target Zones." *International Review of Economics and Finance*, 17(1): 366-379.

Levy-Yeyati, Eduardo, and Federico Sturzenegger. 2005. "Classifying Exchange Rate Regimes: Deeds versus Words." *European Economic Review*, 49(6): 1603-1635.

Lindberg, Hans, and Paul Soderlind. 1994. "Testing the Basic Target Zone Model on Swedish Data: 1982-1990." *European Economic Review*, 38(1): 1441-1469.

López, Jesús, and Hugo Mendizábal. 2007. "The Optimal Degree of Exchange Rate Flexibility: A Target Zone Approach." *Review of International Economics*, 15(4): 803-822.

Lutkepohl, Helmut, and Marcus Kratzig. 2004. *Applied Time Series Econometrics.* Cambridge: Cambridge University Press.

Maddala, G. S., and In-Moo Kim. 1999. *Unit Roots, Cointegration and Structural Change*. Cambridge: Cambridge University Press.

Magnier, Antoine. 1992. "Théorie des zones cibles et fonctionnement du SME." *Economie et Prévision*, 104(1): 1992-1993.

McKinnon, Robert. 1984. *An International Standard for Monetary Stabilisation*. Washington: Institute for International Economics.

Pagan, Adrian, and Aman Ullah. 1999. *Nonparametric Econometrics*. Cambridge: Cambridge University Press.

Pansard, Fabrice. 1997. "La détermination du taux de change en zones cibles: une synthèse des théories." Économie Internationale Document de Travail 1997-12/EI.

Reinhart, Carmen, and Kenneth Rogoff. 2004. "The Modern History of Exchange Rate Arrangements: A Reinterpretation." *The Quarterly Journal of Economics*, 119(1): 1-48.

Svensson, Lars. 1991a. "Target Zones and Interest Rate Variability." *Journal of International Economics*, 31(2): 27-54.

Svensson, Lars. 1991b. "The Simplest Test of Target Zone Credibility." *IMF Staff Paper*, 38(1): 655-665.

Svensson, Lars. 1992. "An Interpretation of Recent Research on Exchange Rate Target Zones." *Journal of Economic Perspectives*, 6(4): 119-144.

Svensson, Lars. 1994. "Why Exchange Rate Bands? Monetary Independence in Spite of Exchange Rates." *Journal of Monetary Economics*, 33(1): 157-99.

Taylor, Mark, and Matteo Iannizzotto. 2001. "On the Mean-Reverting Properties of Target Zone Exchange Rates: A Cautionary Note." *Economics Letters*, 71(1): 117-29.

Tronzano, Marco, Zacharias Psaradakis, and Martin Sola. 2003. "Target Zone Credibility and Economic Fundamentals." *Economic Modelling*, 20(1): 791-807.

Williamson, John. 1985. *The Exchange Rate System*. Washington: Institute for International Economics.

Williamson, John, and Marcus Miller. 1987. *Target and Indicators: A Blueprint for the International Coordination of Economic Policy*. Washington: Institute for International Economics.

Appendix 1 Variables Used in the Empirical Analysis

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 PTE/DM
LS_PTE_DM	Official upper edge for 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 PTE/DM and an unofficial exchange rate band of ±6%
No_LS_PTE_DM_6	Unofficial upper edge for PTE/DM and an unofficial exchange rate band of ±6%
Dif_O	Differential between the Portuguese overnight interest rate and the German overnight interest rate (%)
Dif_28	Differential between the Portuguese interest rate with a maturity of 28 to 32 days and the German interest rate with a maturity of 28 to 32 days (%)
(i-i*)_O	Differential between the Portuguese overnight interest rate and the German overnight interest rate (log)
(i-i*)_28	Differential between the Portuguese interest rate with a maturity of 28 to 32 days and the German interest rate with a maturity of 28 to 32 days (log)
DC_PTE/DM	Deviation of the PTE/DM exchange rate from the central parity
RF_DC_PTE/DM	Relative frequency of DC_PTE/DM (%)
SD_V_PTE/DM	Standard deviation of the PTE/DM variation (log)
SD_V_(i-i*)_O	Standard deviation of the variation of (i-i*)_O
SD_V_(i-i*)_28	Standard deviation of the variation of (i-i*)_28

Source: The authors.

Appendix 2 Figures

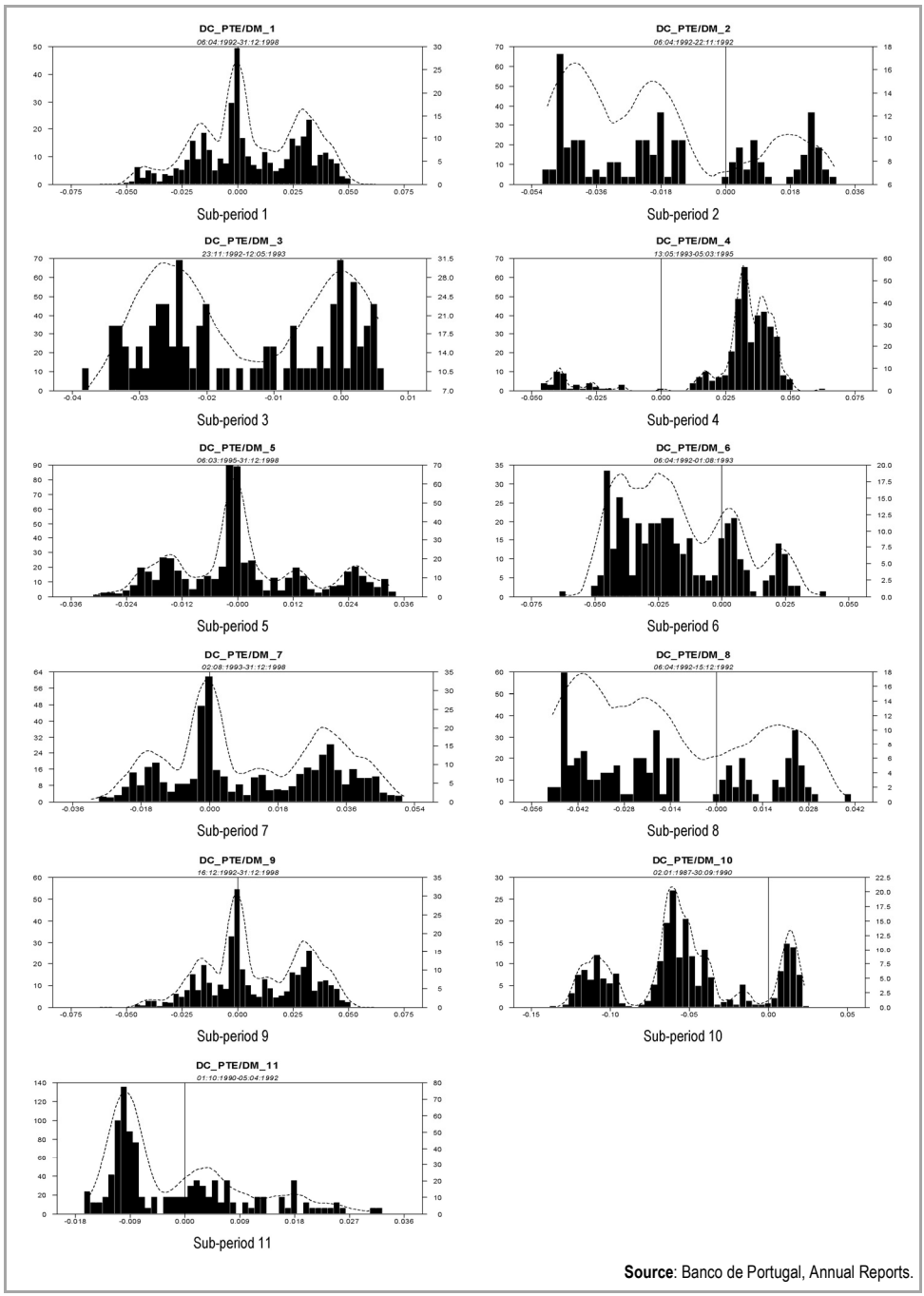
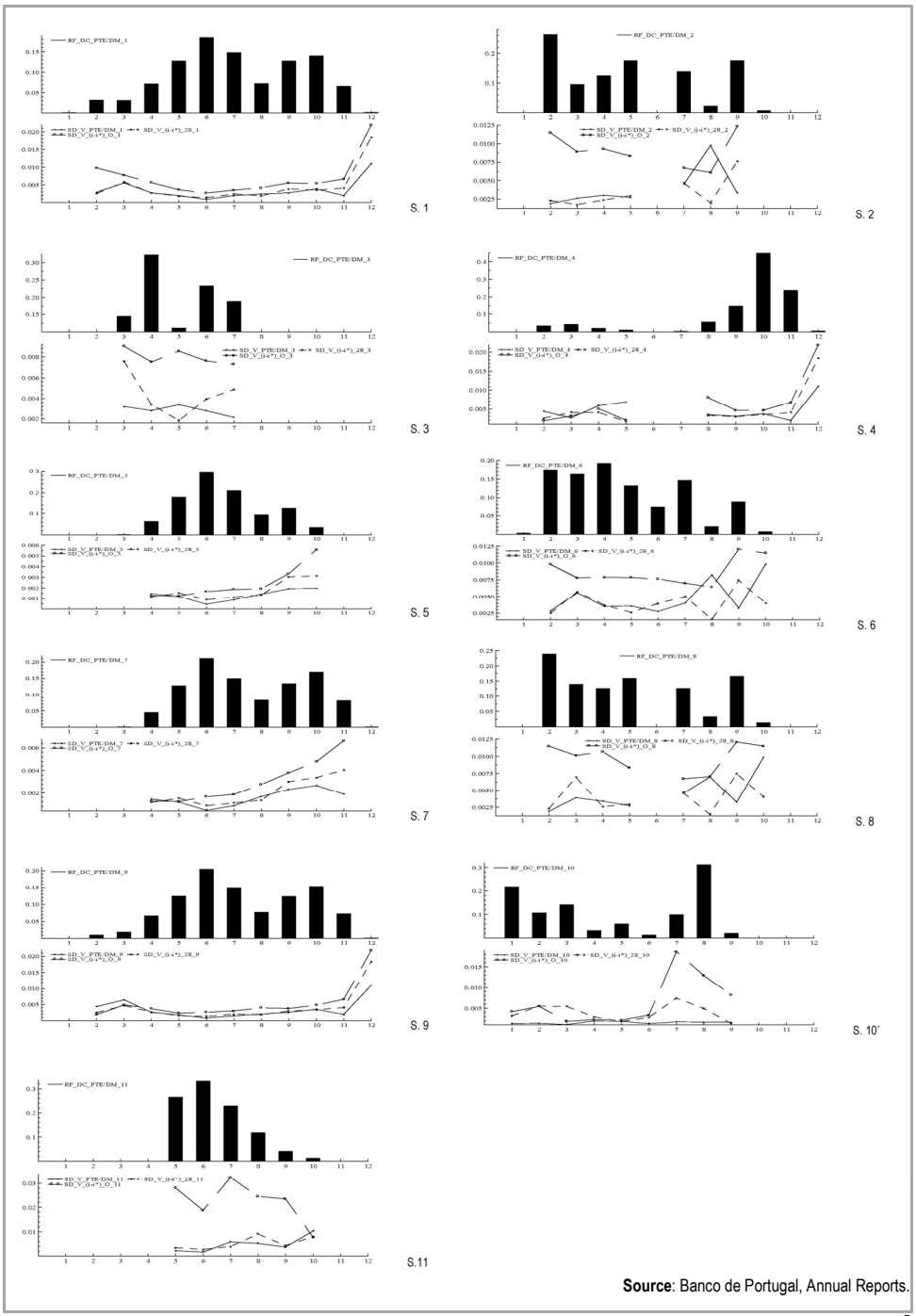


Figure A.1 Frequency Distribution and Kernel Estimation of the Probability Density Function (PTE/DM, All Sub-periods)



Source: Banco de Portugal, Annual Reports.

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Figure A.2 Exchange Rate and Interest Rate Distribution and Volatility (PTE/DM, All Sub-periods)