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Were The Peseta Exchange Rate Crises Forecastable During Target Zone Period?

M. Isabel Campos & Zenón Jiménez-Ridruejo[*†]
University of Valladolid (Spain)

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Abstract

During the 1990's several fixed or quasi-fixed exchange rate systems collapsed. Currency crises have happened in both developed and emerging countries so it is necessary to forecast and avoid them. However, financial market crises have been extremely difficult to forecast. Economic agents' expectations are non-observable variables that cannot be ignored in our models. In addition, if we want to study the European case during the 1990's, the censored disposition of the exchange rate cannot be ignored either. We propose a discrete time target zones model where these aspects are taken into account. It will be tested in a peseta/deutsche mark exchange rate framework, from June 1989 to December 1998. The results indicate differences between before and after the shift in band widths in August 1993.

Keywords: Target Zones, Currency Crises, Mean Reversion, Realignment Probability

JEL: F31-Foreign Exchange

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[†] Department of Economic Analysis. Economic and Business Faculty (University of Valladolid). Avda Valle Esgueva, 6, 47.011-Valladolid- (Spain). Tf: +34 983 423382. Fax: +34 983 423299. E-mail: maribel@eco.uva.es; zenon@eco.uva.es

1 Introduction

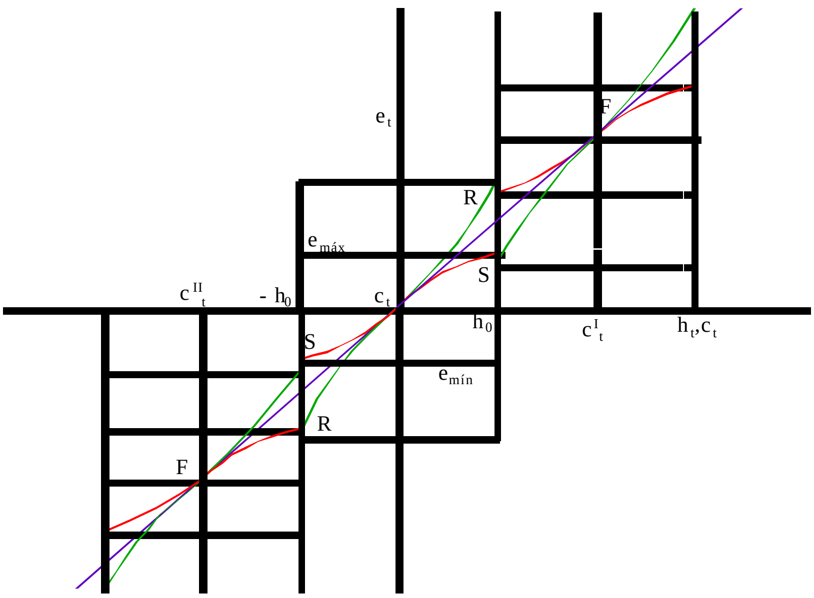
During the 1990's several …xed or quasi-…xed exchange rate systems collapsed. Episodes such as the crisis of the European ERM [Exchange Rate Mechanism] in 1992-93, the Turkish lira crisis in 1994, the collapse of the Mexican peso in 1994-95, the crash of the Czech Krona in 1997, the East Asian turmoil in 1997-98, the fall of the Russian ruble in 1998, or the crisis of the Brazilian real in 1999, have renewed interest concerning the e¤ectiveness of intervention capable of reducing, or at least preventing, …nancial market crises. Thus, speculative attacks have manifested not only realignments, but also intensive pressure on the exchange rate, where governments have avoided them at the expense of sizeable losses in foreign exchange reserves and/or large increases in interest rates.

Then, it is important to forecast and avoid currency crises. However, the …nancial market crises have been extremely di¢cult to forecast because the economic agents' expectations are non-observable variables that cannot be ignored in our models.

If we also want to study the European case during the 1990's, the censored disposition of exchange rate cannot be ignored either. An important part of the exchange rate literature, both theoretical and empirical, has modeled the behaviour of the target zone exchange rate. These studies, characterized by a continuous stochastic time modelization, have been called "Target Zones Models" in continuous time. Since the initial papers by Flood & Garber (1983), Williamson & Miller (1987), or the well-known paper by Krugman (1991), the features of these models point out the fact that the band, if credible, plays a stabilizing e¤ect [it is known as "honeymoon e¤ect"] on the exchange rate which exhibits less variability than in the free ‡oat case. In a simple two countries monetary model, in continuous time, the exchange rate will be a function of both fundamentals and expected depreciation of exchange rate. The typical expression for the exchange rate behaviour is the following:

$$e_t = e(h_t) = h_t + ° E_t(de_t = dt) \qquad (1.1)$$

where e_t is the log of exchange rate, defined as the domestic price of a unit of foreign currency, h_t represents the "fundamentals" or basic variables that determine e_t, γ is the semi-elasticity of money demand with respect to interest rate, and $E_t\,(de_t/dt)$ describes the expectation of exchange rate depreciation in period t. In figure 1, the SS curve represents the exchange rate evolution in a target zone with full credibility. However, as Bertola and Caballero (1992.a, 1992.b) suggest, the realignment expectations in the band could invert the Krugman (1991) SS curve. There will not be an S shaped curve between exchange rate and fundamentals, and so, there will not be a honeymoon effect as target zones literature predicts. On the contrary, there will be a RR curve, as is represented in figure 1 and is known, in this literature, as "divorce effect". This paper will suggest, depending on the band width, both possibilities in the peseta/deutsche mark evolution during the target zone period.



Exchange rate with possibility of realignment

One of the deeper aspects studied by target zones literature has been the credibility degree of the target zone. There are di¤erent methodologies to estimate expected exchange rate depreciation in a target zone.[1] The common feature is the introduction of a stochastic continuous time modelling, taking the exchange rate as a non-censored dependent variable.[2]

We propose a model of target zone in discrete time where we take into account the censored nature of exchange rates and the fact that economic agents include this censored nature and the possibility of the realignments in their expectations; because these aspects could, to some extent, in‡uence the estimation signi…cance level. We will develop a theoretical model of Limited Dependent Rational Expectations [LD-RE] and we will estimate the LD-RE model [3] for the peseta/deutsche mark exchange rate by maximum likelihood.

As we shall see, our results do not verify the regularities found for other exchange rates in the European Monetary System. In previous papers,[4] we suggested, at least in the narrow band, that there was not an S shaped curve between exchange rate and fundamentals. In this paper, using two alternative formulations of conditional variance of exchange rate shocks, we will …nd, depending on the band width, di¤erent evidence of mean reversion and the possible e¤ect of a reduction in exchange rate volatility, which is known as honeymoon e¤ect in the Target Zones Literature.

[1] From the so called "Basic Model" developed by Krugman (1991), taking into account the poor results of his empirical tests, several ways of development have arisen to improve the ‡exibility of the assumptions about perfect credibility of bands and in…nitesimal intervention. Vid: Bertola & Caballero (1992.a, 1992.b), Svensson (1991), Bertola & Svensson (1993), Svensson (1992) or Tristani (1994), among others.

[2] Since the edition of the Bertola & Svensson (1993) paper, a lot of new methods have been developed to pull up information about market expectations. We shall mention the papers by Mizrach (1995), Ayuso & Pérez Jurado (1997), Gómez Puig & Montalvo (1997), Söderlind & Svensson (1997) or Bekaert & Gray (1998), which detail target zones models with stochastic devaluation jumps, constants or variables through time.

[3] There are a lot of papers about the econometric estimation of models with censored dependent variables. This work was developed from an initial paper by Tobin (1958), who suggested an iterative process to solve this kind of equations and to estimate by maximum likelihood. It was followed by the papers by Chanda & Maddala (1983), Shonkwiler & Maddala (1985), Pesaran (1989) or Holt & Johnson (1989). Recent developments are provided by Pesaran & Samiei (1992.a, 1992.b, 1995), Donald & Maddala (1992), Lee (1994) or Pesaran & Ruge-Murcia (1996, 1999). Our estimation procedure is based on the tecnique developed by Pesaran & Ruge-Murcia (1999).

[4] See Campos et al., 1999.a, 1999.b.

2 The Theoretical LD-RE[5] Model

The theoretical model of exchange rate determination that we use in this paper is an extension of Dornbusch's (1976) model for two countries, adding variable output and considering the economy is not always in the potential output. The equations are the following:

$$(m_t - m_t^*) = (p_t - p_t^*) - \alpha_1 (i_t - i_t^*) + \alpha_2 (y_t - y_t^*) + \varepsilon_{0t} \tag{2.1}$$

$$(y_t - y_t^*) = (\alpha_0 - \alpha_0^*) - \alpha_4 (r_t - r_t^*) + \alpha_5 (e_t - p_t + p_t^*) + \varepsilon_{1t} \tag{2.2}$$

$$\left[\left(p_{t+1} - p_{t+1}^*\right) - (p_t - p_t^*)\right] = \alpha_6 (y_t - y_t^*) - \alpha_6 (\bar{y} - \bar{y}^*) + \varepsilon_{2t} \tag{2.3}$$

$$E\left(e_{t+1}/I_t\right) - e_t = (i_t - i_t^*) + PR_t \tag{2.4}$$

$$(r_t - r_t^*) = (i_t - i_t^*) - \left[\left(p_{t+1} - p_{t+1}^*\right) - (p_t - p_t^*)\right] \tag{2.5}$$

Equation (2.1) represents the money market equilibrium differential with predetermined prices in the short term, where the asterisk denotes the foreign country, the variables are expressed in logs and the notation is the usual.

Equation (2.2) represents the aggregate demand functions differential, where the output in each country could be different to the full employment level function. In the case of predetermined prices we assume that, in the short term, the output is demand determined.[6]

Expression (2.3) explains predetermined price adjustment, which responds to excess of demand for each country.

Equation (2.4) expresses deviation from Uncovered Interest Parity to the exchange rate. With perfect capital mobility, the UIP condition implies that

[5] "Limited Dependent Rational Expectations"

[6] The seminal Dornbusch (1976) model would suppose the production is always at the full employment level.

the interest rates differential equals the expected depreciation of the exchange rate.

The last equation (2:5) expresses the real interest rates differential obtained from the Fisher equation for each country.

Substituting and operating in the previous expressions, we get the equation that describes the evolution of the exchange rate as a function of its fundamentals:

$$
\begin{aligned}
\Rightarrow \quad e_t = {} & \frac{(\alpha_0 - \alpha_0^*)}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)} + \frac{\alpha_6\alpha_4}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)}(\bar{y} - \bar{y}^*) + \\
& + \frac{(\alpha_4 - \alpha_1\alpha_5)}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)} E(e_{t+1}/I_t) - \frac{\alpha_5}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)}(m_t - m_t^*) + \\
& + \frac{(\alpha_2\alpha_5 - 1 + \alpha_4\alpha_6)}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)}(y_t - y_t^*) + \frac{(\alpha_4 - \alpha_1\alpha_5)}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)} PR_t + \\
& + \frac{\alpha_5}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)} \upsilon_{0t} + \frac{\alpha_4}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)}(\upsilon_{1t} + \upsilon_{2t}) - \\
& - \frac{(\alpha_1\alpha_5 - \alpha_4)}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)} \mu_{3t} \qquad (2.6)
\end{aligned}
$$

To simplify the notation, we call the new set of parameters β_j and the new disturbance term ε_t:

$$\beta_0 = \frac{(\alpha_0 - \alpha_0^*) + \alpha_6\alpha_4(\bar{y} - \bar{y}^*)}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)}$$

$$\beta_1 = \frac{(\alpha_4 - \alpha_1\alpha_5)}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)}$$

$$\beta_2 = \frac{\alpha_5}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)}$$

$$\beta_3 = \frac{(\alpha_2\alpha_5 - 1 + \alpha_4\alpha_6)}{(\alpha_4 - \alpha_1\alpha_5 - \alpha_5)}$$

$$\varepsilon_t = \frac{\alpha_5 \upsilon_{0t} + \alpha_4 (\upsilon_{1t} + \upsilon_{2t}) - (\alpha_1 \alpha_5 - \alpha_4)\, \mu_{3t}}{(\alpha_4 - \alpha_1 \alpha_5 - \alpha_5)}$$

and we get the following equation of exchange rate, where χ is the coefficient vector and h_t' is the fundamental vector.

$$e_t = \beta_1 E\,(e_{t+1}/I_t) + \chi h_t + \varepsilon_t \tag{2.7}$$

where: $\chi = [\beta_0; -\beta_2; \beta_3; \beta_1]$ is a 1 x 4 coefficient vector

$h_t' = [1; (m_t - m_t^*); (y_t - y_t^*); PR_t]$ such h_t is a 4 x 1 fundamental vector

In a target zone regime there are maximum and minimum limits. We can assume that the exchange rate is described by the following non linear process, if the band is credible, where c_t is the log of central parity, ρ is the band width and, without lost of generality, we can assume that the band is symmetric.

In this case, we can assume that the exchange rate is described by the following non linear process:

$$e_t = \begin{cases} e_{max;t} & \text{if} \quad \beta_1 E\,(e_{t+1}/I_t) + \chi h_t + \varepsilon_t \geq e_{max;t} \\ \tilde{e}_t^* & \text{if} \quad e_{min;t} < \beta_1 E\,(e_{t+1}/I_t) + \chi h_t + \varepsilon_t < e_{max;t} \\ e_{min;t} & \text{if} \quad \beta_1 E\,(e_{t+1}/I_t) + \chi h_t + \varepsilon_t \leq e_{min;t} \end{cases} \tag{2.8}$$

where:

$$\tilde{e}_t^* = \beta_1 E\,(e_{t+1}/I_t) + \chi h_t + \varepsilon_t$$

$$e_{max;t} = c_t + \frac{\rho}{2}; \text{ y } e_{min;t} = c_t - \frac{\rho}{2}$$

To solve this equation we must take expectations over an infinitive sequential of censored variables, analytically described by an infinite set of integrals and unresolved mathematically.[7] Bearing in mind previous works of Pesaran & Samiei (1992.a, 1992.b) and Pesaran & Ruge-Murcia (1999) we will assume the

[7] This aspect was studied by Pesaran & Samiei (1995) finding an exact solution in a LD-RE model with perfect credibility of the band and h_t made up of serially independents variables.

following approximation: "The stable solution to a mathematical model with future expectations is equivalent to a model with current expectations".

Then, we can express the exchange rate in a target zone as follows:

$$e_t = \begin{cases} e_{max,t} & \text{if} \quad \tilde{e}_t \geq e_{max,t} \\ \tilde{e}_t & \text{if} \quad e_{min,t} < \tilde{e}_t < e_{max,t} \\ e_{min,t} & \text{if} \quad \tilde{e}_t \leq e_{min,t} \end{cases} \tag{2.9}$$

where δ is a 1 x n new parameter vector, $f_t = [h_t; \Delta h_{t-1}; \ldots]$ is an n x 1 new fundamental vector and

$$\tilde{e}_t = \beta_1 E\left(e_t / I_{t-1}\right) + \delta f_t + \varepsilon_t \tag{2.9}$$

3 The Statistical Model

3.1 The Data Set

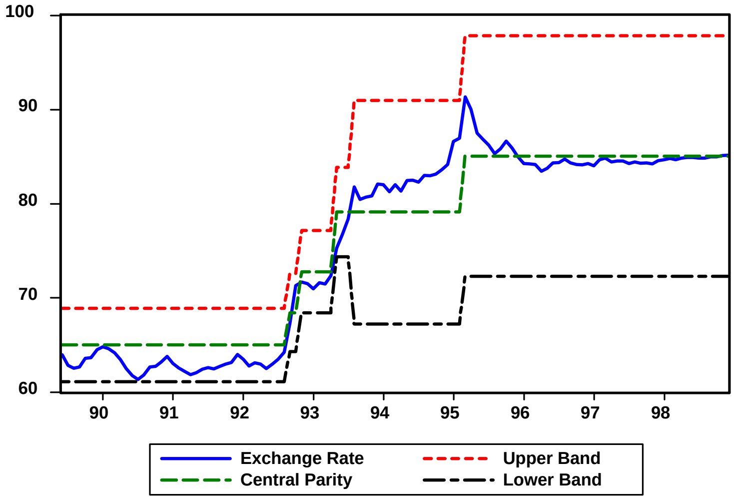
We use monthly data for the peseta/deutsche mark exchange rate from June 1989 to December 1998. The choice of the sample period is a consequence of the moment in which Spain joined the Exchange Rate Mechanism [ERM] of the European Monetary System [EMS] and the European Monetary Union [EMU] began to be effective. During this period, the band width was modified from $\pm 6\%$ to $\pm 15\%$ on August, 2nd 1993. This fact forces us to divide the sample in two periods because the band width influences agents' expectations. However, it must be taken into account that, due to lags in estimation, the real sample starts in September 1989 and November 1993, respectively.

We choose the Spanish peseta case because it is one of the EMS currencies which suffered both realignments and significant exchange rate depreciation, and definitively, the expense of large losses of foreign exchange reserves and increases in interest rates. In addition, it has been, with the Portuguese escudo, the only currency that was realigned after the shift in band widths.

With respect to the fundamentals, the output in each country is measured by the Index of Industrial Production seasonally unadjusted.[8] The money supply

[8] Our choice could be arguable, but we follow Espasa & Cancelo (1993): "In an

is the M_1 series seasonally unadjusted and the interest rates are the three-month interbank money market rates. All the data were extracted from the Main Economic Indicators series of OECD. The central parity exchange rate is obtained from the Spain Financial Accounts published by the Spanish Central Bank.



Evolution of peseta/deutsche mark exchange rate

As is well-known, not all currencies which belonged to the ERM enjoyed the same credibility so far as their commitment to the defence of the band is concerned. Thus, the choice of the particular exchange rate is important. The Spanish peseta is an interesting case as …gure 2 shows.[9] Only a glance at this …gure leads us to think of di¤erent behaviours of the exchange rate depending on the band width [June 1989 to July 1993, and August 1993 to December 1998]. In the narrow band period, §6% in the Spanish case, at the beginning of the 90's, an initial phase can be found with high exchange rate volatility but

econometrics model, when we try to study the dynamic relation among two or more variables, the analysis must be done using the observed variables, never the extracted signals on the basis of eliminating stochastic seasonality" [13, Ch.. 4, pp. 318]. [38, Vid: Wallis, 1974]

[9] Other currencies that could be interesting to analyze are the Italian lira or the pound Sterling, which also su¤ered episodes of exchange rate instability resulting in realignment of parities or high volatilities. However, both countries, at least in the 1992 period of turbulence, left the EMS. The Portuguese escudo could be another currency to choose, but its evolution is similar to that of the Spanish currency.

without realignment, where the peseta was overvalued and it was grazing the lower band, followed by a period of turbulence [1992-93], where the Spanish peseta suffered three devaluations [September, 17th 1992, November, 23th 1992, and May, 14th 1993]. During the period after the shift in band width, the peseta showed a relative trend to depreciation that became more intense in 1995, when the Spanish peseta and the Portuguese escudo were the only currencies that were realigned [March, 6th 1995]. However, from mid 1996, the evolution of the exchange rate could be shown as relatively stable, with the deviation from central parity values close to zero.

3.2 Econometric Specification

The analytic formulation that we shall use to solve expression (2:7) assumes that the fundamentals h_t follow an autorregressive process which, in our case, will be an AR(1) with parameter P. We have shown that there is autocorrelation in the residuals. This is because the exchange rate follows a random walk;[10] thus, we shall estimate the exchange rate equation by including the lagged exchange rate as an additional variable.[11] Finally, if we assume that a stable future rational expectations solution is equivalent to a stable current rational expectations solution, we could state the exchange rate process as follows:

$$e_t = \beta_1 E\left(e_t / I_{t-1}\right) + z_1 \left(1 - \beta_1\right) e_{t-1} + \chi h_t + \left(\frac{\chi P \beta_1}{1 - P \beta_1}\right) \Delta h_t + \varepsilon_t =$$

$$= \beta_1 E\left(e_t / I_{t-1}\right) + \delta f_t + \varepsilon_t \qquad (3.1)$$

with $f_t' = [e_{t-1}; h_t; \Delta h_t]$ and where β_1 1, and $|z_1| < 1$ to find a unique and stable solution.[12]

The analytic formulation we use in the equation (3:1) is included in the appendix. Essentially, the adopted approach is an extension of previous papers

[10] We have tested using ADF [Augmented Dickey-Fuller] and Phillips-Perron tests, and we could not reject the existence of a unit root.

[11] The procedure was used by Bajo (1986, 1987), who tested the existence of autocorrelation in the residuals in the peseta/mark exchange rate from 1977 to 1984, and it was corrected with the incorporation of lagged exchange rate.

[12] z_1 is the root of the equation $\phi z + \beta_1 z^{-1} = 1$.

(Campos et al., 1999.a, 1999.b), where we have suggested there was no evidence of mean reversion or honeymoon effect, at least in the narrow band period. The specification of this paper is to prove those aspects. Thus, we will represent the shock ε_t in the exchange rate equation with two alternative formulations. In this way, the conditional variance of exchange rate shocks could express both the possible effect of a reduction in exchange rate volatility (as target zone models forecast), and the divorce effect where there was not an S shaped curve between the exchange rate and fundamentals.[13] Then, the following equations will be, respectively:

$$\sigma^2_{\varepsilon_t} = \tau_0 + \tau_1 (e_{t-1} - c_{t-1})^2 \tag{3.2a}$$

$$\sigma^2_{\varepsilon_t} = \tau'_0 + \tau'_1 (e_{t-1} - c_{t-1})^{-2} \tag{3.2b}$$

4 Estimation Results

We have carried out the estimation using four different models in each one of the subsamples, and the alternative formulations of the conditional variance of exchange rate shocks (3:2a) or (3:2b). The Mod_1 model refers to a linear rational expectations model, where the existence of the band does not matter in the economic agents' expectations. Models Mod_2, Mod_3 and Mod_4 are non linear rational expectations models in which the band influences agents' expectations and their differences arise from the probability value P_{01}.[14]

We shall study which of these models is the best to explain the behaviour of the peseta/deutsche mark exchange rate from different viewpoints using the equations (3:2a) or (3:2b) respectively. We have estimated the values of the coefficients in the alternative models, the conditional variance of the exchange

[13] Bertola & Caballero (1992.a, 1992.b) suggest that the realignment expectations in the band could invert the Krugman (1991) SS curve. It is known as the divorce effect in the target zone literature.

[14] The probability value will be: $P_{01} = 0$ in Mod_2, P_{01} is a constant different from zero in Mod_3, and P_{01} is a variable function in Mod_4 which depends on $\left(r_{t-1} - r^*_{t-1}\right)$, $(e_{t-1} - o_{t-1})$, $\left(y_{t-1} - y^*_{t-1}\right)$ and $\left[\Delta\left(m_{t-1} - m^*_{t-1}\right) - \Delta\left(m_{t-2} - m^*_{t-2}\right)\right]$.

rate shock and the realignment probability of the band in Mod_3 and Mod_4 models. Finally, we have applied different selection models criteria.

Our aim is to compare the alternative models using the expressions of conditional variance of exchange rate shock to choose the best formulation to explain the behaviour of the peseta/deutsche mark exchange rate.

The estimated values of the coefficients in the different models, when we use the formulation (3:2a) or (3:2b) of conditional variance of exchange rate shocks with their significance levels for the two subsamples, are shown in tables 1 and 2.[15] In the first period [September 1989 to July 1993], using the equation (3:2a), only the Mod_4 model shows parameters with significance levels different from zero, using the t-statistic. These parameters are the lagged exchange rate, expectations, money supplies differential and lagged interest rates differential as a risk premium proxy variable. When we are using the second $\sigma^2_{\varepsilon t}$ formulation, we show the exchange rate expectations parameter is significative in the linear rational expectations model Mod_1, and in the Mod_4 model, although it is not less than one.[16] Money supplies and lagged interest rates differential are also significative in the Mod_4 model.

In the second period [November 1993 to December 1998] the results, using the equation (3:2a), in significance terms, are not so conclusive as in the first one. In the linear rational expectations model Mod_1 the parameter of exchange rate expectations is significative, as in the Mod_4 model, but is not less than one. Lagged exchange rate is significative in the Mod_3 model. With respect to the second $\sigma^2_{\varepsilon t}$ formulation, neither of the results are conclusive. Lagged exchange rate and expectations are significative in all the models.

Concerning the estimated conditional variance of the exchange rate shock, $\sigma^2_{\varepsilon t}$, using the alternative expressions shown in tables 3 and 4, we obtain different results in each period. The variance, $\sigma^2_{\varepsilon t}$, is constant and then homoskedastic in

[15] Having analyzed the correlation among the variables used in the estimation, and taking into account that it is almost impossible to find two economic variables that are not correlated, we have observed certain multicollinearity problems but not so important as to be very significant.

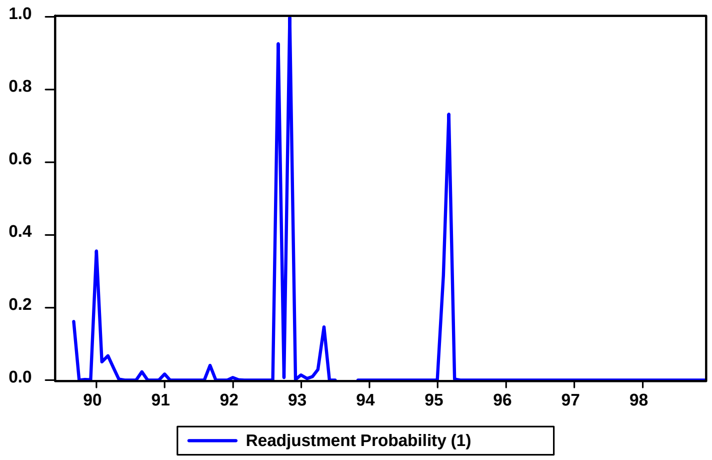
[16] If β_1 is not less than one, the rational expectations solution could not be the only one.

the first sample using the formulation (3:2a). This result implies, in this period, the exchange rate variability does not depend on the exchange rate position with respect to the central parity. Thus, it does not verify the honeymoon effect as was forecasted by the target zones literature, and represented by an S shaped curve between the exchange rate and fundamentals. This result is confirmed by the estimates obtained with the second $\sigma_{\varepsilon t}^2$ expression, where the parameter of $(e_{t-1} - c_{t-1})^{-2}$ is significative in all the models during the first period. Then, the divorce effect could characterize the exchange rate behaviour during this sample.

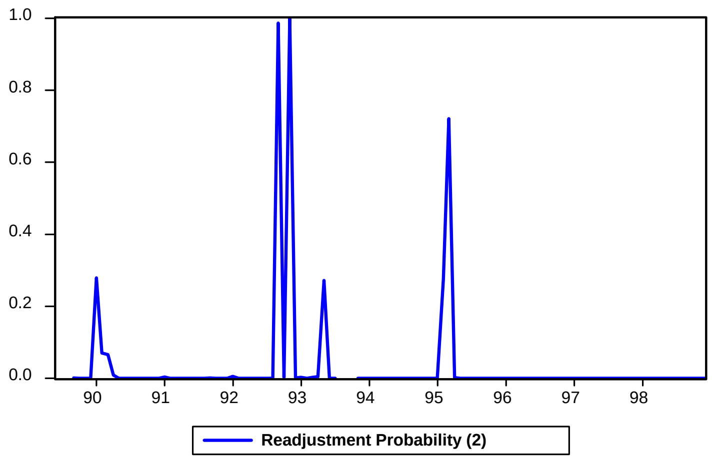
In the second period, using the expression (3:2a), all estimated coefficient values are close to zero and are not significative. We could deduce a reduced exchange rate variability, at least since 1996, as can be seen in figure 2. Once more these results are confirmed by the second $\sigma_{\varepsilon t}^2$ formulation, where only the constant parameter is significative in all the models.

In the econometric specification of the rational expectations solution we assume that there is a saddle path when the parameter $|z_1| < 1$. The z_1 estimated values are, in our case, 1:000, 1:008, 1:005 and 1:021 in Mod_1, Mod_2, Mod_3 and Mod_4 models respectively, in the first case; and the values 1:038, 1:021, 1:028 and 1:019 in Mod_1, Mod_2, Mod_3 and Mod_4 models respectively, in the second case. Then, the estimated value is not less than one in any model, suggesting that the exchange rate follows an explosive path. In the first period and in both cases, we could say there is no mean reversion as target zone models forecast. Once the financial markets assign devaluation expectations, the continuous intramarginal or infinitesimal interventions of monetary authorities will not be able to control capital movements in the markets which are usually bigger than interventions. The policies become more accommodating, causing the inevitable devaluation, and a new exchange rate central parity. This is know as self-fulfilling crises or self-fulfilling attacks in the Currency Crises Literature.[17]

[17] This approach has developed following the seminal contributions of Obstfeld (1986, 1994, 1996). See a survey in Jeanne (1999).



Estimated readjustment probability in the ...rst case.



Estimated readjustment probability in the second case.

In the second sample, the z_1 estimated values are respectively, 0:964, 1:001, 0:996 and 0:996, in the ...rst case; and 0:970, 1:001, 0:997 and 0:998, in the second. So, the coe¢cient is less than one except in the Mod_2 model. However, these values are almost 1 and it would show a quasi-explosive path. Then, we cannot reject the existence of mean reversion in the second period.

We assume constant probability in the nonlinear rational expectations

Mod_3 model and in the Mod_4 model we assume that realignment probability depends on a constant, on $\left(i_{t-1} - i^*_{t-1}\right)$, $(e_{t-1} - c_{t-1})$, $\left(y_{t-1} - y^*_{t-1}\right)$ and $\Delta\left(m_{t-1} - m^*_{t-1}\right) - \Delta\left(m_{t-2} - m^*_{t-2}\right)$. We have estimated the realignment probability of the band in both models and $\sigma^2_{\varepsilon t}$ expressions. Tables 5 and 6 show the estimated values in the sample and figures 3 and 4 the realignment probabilities.[18] As a general rule in both figures, the observed peaks in probability correspond to realignments, with the exception of the first one, which appears as the result of tensions produced by the fall of the dollar and rumors about a revaluation of the deutsche mark that never happened, and the entrance of the Italian lira to the narrow bands of EMS at the beginning of the 90's. In line with Bekaert & Gray's (1998) paper, our results show that the exchange rate jumps within the band could be of the same amount as the realignments. Then, if we model the exchange rate jumps, we must take into account both realignments and exchange rate movements within the band.[19]

If we verify which model better explains the behaviour of realignment probability [Mod_3 model with constant or Mod_4 model with variable probability] we could contrast both models using the likelihood ratio test,[20] The likelihood ratio test formulation is: $LR = -2\left[L^3(\theta) - L^4(\theta)\right]$ and is distributed like a χ^2 with four degrees of freedom. For the first sample, the value of the LR-Test, in each $\sigma^2_{\varepsilon t}$ expression, is 41.724 or 12.71, and allows us not to reject the Mod_4 model at a 99% or a 98.72% significance level, respectively. In the second period the value is 7.948 or 11.894 and 91% or 98.18% significance level.

We are not only looking for the best model to explain the probability, but also the best one to feature the exchange rate behaviour. Thus, we will compare the four estimated models with two others which assume the exchange rate

[18] Figures 3 and 4 reflect the probability in the real sample. [September 1989 to July 1993 and November 1993 to December 1998].

[19] The estimated probability value in January 1990 was, depending on the $\sigma^2_{\varepsilon t}$ expression, 0.3556 or 0.2794, respectively. The values are bigger than the estimated probability in May 1993 [0.1467 or 0.2712], date when a realignment took place. The other three peaks correspond to realignments: September 1992 [0.9258 or 0.9864], November 1992 [0.9989 or 1.00] and March 1995 [0.7325 or 0.7210].

[20] The maximized log-likelihood value is shown, depending on the period, in table 7 or 8, respectively.

follows a random walk, RW, or a GARCH(1,1) [Generalized Autorregressive Conditional Heteroscedasticity] process, RW_{GARCH}. The criteria used are the AIC [Akaike Information Criterion][21, 22], the RMSFE [Root Mean Squared Forecast Errors][23] and the AMFE [Absolute Mean Forecast Errors].[24] The results and the different criteria are compiled for both samples in tables 7 and 8, respectively.

The three criteria show that, using both the first $\sigma^2_{\varepsilon_t}$ expression and period, the Mod_4 model is the best one [nonlinear rational expectations with variable probability of band realignment]. Then, in this case, the peseta/deutsche mark exchange rate behaviour must be explained incorporating the band in economic agents' expectations, the lagged exchange rate, the money supplies differential and the risk premium [approached by lagged interest rates differential]. In addition, the realignment probability exists with values different from zero and, this probability is a function of the output differential between Germany and Spain. With the second $\sigma^2_{\varepsilon_t}$ expression, using the AIC criterion, we will choose the Mod_2 model; however, using the RMSFE or AMFE criteria, the Mod_4 is the best one.

The second period could be represented, with the exception of the March 1995 devaluation, as a stable period, at least from mid 1996. Using the second $\sigma^2_{\varepsilon_t}$ expression the results are not so conclusive as if we use the first $\sigma^2_{\varepsilon_t}$ formulation, where the Mod_1 model is the best one.[25] This result points out

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[21] It is computed as in Pesaran and Ruge-Murcia (1999). It is the difference between the maximized value of the likelihood function associated to the exchange rate and the number of estimated parameters in each equation. [15 parameters in Mod_1 and Mod_2 models, 16 in Mod_3, 20 in Mod_4, 2 in RW and, 4 in RW_{GARCH} model].

[22] About selection criteria of models see Lütkepohl (1991) [21, pp. 118-166]

[23]

$$RMSFE = \sqrt{\frac{\sum_{t=1}^{T} [e_t - E_{t-1}(e_t/I_{t-1})]^2}{T}}$$

where T represents the number of observations in the sample.

[24]

$$AMFE = \frac{\sum_{t=1}^{T} |e_t - E_{t-1}(e_t/I_{t-1})|}{T}$$

where T represents the number of observations in the sample.

[25] In this model, economic agents do not bear in mind the band in their expectations and the realignment probability is zero.

that, with a band of 30%, the economic agents behave as if they are in a quasi-flexible exchange rate system. In addition, the perspectives of the incorporation of Spain in the first phase of the EMU could explain the realignment probability values close to zero in most of the second period.[26]

Finally, if we use the value of maximized log-likelihood function, $L(\varpi)$, as the fourth selection criterion, tables 7 and 8 show that, in the first sample, the Mod_4 model is the best one, which is obtained using the second $\sigma^2_{\varepsilon t}$ expression. In the second period, we will also choose the Mod_4 model, but using the first $\sigma^2_{\varepsilon t}$ expression. This result marks large differences between the two sample periods, at least with respect to the shock ε_t formulation in the exchange rate equation.

5 Conclusions

In the last decade, both developed and emerging countries have undergone speculative attacks against their currencies. The European ERM was severely beaten by intense speculative pressure in 1992-93, which led to the exit of the pound sterling and the Italian lira in 1992 and the shift in band widths in 1993, and included the Spanish peseta and Portuguese escudo realignment in 1995. It has renewed the interest about the effectiveness of interventions capable of reducing, or at least preventing, financial market crises.

This paper looks for evidence concerning the forecastable currency crises in the European ERM during the target zone period. We have studied the Spanish peseta exchange rate because it is one of the most interesting cases, not only bearing in mind the number of realignments, but also considering the intensity of the speculative attacks against the exchange rate.

Our results show relevant differences with respect to the regularities found in other studies for EMS currencies. The evidence indicates the different behaviour of the Spanish peseta before and after the shift in band widths. This question is confirmed by resolving the rational expectations model and

[26] Figures 3 and 4 show, in the second period, only 10 or 9 values, respectively, different from zero. [The number of observations in this period is 62].

we do not obtain a saddle path. We can then conclude there are self-ful…lling attacks and we could reject the mean reversion hypothesis in the narrow band period [§6% in the Spanish case]. The use of two alternative formulations of the conditional variance of exchange rate shock con…rms this fact and more, it suggests that there was increasing exchange rate volatility (divorce e¤ect) in contrast to an S shaped behaviour (honeymoon e¤ect) as the target zone literature predicted. After the shift in band widths with an estimated coe¢cient of rational expectations $jz_1j < 1$, but almost 1, does not let us reject the mean reversion hypothesis. This result seems to be con…rmed when we study the estimate of conditional variance of exchange rate shock and the maximized value of the log-likelihood function.

In addition, the di¤erences between subsamples are maintained by analyzing the estimated coe¢cients which are signi…cative in the alternative models. The Mod_4 model [LD-RE model with variable probability] is chosen as it is the best model to explain the behaviour of the exchange rate in the majority of the criteria selected. In both periods the exchange rate expectations are signi…cative. However, during the narrow band period, both fundamentals and the di¤erential of lagged interest rates, as a risk premium proxy variable, are also signi…cative. Fundamentals are represented by the di¤erential of monetary supplies in this model. This result also appears when we estimated the realignment probability of the band in the models which suppose it to be constant, but di¤erent from 0, or a variable function.

To sum up, in spite of the fact that we could suggest the Mod_4 model as the best one to characterize the peseta/Deutsche mark exchange rate behaviour during the target zone period, the formulation of this model is clearly di¤erent in each sample. This question has an e¤ect on the forecast of Spanish peseta crises. In the …rst sample, we have borne in mind not only the expectations of the economic agents, but also the fundamentals. In the second one, with 30% of band width, the devaluation in March 1995 was considered by the Spanish Central Bank as a technical realignment and it did not seem to be necessary if we are bearing in mind the fundamentals of the economy. This devaluation took place before the exchange rate reached the maximum value of depreciation within the band.[27] We can thus conclude that the economic agents forecasted the four realignments which the Spanish peseta su¤ered. They assumed that the band width in‡uenced their expectations; although the features of the last devaluation are de…nitely di¤erent from the previous three.

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Table 1: Estimated Parameters in the First Sample
(September 1989-July 1993)

Explanatory Variables	Mod_1 First	Mod_1 Second	Mod_2 First	Mod_2 Second	Mod_3 First	Mod_3 Second	Mod_4 First	Mod_4 Secor…
Constant	0.068 (0.022)	0.419 (0.022)	−0.825 (−0.245)	−0.752 (−0.050)	−0.326 (−0.149)	−1.533 (−0.252)	−0.535 (−0.124)	−0.53… (−0.20…
e_{t-1}	−0.819 (−0.590)	−0.037 (−0.229)	0.518 (0.344)	0.231 (0.098)	0.622 (0.650)	0.742 (0.159)	0.168** (1.883)	0.19… (0.473…
$E(e_t/I_{t-1})$	1.818 (1.295)	1.036*** (6.011)	0.487 (0.341)	0.774 (0.356)	0.381 (0.451)	0.278 (0.071)	0.810*** (11.572)	0.809… (2.051…
$(m_t - m_t^*)$	−0.099 (−0.040)	0.306 (0.201)	−1.193 (−1.590)	−2.747 (−0.735)	0.024 (0.040)	−3.966 (−1.343)	−2.220*** (−1.943)	−2.310 (−3.53…
$(y_t - y_t^*)$	0.925 (0.541)	0.011 (0.006)	−1.026 (−0.584)	−0.040 (−0.023)	−0.504 (−0.051)	−0.102 (−0.053)	−0.015 (−0.002)	−0.10… (−0.04…
$(i_{t-1} - i_{t-1}^*)$	−0.344 (−0.259)	0.101 (0.007)	−0.567 (−0.450)	−0.857 (−0.153)	−0.323 (−0.317)	−1.210 (−0.317)	−1.218*** (−3.210)	−0.848 (−3.53…
$(e_{t-1} - c_{t-1})$	−0.012 (−0.065)	0.003 (0.006)	0.027 (0.214)	−0.032 (−0.029)	0.070 (0.008)	−0.027 (−0.035)	−0.018 (−0.021)	−0.0… (−0.04…
$\Delta(m_{t-1} - m_{t-1}^*)$	−1.305 (−0.395)	0.139 (0.002)	0.978 (0.466)	−0.675 (−0.060)	0.997 (0.721)	−0.703 (−0.075)	−0.394 (−0.134)	−0.42… (−0.22…
$\Delta(y_{t-1} - y_{t-1}^*)$	−0.091 (−0.051)	0.038 (0.064)	−1.158* (−1.714)	−0.237 (−0.080)	−0.086 (−0.080)	−0.339 (−0.107)	0.371 (0.484)	−0.1… (−0.08…
$\Delta(m_{t-2} - m_{t-2}^*)$	−1.344 (−0.341)	0.212 (0.118)	0.165 (0.033)	−0.973 (−0.147)	0.593 (0.314)	−1.141 (−0.156)	0.365 (0.028)	−0.0… (−0.01…
$\Delta(y_{t-2} - y_{t-2}^*)$	0.169 (0.212)	0.052 (0.026)	−1.110 (−1.344)	−0.349 (−0.023)	−0.268 (−0.772)	−0.485 (−0.220)	−0.219 (−0.693)	−0.3… (−0.22…
$\Delta(i_{t-2} - i_{t-2}^*)$	0.056 (0.019)	0.040 (0.008)	0.653 (0.221)	0.274 (0.091)	0.385 (0.239)	0.119 (0.026)	0.056 (0.031)	0.12… (0.054…
$\Delta(e_{t-2} - c_{t-2})$	−0.073 (−0.073)	−0.002 (−0.005)	0.100 (1.610)	0.011 (0.004)	0.055 (0.630)	0.023 (0.004)	0.003 (0.0004)	0.00… (0.014…

Note: Mod_1 refers to a linear RE model that does not take into account the effect of the band on expectations. Mod_2, Mod_3 and Mod_4 are non linear RE models where the band affects agents' expectations and different realignment probabilities. $P_{01} = 0$ in Mod_2, P_{01} is a constant different from zero in Mod_3 and P_{01} is a function of $(i_{t-1} - i_{t-1}^*)$, $(e_{t-1} - c_{t-1})$, $\Delta(m_{t-1} - m_{t-1}^*) - \Delta(m_{t-2} - m_{t-2}^*)$ and $(y_{t-1} - y_{t-1}^*)$ in Mod_4. First and Second refer to the two alternative formulations of the conditional variance of exchange rate shocks. The values in parentheses are the t rate and *, ** and *** denote the significance of 10, 5 or 1 % respectively.

Table 2: Estimated Parameters in the Second Sample
(November 1993-December 1998)

Explanatory Variables	Mod_1		Mod_2		Mod_3		Mod_4
	First	Second	First	Second	First	Second	First
Constant	-1.223 (-1.379)	-1.263^{***} (-5.521)	0.113 (0.126)	0.062 (0.005)	0.153 (0.233)	0.205 (0.211)	0.152 (0.510)
e_{t-1}	-0.074 (-0.149)	-0.096^{***} (-13.942)	0.108 (0.060)	0.210^{***} (4.320)	0.888^{***} (4.118)	0.814^{***} (8.440)	0.145 (0.947)
$E(e_t/I_{t-1})$	1.077^{***} (2.030)	1.099^{***} (14.563)	0.891 (0.490)	0.790^{***} (15.240)	0.108 (0.519)	0.183^{***} (2.020)	0.855^{***} (5.553)
$(m_t - m_t^*)$	-0.238 (-0.012)	-0.228 (-0.056)	0.107 (0.245)	-0.473 (-0.375)	0.243 (0.062)	0.326 (0.103)	0.319 (0.119)
$(y_t - y_t^*)$	0.024 (0.0009)	0.024 (0.013)	-0.045 (-0.062)	-0.017 (-0.011)	-0.050 (-0.014)	-0.033 (-0.006)	-0.061 (-0.005)
$\left(i_{t-1} - i^*_{t-1}\right)$	-0.007 (-0.0004)	-0.011 (-0.012)	-0.050 (-0.074)	-0.237 (-0.070)	-0.011 (-0.005)	-0.034 (-0.0008)	-0.017 (-0.013)
$(e_{t-1} - c_{t-1})$	-0.003 (-0.0007)	-0.009 (-0.108)	0.007 (0.007)	0.022 (0.029)	0.005 (0.0009)	0.016 (0.025)	0.007 (0.002)
$\Delta\left(m_{t-1} - m^*_{t-1}\right)$	0.311 (0.054)	0.229 (0.193)	-0.269 (-0.346)	-0.030 (-0.014)	-0.310 (-0.565)	-0.205 (-0.044)	-0.437 (-0.481)
$\Delta\left(y_{t-1} - y^*_{t-1}\right)$	-0.003 (-0.0001)	-0.016 (-0.035)	-0.015 (-0.018)	-0.021 (-0.055)	-0.004 (-0.001)	-0.008 (-0.025)	-0.005 (-0.0005)
$\Delta\left(m_{t-2} - m^*_{t-2}\right)$	-0.194 (-0.028)	-0.032 (-0.163)	0.389 (0.913)	0.723^{***} (2.390)	0.223 (0.277)	0.042 (0.096)	0.367 (0.036)
$\Delta\left(y_{t-2} - y^*_{t-2}\right)$	0.070 (0.005)	-0.023 (-0.071)	-0.114 (-0.143)	-0.133 (-1.271)	-0.101 (-0.008)	0.051 (0.102)	-0.137 (-0.0006)
$\Delta\left(i_{t-2} - i^*_{t-2}\right)$	1.461 (1.200)	1.369^{***} (5.757)	-1.910 (-0.632)	-1.785 (-1.569)	-2.102 (-1.021)	-2.037^{***} (-2.280)	-2.768 (-0.768)
$\Delta(e_{t-2} - c_{t-2})$	0.005 (0.0006)	-0.053 (1.637)	-0.011 (-0.143)	0.082 (1.436)	-0.007 (-0.003)	0.089 (0.709)	-0.010 (-0.004)

Note: Mod_1 refers to a linear RE model that does not take into account the effect of the band on expectations. Mod_2, Mod_3 and Mod_4 are non linear RE models where the band affects agents' expectations and different realignment probabilities. $P_{01} = 0$ in Mod_2, P_{01} is a constant different from zero in Mod_3 and P_{01} is a function of $\left(i_{t-1} - i^*_{t-1}\right)$, $(e_{t-1} - c_{t-1})$, $\Delta\left(m_{t-1} - m^*_{t-1}\right) - \Delta\left(m_{t-2} - m^*_{t-2}\right)$ and $\left(y_{t-1} - y^*_{t-1}\right)$ in Mod_4. First and Second refer to the two alternative formulations of the conditional variance of exchange rate shocks. The values in parentheses are the t rate and *, ** and *** denote the significance of 10, 5 or 1 % respectively.

Table 3: Estimation of the Conditional Variance of Exchange Rate Shocks in the First Sample (September 1989-July 1993)

Models		Constant	$(e_{t-1} - c_{t-1})^{2}$
Mod_1	First	1.900 (1.503)	0.000 (0.000)
	Second	0.000 (0.000)	4.413*** (5.927)
Mod_2	First	1.445*** (5.162)	0.000 (0.000)
	Second	0.001 (0.0002)	−4.358*** (5.313)
Mod_3	First	1.576*** (6.065)	0.000 (0.000)
	Second	0.000 (0.000)	−4.875*** (2.503)
Mod_4	First	1.219 (0.286)	0.000 (0.000)
	Second	0.292 (0.276)	−2.258*** (4.945)

Table 4: Estimation of the Conditional Variance of Exchange Rate Shocks in the Second Sample (November 1993-December 1998)

Models		Constant	$(e_{t-1} - c_{t-1})^{2}$
Mod_1	First	0.050 (0.006)	0.072 (0.003)
	Second	0.424*** (21.323)	0.000 (0.000)
Mod_2	First	0.055 (0.004)	0.073 (0.032)
	Second	0.379*** (30.789)	0.000 (0.000)
Mod_3	First	0.055 (0.002)	0.071 (0.002)
	Second	0.490*** (14.414)	0.000 (0.000)
Mod_4	First	0.053 (0.033)	0.073 (0.004)
	Second	0.684*** (2.009)	0.000 (0.000)

Note: Mod_1 refers to a linear RE model that does not take into account the effect of the band on expectations. Mod_2, Mod_3 and Mod_4 are non linear RE models where the band affects agents' expectations and different realignment probabilities. $P_{01} = 0$ in Mod_2, P_{01} is a constant different from zero in Mod_3 and P_{01} is a function of $(i_{t-1} - i^*_{t-1})$, $(e_{t-1} - c_{t-1})$, $\Delta(m_{t-1} - m^*_{t-1}) - \Delta(m_{t-2} - m^*_{t-2})$ and $(y_{t-1} - y^*_{t-1})$ in Mod_4. First and Second refer to the two alternative formulations of the conditional variance of exchange rate shocks. The values in parentheses are the t rate and *, ** and *** denote the significance of 10, 5 or 1 % respectively.

Table 5: Estimation of the Realignment Probability of the Band in the First Sample (September 1989-July 1993)

Explanatory Variables	Mod_3		Mod_4	
	First	Second	First	Second
Constant	0.042 (0.478)	0.046 (0.080)	-5.170^{***} (-2.042)	-1.535 (-0.198)
$\left(i_{t-1} - i^*_{t-1}\right)$			8.290 (0.849)	3.802 (0.002)
$(e_{t-1} - c_{t-1})$			2.098 (0.869)	3.974 (0.635)
$\left(y_{t-1} - y^*_{t-1}\right)$			-18.407^{***} (-2.715)	-21.770 (-1.096)
$\left[\left(m_{t-1} - m^*_{t-1}\right) - \left(m_{t-2} - m^*_{t-2}\right)\right]$			10.675 (0.788)	8.869 (0.409)
L_o	-11.264	-11.156	-2.926	-1.820

Table 6: Estimation of the Realignment Probability of the Band in the Second Sample (November 1993-December 1998)

Explanatory Variables	Mod_3		Mod_4	
	First	Second	First	Second
Constant	0.018 (0.107)	0.018 (0.081)	-27.06 (-0.320)	-27.09 (-0.215)
$\left(i_{t-1} - i^*_{t-1}\right)$			-1.452 (-0.013)	-1.543 (-0.012)
$(e_{t-1} - c_{t-1})$			3.080 (0.006)	3.080 (0.104)
$\left(y_{t-1} - y^*_{t-1}\right)$			-14.47 (-0.242)	-14.46 (-0.230)
$\left[\left(m_{t-1} - m^*_{t-1}\right) - \left(m_{t-2} - m^*_{t-2}\right)\right]$			12.547 (0.035)	12.59 (0.034)
L_o	-5.108	-5.106	-0.651	-0.650

Note: The values in parentheses are the t rate and *, ** and *** denote the significance of 10, 5 or 1 % respectively. L_o is the maximized value of the log-likelihood function associated with changes in central parity. First and Second refer to the two alternative formulations of the conditional variance of exchange rate shocks.

Table 7: Selection Models Criteria in the First Sample (September 1989-July 1993)

Models		L_e	AIC	RMSFE	AMFE	$L(\theta)$	ρ
Mod_1	First	-40.084	-55.084	1.429	0.991	185.765	1
	Second	-20.506	-35.506	1.271	0.805	206.343	1
Mod_2	First	-37.233	-52.233	1.328	0.986	188.977	12.00
	Second	-19.737	-34.737	1.288	0.824	207.098	12.00
Mod_3	First	-39.671	-55.671	1.406	1.016	216.348	12.00
	Second	-19.542	-35.542	1.317	0.842	237.582	12.00
Mod_4	First	-27.139	-47.139	1.078	0.790	237.210	12.00
	Second	-21.430	-41.430	1.078	0.744	243.937	12.00
RW	First	-79.936	-81.936	1.375	0.988	79.936	1
	Second	-79.936	-81.936	1.375	0.988	79.936	1
RW_{GARCH}	First	-75.929	-79.929	1.389	0.978	75.930	1
	Second	-75.929	-79.929	1.389	0.978	75.930	1

Table 8: Selection Models Criteria in the Second Sample (November 1993-December 1998)

Models		L_e	AIC	RMSFE	AMFE	$L(\theta)$	ρ
Mod_1	First	15.697	0.697	0.1324	0.5063	394.545	1
	Second	-25.726	-40.726	0.107	0.532	352.855	1
Mod_2	First	13.920	-1.08	0.1336	0.5234	392.992	30.00
	Second	-31.691	-46.691	0.110	0.551	346.632	30.00
Mod_3	First	14.308	-1.692	0.1333	0.5199	401.920	30.00
	Second	-23.295	-39.295	0.108	0.545	364.221	30.00
Mod_4	First	14.417	-5.583	0.1330	0.5208	405.894	30.00
	Second	-21.255	-41.255	0.109	0.549	370.168	30.00
RW	First	-83.818	-85.818	0.9352	0.5250	83.818	1
	Second	-83.818	-85.818	0.9352	0.525	83.818	1
RW_{GARCH}	First	-58.040	-62.040	0.9364	0.5241	58.040	1
	Second	-58.040	-62.040	0.9364	0.524	58.040	1

Note: Mod_1 refers to a linear RE model that does not take into account the effect of the band on expectations. Mod_2, Mod_3 and Mod_4 are non linear RE models where the band affects agents' expectations and different realignment probabilities. $P_{01} = 0$ in Mod_2, P_{01} is a constant different from zero in Mod_3 and P_{01} is a function of $\left(i_{t-1} - i^*_{t-1}\right)$, $(e_{t-1} - c_{t-1})$, $\Delta\left(m_{t-1} - m^*_{t-1}\right) - \Delta\left(m_{t-2} - m^*_{t-2}\right)$ and $\left(y_{t-1} - y^*_{t-1}\right)$ in Mod_4. The RW and RW_{GARCH} models express exchange rate behaviour as a random walk with drift, RW, with homoskedastic variance, or conditional variance GARCH(1,1), RW_{GARCH}, respectively. L_e represents the value of maximized log-likelihood function associated with the exchange rate and $L(\theta) = L_f(\theta_1) + L_a(\theta_2) + L_o(\theta_3) + L_e(\theta_4)$ is the maximized value of log-likelihood. First and Second refer to the two alternative formulations of the conditional variance of exchange rate shocks.

6 Appendix

The econometric specification we use to estimate the exchange rate equation is the following:

- The fundamentals $h_t' = [(m_t - m_t^*); (y_t - y_t^*); PR_t]$ will be approached by the vector f_t:

$$f_t' = [(m_t - m_t^*); (y_t - y_t^*); x_t] \tag{6.1}$$

with:

$$x_t' = \begin{bmatrix} 1; e_{t-1}; \left(i_{t-1} - i_{t-1}^*\right); (e_{t-1} - c_{t-1}); \\ \Delta\left(m_{t-1} - m_{t-1}^*\right); \Delta\left(y_{t-1} - y_{t-1}^*\right); \Delta\left(m_{t-2} - m_{t-2}^*\right); \\ \Delta\left(y_{t-2} - y_{t-2}^*\right); \Delta\left(i_{t-2} - i_{t-2}^*\right); \Delta\,(e_{t-2} - c_{t-2}) \end{bmatrix}$$

where we have included $\left(i_{t-1} - i_{t-1}^*\right)$ and $(e_{t-1} - c_{t-1})$ as a proxy variable to the risk premium. In addition, we have incorporated lags in the variables in order to correct the possibility of error in the estimation for approaching the solution of future rational expectations to the current ones.

- To estimate the exchange rate expectations,[28] $E\,(e_t/I_{t-1})$, the specification of $(m_t - m_t^*)$ and $(y_t - y_t^*)$ is, respectively, the following:[29]

$$\Delta\,(m_t - m_t^*) = \varrho_0 + \varrho_1 \Delta\left(m_{t-1} - m_{t-1}^*\right) + \varrho_2 \Delta\left(m_{t-2} - m_{t-2}^*\right) +$$

$$+\varrho_{12} \Delta\left(m_{t-12} - m_{t-12}^*\right) + \Xi_{1t} \tag{6.2}$$

where Ξ_{1t} is white noise.

$$(y_t - y_t^*) = \psi_0 + \psi_1 \left(y_{t-1} - y_{t-1}^*\right) + \psi_2 \left(y_{t-12} - y_{t-12}^*\right) + \Xi_{2t} \tag{6.3}$$

where the shock Ξ_{2t} is white noise.

[28] If we do not take into account the target zone, the expression to estimate $E\,(e_t/I_{t-1})$ will be:

$$E\,(e_t/I_{t-1}) = \frac{[\gamma_1 (m_t - m_t^*) + \gamma_2 (y_t - y_t^*) + x_t]}{(1 - \beta_1)}$$

where $(m_t - m_t^*)$ and $(y_t - y_t^*)$ follow the expressions (6:2) and (6:3), respectively.

[29] We test the stationary nature of $(m_t - m_t^*)$ and $(y_t - y_t^*)$ using the ADF test [Augmented Dickey-Fuller]. We cannot reject the unit root in $(m_t - m_t^*)$, but we can reject it in $(y_t - y_t^*)$ after correcting the seasonal nature.

- The realignment process of central parity could be written:

$$c_t = c_{t-1} + a_t \left(b_t + z_t\right) \tag{6.4}$$

where a_t is 1 or 0 depending on whether there is a realignment in central parity or not. We assume that b_t is constant, because only three realignments took place in the first period and only one in the second.

- The matrix of transition probabilities will be:

$$P(t) = \begin{pmatrix} P_{00}(t) & P_{01}(t) \\ 1 & 0 \end{pmatrix} \tag{6.5}$$

where $P_{11}(t)$ is zero, because we cannot find two successive periods when a realignment of central parity took place. Depending on the model used for estimation, P_{01} will be zero, constant or a variable function that depends on $\left(i_{t-1} - i^*_{t-1}\right)$, $(e_{t-1} - c_{t-1})$, $\left[\left(m_{t-1} - m^*_{t-1}\right) - \left(m_{t-2} - m^*_{t-2}\right)\right]$ and $\left(y_{t-1} - y^*_{t-1}\right)$ variables.

- We represent the shock ε_t in the exchange rate equation with two alternative expressions, in this way the variance shall express:

  – the possible effect of a reduction in exchange rate volatility [honeymoon effect], as target zones models predict. Then the equation will be the following:

$$\sigma^2_{\varepsilon_t} = \tau_0 + \tau_1 \left(e_{t-1} - c_{t-1}\right)^2 \tag{6.6a}$$

  – or the divorce effect where there is not an S shaped curve between the exchange rate and fundamentals. The expression will be:

$$\sigma^2_{\varepsilon_t} = \tau'_0 + \tau'_1 \left(e_{t-1} - c_{t-1}\right)^{-2} \tag{6.6b}$$

With respect to the variances of the shocks ν_{1t} and ν_{2t} we assume that they are homoskedastic.

- We got the variance-covariance matrix of the maximum likelihood estimator by calculating the estimator called "BHHH".[30]

[30] As Greene (1998) [16, pp. 123-125] explains, the variance-covariance matrix of maximum likelihood estimator depends on the parameters. We have applied two alternative methods of estimation: First, the estimator used in Pesaran and Ruge-Murcia (1999), evaluating the second derivatives matrix of maximum likelihood estimator; second, using the BHHH matrix. As Greene (1998) [16, pp. 124] says, it is very convenient to make use of this matrix in some cases because we do not need any additional calculations to get it.

Table 1: Estimated Parameters in the First Sample
(September 1989-July 1993)

Explanatory Variables	Mod_1		Mod_2		Mod_3		Mod_4	
	First	Second	First	Second	First	Second	First	Second
Constant	0.068 (0.022)	0.419 (0.022)	−0.825 (−0.245)	−0.752 (−0.050)	−0.326 (−0.149)	−1.533 (−0.252)	−0.535 (−0.124)	−0.535 (−0.207)
e_{t-1}	−0.819 (−0.590)	−0.037 (−0.229)	0.518 (0.344)	0.231 (0.098)	0.622 (0.650)	0.742 (0.159)	0.168** (1.883)	0.194 (0.473)
$E(e_t/I_{t-1})$	1.818 (1.295)	1.036*** (6.011)	0.487 (0.341)	0.774 (0.356)	0.381 (0.451)	0.278 (0.071)	0.810*** (11.572)	0.809*** (2.051)
$(m_t - m_t^*)$	−0.099 (−0.040)	0.306 (0.201)	−1.193 (−1.590)	−2.747 (−0.735)	0.024 (0.040)	−3.966 (−1.343)	−2.220*** (−1.943)	−2.310*** (−3.533)
$(y_t - y_t^*)$	0.925 (0.541)	0.011 (0.006)	−1.026 (−0.584)	−0.040 (−0.023)	−0.504 (−0.051)	−0.102 (−0.053)	−0.015 (−0.002)	−0.106 (−0.049)
$\left(i_{t-1} - i_{t-1}^*\right)$	−0.344 (−0.259)	0.101 (0.007)	−0.567 (−0.450)	−0.857 (−0.153)	−0.323 (−0.317)	−1.210 (−0.317)	−1.218*** (−3.210)	−0.848*** (−3.532)
$(e_{t-1} - c_{t-1})$	−0.012 (−0.065)	0.003 (0.006)	0.027 (0.214)	−0.032 (−0.029)	0.070 (0.008)	−0.027 (−0.035)	−0.018 (−0.021)	−0.043 (−0.047)
$\Delta\left(m_{t-1} - m_{t-1}^*\right)$	−1.305 (−0.395)	0.139 (0.002)	0.978 (0.466)	−0.675 (−0.060)	0.997 (0.721)	−0.703 (−0.075)	−0.394 (−0.134)	−0.429 (−0.229)
$\Delta\left(y_{t-1} - y_{t-1}^*\right)$	−0.091 (−0.051)	0.038 (0.064)	−1.158* (−1.714)	−0.237 (−0.080)	−0.086 (−0.080)	−0.339 (−0.107)	0.371 (0.484)	−0.120 (−0.083)
$\Delta\left(m_{t-2} - m_{t-2}^*\right)$	−1.344 (−0.341)	0.212 (0.118)	0.165 (0.033)	−0.973 (−0.147)	0.593 (0.314)	−1.141 (−0.156)	0.365 (0.028)	−0.023 (−0.015)
$\Delta\left(y_{t-2} - y_{t-2}^*\right)$	0.169 (0.212)	0.052 (0.026)	−1.110 (−1.344)	−0.349 (−0.023)	−0.268 (−0.772)	−0.485 (−0.220)	−0.219 (−0.693)	−0.324 (−0.221)
$\Delta\left(i_{t-2} - i_{t-2}^*\right)$	0.056 (0.019)	0.040 (0.008)	0.653 (0.221)	0.274 (0.091)	0.385 (0.239)	0.119 (0.026)	0.056 (0.031)	0.123 (0.054)
$\Delta(e_{t-2} - c_{t-2})$	−0.073 (−0.073)	−0.002 (−0.005)	0.100 (1.610)	0.011 (0.004)	0.055 (0.630)	0.023 (0.004)	0.003 (0.0004)	0.006 (0.014)

Note: Mod_1 refers to a linear RE model that does not take into account the effect of the band on expectations. Mod_2, Mod_3 and Mod_4 are non linear RE models where the band affects agents' expectations and different realignment probabilities. $P_{01} = 0$ in Mod_2, P_{01} is a constant different from zero in Mod_3 and P_{01} is a function of $\left(i_{t-1} - i_{t-1}^*\right)$, $(e_{t-1} - c_{t-1})$, $\Delta\left(m_{t-1} - m_{t-1}^*\right) - \Delta\left(m_{t-2} - m_{t-2}^*\right)$ and $\left(y_{t-1} - y_{t-1}^*\right)$ in Mod_4. First and Second refer to the two alternative formulations of the conditional variance of exchange rate shocks. The values in parentheses are the t rate and *, ** and *** denote the significance of 10, 5 or 1 % respectively.

Table 2: Estimated Parameters in the Second Sample
(November 1993-December 1998)

Explanatory Variables	Mod_1		Mod_2		Mod_3		Mod_4	
	First	Second	First	Second	First	Second	First	Second
Constant	-1.223 (-1.379)	-1.263^{***} (-5.521)	0.113 (0.126)	0.062 (0.005)	0.153 (0.233)	0.205 (0.211)	0.152 (0.510)	0.241 (0.326)
e_{t-1}	-0.074 (-0.149)	-0.096^{***} (-13.942)	0.108 (0.060)	0.210^{***} (4.320)	0.888^{***} (4.118)	0.814^{***} (8.440)	0.145 (0.947)	0.238^{***} (4.046)
$E(e_t/I_{t-1})$	1.077^{***} (2.030)	1.099^{***} (14.563)	0.891 (0.490)	0.790^{***} (15.240)	0.108 (0.519)	0.183^{***} (2.020)	0.855^{***} (5.553)	0.761^{***} (12.593)
$(m_t - m_t^*)$	-0.238 (-0.012)	-0.228 (-0.056)	0.107 (0.245)	-0.473 (-0.375)	0.243 (0.062)	0.326 (0.103)	0.319 (0.119)	0.295 (0.064)
$(y_t - y_t^*)$	0.024 (0.0009)	0.024 (0.013)	-0.045 (-0.062)	-0.017 (-0.011)	-0.050 (-0.014)	-0.033 (-0.006)	-0.061 (-0.005)	-0.040 (-0.015)
$\left(i_{t-1} - i_{t-1}^*\right)$	-0.007 (-0.0004)	-0.011 (-0.012)	-0.050 (-0.074)	-0.237 (-0.070)	-0.011 (-0.005)	-0.034 (-0.0008)	-0.017 (-0.013)	-0.058 (-0.002)
$(e_{t-1} - c_{t-1})$	-0.003 (-0.0007)	-0.009 (-0.108)	0.007 (0.007)	0.022 (0.029)	0.005 (0.0009)	0.016 (0.025)	0.007 (0.002)	0.022 (0.159)
$\Delta\left(m_{t-1} - m_{t-1}^*\right)$	0.311 (0.054)	0.229 (0.193)	-0.269 (-0.346)	-0.030 (-0.014)	-0.310 (-0.565)	-0.205 (-0.044)	-0.437 (-0.481)	-0.349 (-0.006)
$\Delta\left(y_{t-1} - y_{t-1}^*\right)$	-0.003 (-0.0001)	-0.016 (-0.035)	-0.015 (-0.018)	-0.021 (-0.055)	-0.004 (-0.001)	-0.008 (-0.025)	-0.005 (-0.0005)	-0.019 (-0.021)
$\Delta\left(m_{t-2} - m_{t-2}^*\right)$	-0.194 (-0.028)	-0.032 (-0.163)	0.389 (0.913)	0.723^{***} (2.390)	0.223 (0.277)	0.042 (0.096)	0.367 (0.036)	0.275 (0.398)
$\Delta\left(y_{t-2} - y_{t-2}^*\right)$	0.070 (0.005)	-0.023 (-0.071)	-0.114 (-0.143)	-0.133 (-1.271)	-0.101 (-0.008)	0.051 (0.102)	-0.137 (-0.0006)	-0.020 (-0.026)
$\Delta\left(i_{t-2} - i_{t-2}^*\right)$	1.461 (1.200)	1.369^{***} (5.757)	-1.910 (-0.632)	-1.785 (-1.569)	-2.102 (-1.021)	-2.037^{***} (-2.280)	-2.768 (-0.768)	-2.765^{*} (-1.707)
$\Delta(e_{t-2} - c_{t-2})$	0.005 (0.0006)	-0.053 (1.637)	-0.011 (-0.143)	0.082 (1.436)	-0.007 (-0.003)	0.089 (0.709)	-0.010 (-0.004)	0.125 (1.172)

Note: Mod_1 refers to a linear RE model that does not take into account the effect of the band on expectations. Mod_2 , Mod_3 and Mod_4 are non linear RE models where the band affects agents' expectations and different realignment probabilities. $P_{01} = 0$ in Mod_2, P_{01} is a constant different from zero in Mod_3 and P_{01} is a function of $\left(i_{t-1} - i_{t-1}^*\right)$, $(e_{t-1} - c_{t-1})$, $\Delta\left(m_{t-1} - m_{t-1}^*\right) - \Delta\left(m_{t-2} - m_{t-2}^*\right)$ and $\left(y_{t-1} - y_{t-1}^*\right)$ in Mod_4. First and Second refer to the two alternative formulations of the conditional variance of exchange rate shocks. The values in parentheses are the t rate and *, ** and *** denote the significance of 10, 5 or 1 % respectively.