Economics Working Paper 128*

Bands Width, Credibility and Exchange Risk: Lessons from the EMS Experience[†]

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June 1995[††]

Keywords: Credibility, target zones, markov switching model.

Journal of Economic Literature classification: C22, F31, F33.

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*This paper is also number 1 Finance and Banking Discussion Papers Series, UPF.

†This paper is based upon work supported by the DGICYT under grant number PB93-0388. We would like to thank Analistas Financieros Internacionales, S.A. who have kindly provided the data used in the empirical part of the paper.

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††First draft: December 1994.

Abstract

This paper presents an analysis of the credibility of the EMS currencies that covers the period before and after the increase in the bands of fluctuation. Our credibility indicator is based on the inferred probabilities derived from the estimation of a Markov-switching model (Hamilton (1989)) applied to the expected rate of depreciation. The results show that, for most of the currencies, credibility has improved, at least transitorily, after the increase in the bands. However, for all currencies, the credibility measured by the indicator proposed in this paper has been eroded recently even with the widened bands.

1 Introduction.

The European Monetary System (EMS) was initially thought as an agreement to reduce the variability of exchange rates for an Europe in transition to economic integration. The Exchange Rate Mechanism (ERM) is the basic instrument to obtain such stability. The ERM imposes to the economic authorities the obligation to intervene whenever the exchange rate of their currencies gets close to the boundaries of fluctuation defined around bilateral central rates relative to each participating currency.

However, the ERM recognizes explicitely the possibility of realignment when central banks interventions are not enough to keep currencies within the bands. Therefore, the target zone approach to exchange rates modelling, originated in Krugman (1991), is not completely satisfactory for the EMS case. The Krugman model has two crucial assumptions. First, the exchange rate target zone is perfectly credible. Second, the target zone is defended with "marginal" interventions only. However, the EMS can be defined as an area of bounded exchange rate fluctuations with imperfect credibility and interventions that also happen "intramarginally".

In the context of the EMS the stabilizing effect of the bands on the exchange rates depends crucially on the credibility of the no realignment situation. Bertola and Caballero (1992) point out that the relationship between fundamentals and exchange rates predicted by Krugman (1991) is reversed when there is high risk of realignment. The likelihood of target zone predictions hinges on the probability of realignment perceived by agents.

Consequently, the calculation of a credibility indicator becomes a very relevant task, specially when the last storm in the EMS made clear the importance of the confidence of the agents on the system for its sustainability.

In the summer of 1992 the EMS suffered its biggest crisis, after more than 5 years of no realignments of parities. The crisis led to several devaluations (the Spanish Peseta, the Irish Punt and the Portuguese Escudo) and the exit of the Sterling Pound and the Italian Lira. The crisis ended with the reform of the ERM which implied the increase in the bands defined around the bilateral central rates (see graphs 1.1 to 1.8).

Two years after the reform of the ERM we have enough data to analyze the effects of the widening of the bands on the credibility and stability of the currencies in EMS. The objective of this paper is to obatin a rigorous indicator of target zone credibility as well as comparing its evolution before and after the widening of the bands.

In particular, the construction of this indicator takes into account the fact that exchange rates in the EMS are subject to changes of regime at uncertain moments. Traders at exchange markets assign some probability to the event of change of regime and the interaction of those defines the evolution of exchange rates. For these reasons we addopt the methodology proposed by Hamilton (1989) and some extensions of his approach in order to deal with exchange rates evolution in the EMS.

The remainder of this paper is organized as follows. Section 2 revises the literature on credibility indicators and its empirical implementation. Section 3 presents a brief description of the econometric methods used in this paper. The applications of that econometric methodology to the EMS appear in section 4. Section 5 concludes.

2 Target zone credibility indicators.

Under the uncovered interest parity (UIP) assumption, the interest rate differential between two homogeneous assets nominated in different currencies should be equal to the expected rate of depreciation of one currency relative to the other, during the time interval corresponding to the maturity of those asssets. UIP is a reasonable approximation if the foreign exchange risk premium is small [1].

[1]The existence of a risk premium at the international level depends on several factors: the degree of risk aversion of the agents, the variability of the return of the foreign asset and the correlation between the return of the foreign asset and the return of the portfolio. Svensson (1992) argues that for reasonable levels of risk aversion there is not significant risk premium in a target zone. Ayuso and Restoy (1992) obtain a small estimation for the risk premium component due to the fact that risk can be easily diversified in the EMS.

We can write the uncovered interest parity condition as

$$i_t^\tau - i_t^{*\tau} = E_t \Delta s_{t+\tau} / \tau dt \qquad (1)$$

where i_t^τ is the domestic interest rate at time t for assets of maturity τ (measured in periods), $i_t^{*\tau}$ is the foreign interest rate at time t for assets of the same default risk and the same maturity τ, E_t denotes expectations conditional upon information available at time t, s_t denotes the logarithm of the spot rate (measured in units of domestic currency per foreign currency) and dt is the lenght of the period.

The expected rate of exchange rate depreciation can be written as the sum of the expected change in the deviation of the spot with respect to the central parity, or depreciation within the band (Bertola and Svensson (1993)), and the expected change in the central parity.

$$E_t \Delta s_{t+\tau} / \tau dt = E_t \Delta x_{t+\tau} / \tau dt + E_t \Delta c_{t+\tau} / \tau dt \qquad (2)$$

where s_t is the logarithm of the spot rate, c_t is the logarithm of the central parity and $x_t = s_t - c_t$. Therefore,

$$(i_t^\tau - i_t^{*\tau}) \tau dt = E_t \Delta x_{t+\tau} + E_t \Delta c_{t+\tau} \qquad (3)$$

which implies that the expected rate of realignment is equal to

$$E_t \Delta c_{t+\tau} = (i_t^\tau - i_t^{*\tau}) \tau dt - E_t \Delta x_{t+\tau} \qquad (4)$$

Consequently, when there is no risk premium, the difference between the interest rate differential of two homogeneous assets nominated in different currencies and the expectation of depreciation within the band can be identified as the expected rate of realignment in the central parity.

Most of the credibility indicators proposed in the literature on target zones are based on (4). The so called "simplest test" (Svensson (1991,1993)) calculates that the expected rate of realignment must be bounded by the minimum rate of realignment (interest rate differential minus the maximum rate of depreciation within the band) and the maximum rate of realignment (interest rate differential less the minimun rate of depreciation within the band)

[2]. Others, like Rose and Svensson (1991, 1994), Svensson (1993), Lindberg, Svensson and Söderlind (1993) and Holden and Vikoren (1992) [3] specify econometric models and estimate, by regression methods, the expected rate of depreciation within the band. This method has much better precision than the "simplest test", and is called the "drift-adjustement" method, since the interest rate differential is adjusted by the "drift" of the exchange rate within the band. It was first suggested by Bertola and Svensson (1993). Home and foreign interest rates and the position of the exchange rate within the band are considered as explanatory variables in some econometric specifications of that expected depreciation rate [4].

However, estimating the expected rate of depreciation within the band is not an easy task. When there is risk of realignment the subjective probability distribution of x_t, the same as that of s_t, will not follow a continuous stochastic process. If agents expect the devaluation of a currency, the subjective distribution of probability of the exchange rate within the band will incorporate the probability of that event in the mean and the variance, even if the realignment does not happen. Then, a single normal distribution is not a good choice for the sample distribution (Bertola and Caballero (1992)).

The realignment risk is a particular case of the so called "peso problem" (Krasker 1980). If there is a positive probability of a rare or infrequent event, like a devaluation, or a realignment of parities, the standard tests of efficiency of the forward markets are biased.

Empirical implementations of the traditional indicator of credibility, based on the "drift-adjustment" method, take into account the possibility that agents assign a positive probability to the realignment event in a very indi-

[2]This is the same as examining whether the forward exchange rate, for a given maturity, falls outside the exchange rate bands. For applications to the Spanish case Serrat (1992) and Rodriguez Mendizábal (1993).

[3]For the Spanish case Ayuso, Pérez Jurado and Restoy (1993).

[4]An alternative line of research, which is complementary, rather than competing, looks for systematic relations between actual devaluations and fundamental macroeconomic conditions, other than interest rate differential. Some authors obtain the probability of realignment using limited dependent variable models. Edin and Vredin (1993) calculate the probability of realignment in two steps. In the first step they estimate the probability of realignment using a probit model including several macroeconomic variables. In the second step they estimate the size of the realignment conditional on happening.

rect manner.

Svensson (1993) models the expected rate of depreciation within the band as depending on the probability of realignment perceived by the agents during the time interval corresponding to the maturity. Therefore

$$E_t\Delta x_{t+\tau} = p_t^\tau E_t(\Delta x_{t+\tau} \mid R) + (1 - p_t^\tau)E_t(\Delta x_{t+\tau} \mid NR) \quad (5)$$

where p_t^τ is the probability of a change of regime during the period from time t to time $t + \tau$, R is the event "realignment" and NR is the event "no realignment".

But, since he recognizes that it is complicated to estimate the expected rate of depreciation inclusive of possible jumps at realignment, as the sample distribution of realignments may not be representative, Svensson (1993) proposes to estimate the expected rate of depreciation conditional upon no realignment [5].

Following this strategy he defines the expected rate of devaluation, g_t^τ, as

$$\begin{aligned} g_t^\tau = (i_t^\tau - i_t^{*\tau})\tau dt - E_t(\Delta x_{t+\tau} \mid NR) &= p_t^\tau \left[E_t(\Delta x_{t+\tau} \mid R) - E_t(\Delta x_{t+\tau} \mid NR)\right] \\ &+ E_t\Delta c_{t+\tau} \quad (6) \end{aligned}$$

or

$$g_t^\tau = (i_t^\tau - i_t^{*\tau})\tau dt - E_t(\Delta s_{t+\tau} \mid NR) = p_t^\tau \left[E_t(\Delta s_{t+\tau} \mid R) - E_t(\Delta s_{t+\tau} \mid NR)\right] \quad (7)$$

Hence, the expected rate of devalulation g_t^τ (if it is positive a devaluation is expected, if it is negative a revaluation is expected) equals the difference between the interest rate differential and the expected rate of depreciation within the band (conditional upon no realignment). This expected rate of devaluation differs from the expected rate of realignment by the first term on the right-hand side in (6).

[5] See also, Holden and Vikoren (1992), and Ayuso, Pérez Jurado and Restoy (1993), for the Spanish case.

In order to obtain the estimates of the serie x_t conditional on the no realignment event, Svensson (1993) eliminates from the sample the 65 observations corresponding to the three months before a realignment took place, given that he uses $\tau = 3$ months. However, even when the realignment observations are excluded from the sample, the possibility of a future realignment makes the sample movement of x_t conditional on both realignment and no-realignment probabilities [6]. Furthermore, the reduction in the number of observations implied by this strategy leads to a loss of information.

3 Econometric methods.

This section covers the econometric methods proposed for the estimation of the model. The procedures exposed in this section try to overcome some of the problems found in the literature on target zone credibility.

The "peso problem" is the first question to address in order to estimate the expected rate of change of central parities. When there is realignment risk, the sample distribution of the serie x_t may not be an accurate description of the true distribution of the error term. The sample represents a mixture distribution while the underlying distribution has, in fact, two regimes that are switching back and forth: the high probability of realignment regime and the low probability of realignment regime. Given that the regime is unobserved, inferences obtained using the mixture distribution without an appropriate mechanism to estimate the regime will be clearly biased.

Several authors have proposed solution to this problem in the context of the EMS. As it has been described in section 2, Svensson (1993) proposes to estimate the expected rate of depreciation conditional upon no realignment. However, the expected probability of realignment could be very high without an actual change in the central parity. In their study on exchange risk in the EMS after the increase of the bands Ayuso et al. (1994) deal with the jumps. They differenciate between the probability an the size of the jump in the exhange rate. However, this separation is not completely satisfactory

[6]Chen and Giovannini (1993), even though their realignment expectations indicator is "ex-post".

given that they do not estimate the size of the jump, but they take it as given, obtaining, as a residual, the probability of it.

Therefore, we need an estimation procedure that allows us to deal with the mixture distribution generated by two possible situations: realignment and no realignment. Furthermore, the probability that the exchange rate at time t comes from one of the distributions might depend on the past values of the exchange rate. At the same time, this method should estimate jointly the jump and the probability of it. For these reasons it seems plausible to use Hamilton's (1989) model for changes in regimes [7]. This procedure is adequate when there are dramatic breaks in a time series like, for instance, devaluations, and will allow us to obtain a different EMS credibility indicator which will be associated with the probability of a change in regime. Very recently, Ruge-Murcia (1995) has used the same model as an indicator to evaluate the credibility of stabilization policy in Israel during the 80's. He measures the credibility of a stabilization plan as the agent's inferred probability that the joint observation of inflation, the nominal interest rate and government spending were generated by a reformed public expenditure regime. Ruge-Murcia (1995) constructs a structural model and solves for the rational expectations equilibrium were one of the elements of the solution is agents' inferred probability of the regime.

3.1 The switching regimes model.

Assume there are two possible states or regimes: one regime of attacks against some currencies (stormy state) and high variance, associated to low credibility and another regime of stability associated to high credibility. The regime is unobserved and the process switches between states following a discrete-time two states Markov chain. Suppose that exchange traders do not observe the current regime and make inferences based on the observed exchange rates. Define the unobserved regimes as $s_t = 1$ and $s_t = 2$. The observed change in

[7]There are not too many empirical implementations of the Markov-switching model to the estimation of exchange rates evolution. In a free-float context, Engel and Hamilton (1990) apply it to the movements of three bilateral american dollar rates and Engel (1994) fits this model to the behavior of eighteen exchange rates, including eleven non-dollar rates. They all find that the Markov-switching model outperforms the random walk model inside the sample.

the exchange rate is supposed to follow an autorregressive process, where the mean and the variance in each period depend on the state of the economy. An AR(1) example of this kind of processes could be represented as

$$y_t - \mu_1 = \theta(y_{t-1} - \mu_1) + \epsilon_1 \quad \epsilon_1 \sim N(0, \sigma_1) \tag{8}$$
$$y_t - \mu_2 = \theta(y_{t-1} - \mu_2) + \epsilon_2 \quad \epsilon_2 \sim N(0, \sigma_2) \tag{9}$$

In general, we can represent an AR(q) regime switching model as

$$y_t - \mu_{s_t} = \theta_1(y_{t-1} - \mu_{s_{t-1}}) + \theta_2(y_{t-2} - \mu_{s_{t-2}}) + \ldots + \theta_q(y_{t-q} - \mu_{s_{t-q}}) + u_t \tag{10}$$

where $u_t = \sigma_{s_t}\epsilon_t$, $\epsilon_t \sim N(0,1)$ i.i.d. and the θ's are such that the process is stationary. [8]

Suppose that s_t is a discrete-valued random variable. The Markov property and the fact that there are only two states, $s_t = 1$ and $s_t = 2$, describe the process as a 2-states Markov chain. The matrix of transition probabilities can be written as

$$\mathrm{P} = \begin{bmatrix} p_{11} & p_{21} \\ p_{12} & p_{22} \end{bmatrix} \tag{12}$$

where

$$p_{kl} = P(s_t = k \mid s_{t-1} = l, s_{t-2} = m, \ldots) = P(s_t = k \mid s_{t-1} = l) \tag{13}$$

and

$$p_{11} + p_{12} = p_{21} + p_{22} = 1 \tag{14}$$

The unconditional probabilities, or ergodic probabilities, can be calculated as

$$\pi = \mathbb{P}\pi \tag{15}$$

[8] Without loss of generality the mean and the variance could be parametrized as

$$\mu_{s_t} = \beta_1 + \beta_2 s_t \quad \sigma_{s_t} = \gamma_1 + \gamma_2 s_t \tag{11}$$

where **P** is the matrix of transition probabilities and π is a vector that contains the unconditional probabilities

$$\pi = \begin{bmatrix} P(s_t = 1) \\ P(s_t = 2) \end{bmatrix} \tag{16}$$

The objective consists in estimating the parameters of the model summarized in the vector $\theta = (\mu_1, \mu_2, \theta_1, \theta_2, ..., \theta_q, p_{11}, p_{22}, \sigma_1, \sigma_2)$. Hamilton (1989) proposes the maximum-likelihood estimation of these parameters. The conditional loglikelihood function is

$$lnP(y_T, y_{T-1}, ..., y_q \mid y_{q-1}, y_{q-2}, ..., y_0) = \sum_{t=q}^{T} lnP(y_t \mid y_{t-1}, y_{t-2}, ..., y_0) \tag{17}$$

We can find the maximum of this function using numerical techniques. The probability of each observation conditional on its past can be calculated using a nonlinear filter and an initial value for θ. The estimation procedure entails the evaluation of the filter for different values of θ until reaching the maximum likelihood.

Define $\mathcal{Y}_{t-1} = (y_{t-1}, y_{t-2}, ..., y_0)$. The initial input for the filter is the joint probability on the s's conditional on the past values of y

$$P(s_t, s_{t-1}, ..., s_{t-q} \mid \mathcal{Y}_{t-1}) = P(s_t \mid s_{t-1})P(s_{t-1}, ..., s_{t-q} \mid \mathcal{Y}_{t-1}) \tag{18}$$

The first term, on the right-hand side, is a simplification, using the Markov property, of the probability of s_t conditional on its own past. Given the particular value at which the likelihood function is evaluated this part is known. The second part is the output of the filter after iteration t-1.

The joint probability of y_t and s_t, and its past, conditional on the past of y_t is

$$\begin{aligned} P & (y_t, s_t, s_{t-1}, ..., s_{t-q} \mid \mathcal{Y}_{t-1}) = \\ P & (y_t \mid s_t, s_{t-1}, ..., s_{t-q}, \mathcal{Y}_{t-1})P(s_t, s_{t-1}, ..., s_{t-q} \mid \mathcal{Y}_{t-1}) \end{aligned} \tag{19}$$

The first term on the right-hand side of the equation is known for a particular θ given that the conditional probability is a normal distribution with mean and variance described by the elements of the vector θ and the value of s_t. [9] The second part is just the expression derived above.

At this point we can already write the likelihood function as

$$P(y_t \mid \mathcal{Y}_{t-1}) = \sum_{s_t=0}^{1} \sum_{s_{t-1}=0}^{1} \cdots \sum_{s_{t-q}=0}^{1} P(y_t, s_t, s_{t-1}, \dots, s_{t-q} \mid \mathcal{Y}_{t-1}) \qquad (20)$$

These probabilities for different t's are used to construct the full likelihood function in (17).

In addition, using the definition of conditional probability we can obtain the input needed to start the next step of the filter algorithm.

In order to analyze the probability assigned to each state, this procedure also delivers the inferred or filtered probabilities of being in state s_t using the information available at that time [10].

$$P(s_t \mid y_t, y_{t-1}, \cdots, y_0) \qquad (22)$$

The optimal predictions derived from this model have two elements: on the one hand it is necessary to obtain a forecast of y_{t+1} conditional on the regime. On the other hand we have to calculate the probability of being in each regime conditional on the observed values of y_t.

The forecast for the expected value of y_{t+1} conditional on the state is just

$$\begin{aligned} E(y_{t+1} \mid s_{t+1}, \mathcal{Y}_t) &= \mu_{s_t} + \theta_1(y_{t-1} - \mu_{s_{t-1}}) + \theta_2(y_{t-2} - \mu_{s_{t-2}}) \\ &+ \dots + \theta_q(y_{t-q} - \mu_{s_{t-q}}) \end{aligned} \qquad (23)$$

[9] The mean and the variance of this process depend only on s_t and its past values.

[10] It would also be possible to compute the smoothed probabilities which are obtained using all the information in the sample

$$P(s_t \mid y_T, y_{T-1}, \dots, y_t, \dots, y_0) \qquad (21)$$

Define $\hat{y}_{t|s_{t+1}}$ as the vector that contains the two conditional expectations

$$\hat{y}_{t|s_{t+1}} = \begin{bmatrix} E(y_{t+1} \mid s_{t+1} = 1, \mathcal{Y}_t) \\ E(y_{t+1} \mid s_{t+1} = 2, \mathcal{Y}_t) \end{bmatrix} \tag{24}$$

The conditional probabilities of being in one state are computed by the iteration of the expression

$$\hat{\phi}_{t+1|t} = \mathbf{P}\hat{\phi}_{t|t} \tag{25}$$

where $\mathbf{P}$ is the transition matrix probability in (12) and

$$\hat{\psi}_{t+1|t} = \begin{bmatrix} P(s_{t+1} = 1 \mid \mathcal{Y}_t) \\ P(s_{t+1} = 2 \mid \mathcal{Y}_t) \end{bmatrix} \quad \hat{\psi}_{t|t} = \begin{bmatrix} P(s_t = 1 \mid \mathcal{Y}_t) \\ P(s_t = 2 \mid \mathcal{Y}_t) \end{bmatrix} \tag{26}$$

Therefore, the forecast conditional on the observable variables by unconditional on the state can be calculated as

$$\begin{aligned} E(y_{t+1} \mid \mathcal{Y}_t) &= \sum_{i=1}^{2} P(s_t = i \mid \mathcal{Y}_t) E(y_{t+1} \mid s_{t+1} = i, \mathcal{Y}_t) \\ &= \hat{y}'_{t|s_{t+1}} \hat{\psi}_{t+1|t} \end{aligned} \tag{27}$$

3.2 A Markov switching ARCH model.

Many studies on exchange rates are centered on exchange risk and, for this reason, they suggest very elaborated models for the variance of the process. Most of them are transformations of the basic ARCH model. Recently Ayuso et al. (1994) have proposed the use of a modified GARCH(1,1) model to analyze exchange risk in the context of the EMS.

The model presented in the last subsection could be extended to the case of a switching ARCH process. Several authors have argued that changes in regime could induce the misleading conclusion of not being able to reject the existence of an unit root in the level of the series. In the same way, the false high persistence of ARCH models may be caused by structural changes in ARCH process. Hamilton and Susmel (1994) have proposed a modification to the usual ARCH model that allows changes in regime, combining the idea of autoregressive conditional heteroskedasticity and the Markov-switching model (SWARCH). A SWARCH model with two states, a disturbance following an ARCH(1) and a first order autoregressive for y_t, SWARCH(2,1,1), can be written as

$$\begin{aligned} y_t &= \delta_0 + \delta_1 y_{t-1} + u_t \\ u_t &= \sqrt{d_{o_t}} \xi_t \;\; s_t = 1,2 \\ \xi_t &= h_t \epsilon_t \\ h_t^2 &= \alpha_0 + \alpha_1 \xi_{t-1}^2 \end{aligned} \tag{28}$$

where ϵ_t could be specified as a standard normal or a t-distribution [11].

A transformation of the filter described above can be used to evaluate the likelihood function and estimate the parameters of this model.

4 Application to the EMS.

This section presents the application of the econometric methods discussed above to the case of the currencies in the EMS. In particular, we analyze the probability of regime changes in different periods of time for the currencies in the EMS.

In related independent work, Engel and Hakkio (1994) have applied a version of the Markov-switching model to the EMS. They try to improve the jump-diffusion model (Ball and Roma (1993)) by using a version of Hamilton (1989) where the probability of switching from one state to another depends on the position of the exchange rate within the EMS. Their primary objetive is to obtain a procedure for finding outliers. The estimation leads to the implication that near the edge of the bands realignments are more likely the quicker it is the movement to them. [12].

The objective of this paper is different from Engel and Hakkio (1994). We use the Markov-switching model to construct an indicator of credibility with

[11] Cai (1994) presents an alternative parametrization of the switching ARCH model.

[12] Chen and Giovannini (1993) find a positive relationship between the expected rate of realignment and the distance from the central parity.

special emphasis on the comparison between the periods before and after the widening of the bands. Engel and Hakkio (1994) only analyze the French Franc and the Italian Lira. We want to cover more currencies, comparing the evolution of the ones that decided to stay in the system with the evolution of the currencies that exited it. In addition, we analyze the expected rate of depreciation as reflected by the interest rate differentials while Engel and Hakkio are concerned about spot exchange rates.

From a technical point of view our specification of the stochastic process has an autorregresive componenent while Engel and Hakkio (1994) present a model where there is a constant mean in each state and a constant variance. The fact that their parameter estimates and the ergodic probabilities are very similar with and without time varying probabilities imply that the most important part of the specification is the dependence from past states. Finally, we also present results on the use of a switching ARCH model in the specification of the evolution of exchange rates in the EMS. As far as we know this is the first application of the switching ARCH model to the EMS.

As we argued in section 2, the basic idea behind the credibility indicator used in the literature has been the possibility of decomposing the expected change of the spot rate into two parts: the expected rate of realignment $(E_t\Delta c_{t+\tau})$ and the variation of the exchange rate within the band $(E_t\Delta x_{t+\tau})$.

$$E_t\Delta s_{t+\tau} = E_t\Delta c_{t+\tau} + E_t\Delta x_{t+\tau} \tag{29}$$

where $E_t\Delta c_{t+\tau}$ can be characterized as the probability of a jump in the exchange rate (p_t^τ), during the period from time t to time $t+\tau$, times the expected conditional realignment rate (it will be positive if a devaluation is expected, negative if a revaluation is expected).

$$E_t\Delta c_{t+\tau} = (1-p_t^\tau)0 + p_t^\tau E_t(\Delta c_{t+\tau} \mid R) = p_t^\tau E_t(\Delta c_{t+\tau} \mid R) \tag{30}$$

In a perfectly credible target zone the expected rate of realignment should be equal to zero and, therefore, the expected change in the spot rate is equal to the expected change in the spot rate within the band. If there is not perfect credibility, $E_t\Delta c_{t+\tau}$ will be different from zero.

Two additional steps are necessary in order to get an estimate of $E_t \Delta c_{t+\tau}$. Using the uncovered interest parity condition we can write

$$E_t \Delta c_{t+\tau} = (i_t^\tau - i_t^{*\tau})\tau dt - E_t \Delta x_{t+\tau} \tag{31}$$

An econometric estimation of $E_t \Delta x_{t+\tau}$ will provide the final step. In general, this literature does not calculate a separate estimate for p_t^τ and $(E_t \Delta c_{t+\tau} \mid R)$.

The indicator proposed in this paper does not try the above decomposition but estimates separately the probability of the jump and the size of it assuming that the so called "within the band exchange rate" follows an AR stationary process [13]. There are several reasons that justify the presence of this autorregressive term. The basic target zone model relies on a simple flexible-price monetary approach to the exchange rate. However, such kind of models have had no empirical success. In fact for many authors there is clear evidence that sluggish price adjustment is essential to exchange rate analysis. If the fundamentals include the possibility of sluggish domestic price level it is unlikely that they will follow a random walk. The qualitative behavior of the target zone model will be the same if fundamentals have autorregressive components (Krugman and Miller (1993)) [14]. Therefore, if there is credibility or, in terms of our interpretation, just one regime, the expected change in the exchange rate should be stationary without any change of regime. Otherwise, we will observe switching from states or regimes.

Moreover, the fact that we can estimate different variances for the perturbation in different regimes connects also with the target zone literature. If a target zone is perfectly credible there should be the case that the variance is

[13] Several authors, for instance Frankel and Phillips (1991), use the argument of mean reversion on the x_t series to justify the stabilizing effect of the bands, based on the so called "honeymoon effect". The econometric specification is

$$\Delta x_{t+\tau} = \beta_0 + \beta_1 x_t + \epsilon_t \tag{32}$$

where a negative sign for β_1 is interpreted as a symptom of mean reversion.

[14] In addition, the fact that most EMS interventions take place intramarginally, which implies a policy of leaning against the wind, also favors a tendency toward autorregression in the fundamentals. The standard target zone model assumes that interventions take place only at the maximum or minimum exchange rate values ("marginal" interventions).

bounded. In addition, if the bands are credible the variance should be very small when the exchange rate is close to them [15]. Therefore, we define the two states by its respective mean and variance. A period of scarce credibility is characterized as a very volatile situation with a high probability of change in the mean of the process. For the above reason we consider that the Markov-switching model is an adequate specification to deal with the issue of credibility in the EMS.

Table 1 presents some descriptive results of the application of the Markov-switching model to weekly changes of the logarithm of the spot exchange rates, relative to the Deutsche Mark, of currencies in the EMS. For most of the currencies the data cover the period from January 1990 up to March 1995. For other currencies the sample period starts in December 1990. In the case of the Portuguese Escudo and the Sterling Pound the starting point is their respective entrance in the EMS. We can see that, except for the case of the Spanish Peseta, the mean of both states is not significantly different from 0. However, the variance is significantly higher in the second state. This is not surprising once we look at graphs 2.1-2.8. The coefficients of the autorregressive components are not significantly different from 0 in the case of the Spanish Peseta, the Italian Lira and the French Franc. The highest ratio of the variance of the volatile state with respect to the small volatility state corresponds to the Irish Punt (90.62) while the lowest is the calculated for the French Franc (10). This ratio is also small for the case of the Spanish Peseta (11.95).

The unconditional probability of state 1 is very high for the Spanish Peseta, the Portuguese Escudo, the Sterling Pound, the French Franc and the Belgian Franc while it is close to 50% in the cases of the Irish Punt, the Italian Lira and the Danish Krone. This means that for most of the currencies the usual state during this period has been state 1. The probability of being in state 1 next period conditional on being in state 1 this period is very high in all the cases. The probability of being in state 2 next period conditional on being this period in state 2 is also very high except for the Portuguese

[15]The other main result of target zone models is that at the edges of the bands the exchange rate is completely insensitive to the fundamentals. This result derives from the "smooth pasting" condition.

Escudo and the Sterling Pound [16]. Therefore, states are, in general, quite persistent.

However, the analysis of the expected rate of depreciation is the base of our credibility indicator. Table 2 presents the results of the estimation of a two states Markov-switching model to weekly data for three-month interest rate differentials of the EMS currencies with respect to the Deutsche Mark [17]. In this case the means are different from 0 for all the currencies, with the exception of the Belgian Franc. On the other hand, there is strong evidence of autorregressive components for all the currencies. The lowest ratio of the variance of the volatile state with respect to the less volatile state corresponds to the Italian Lira followed by the Belgian Franc, the Spanish Peseta and the Portugese escudo. The relative variance of the high volatility state in the case of the Danish Krone is very large. The unconditional or ergodic probability of state 1 is very high for all currencies, opposite to what happens in the analysis of the change in the spot exchange rates. There is also a lot of persistency of the states, as measured by the conditional probabilities p_{11} and p_{22}, specially of state 1. Graphs 4.1 to 4.6 present the inferred probabilities obtained by the application of the filter described in 3.1. Therefore, they represent the probabilities, perceived by the agents, of being in the high volatility state conditional on the past information about the interest rate differential. The period of the EMS storm presents very high probabilities of state 2. In addition, the probabity of state 2 after the period starting on August 1993 is low, at least for a while. An interesting fact shown by those graphs is that the credibility of the EMS was recovered temporarely, for most of the currencies, with the increase in the bands. The probability of state 2 after the increase in the bands is small for many periods and similar to the probability calculated for the period before the beginning of the storm. [18] It is also interesting to notice that for the Italian Lira, one of the currencies that left the EMS during the crisis, the inferred probability of state 2 has

[16]This fact implies that the Escudo and the Pound suffer short and quick jumps in the probability of being in state 2.

[17]Interest rates for the Irish Punt were not available for serveral weeks and we have chosen to exclude this currency from our estimation.

[18]Many authors have suggested that the probability of realignment may depend on the distance of the exchange rate from the limits of fluctuation or from the central parity. In order to investigate this point we have estimated, for the Spanish Peseta case, a logit for the filtered probabilities of state 2

returned to the level it was before the beginning of the crisis.

However, after two o three months of low probabilities of state 2, some currencies began to show an increase in the probability of the high volatility state. This effect can be seen clearer at the end of the sample period (January-March 1995). The fact that even the Italian lira, out of the EMS discipline since September 1992, shows a similar pattern of the probability of state 2 and the above mentioned end of the sample phenomenon seems to point out that the existence of the bands, or even its widening, do not preserve currencies from speculative attacks.

The graphs 5.1 and 5.2 present the evolution of the three month depreciation rate within the band [19] and the predicted values for the Peseta and the French Franc. The predictions have been obtained using the procedure described in section 3.1. The results of the estimation are presented in table 3. Graphs 6.1 and 6.2 depict the yearly expected rate of realignment obtained by using (31) [20], where the expected rate of depreciation within the band is substituted for its prediction. The probabilities derived from the application of the Markov-switching model to the variable constructed in this way are similar to the ones obtained using the interest rate differentials. The inferred probability of state two is small and decreases during the period after the increase in the bands [21]. Finally, we have also obtained a prediction of the realignment rate, for the case of the Spanish Peseta, as the difference between the prediction of the spot exchange rate depreciation and the prediction of the depreciation within the band. The results have shown that the rate of

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$$p_t = \frac{1}{1+e^{z_t}} \tag{33}$$

where $z_t = \beta_0 + \beta_1 w_t$, and w_t is taken to be a measure of the position of the currency in the band. We have tried two alternative measures: the distance to the upper limit of the band and the distance from the central parity. The estimator of β_1 was never significantly different from 0. We recognize that thit is a very crude approximation to the relationship between the position in the band and the probability of state 2 but it gives some useful information.

[19]Calculated "ex-post".

[20]The so called "drift-adjustment" method (Svensson (1993)).

[21]The sample for the construction of the exchange rate depreciation within the band includes data only until September 1994.

realignment of the Peseta was smaller than expected, at the time of the first devaluation.

Table 4 shows the results of a preliminary application of the switching ARCH model to the case of the three-month interest rate differentials of the Spanish Peseta and the French Franc with respect to the Deutsche Mark. In principle, the parameter associated with the lag of the residuals is not significantly different from 0, which seems to indicate that there is no evidence of autorregressive components in the variance of the regimes.

5 Conclusions.

This paper presents an analysis of the credibility of the EMS currencies that covers the period before and after the increase in the fluctuation bands. Our credibility indicator is different from the most widely used in the target zone literature, which is based on the "drift-adjustment" method. In particular, the indicator of credibility we have obtained hinges on the inferred probabilities derived from the estimation of a Markov-switching model (Hamilton (1989)) applied to the expected rate of depreciation of the EMS currencies. In this way, we avoid the main problem presented by the "drift-adjustment" method, which lies in the difficulty of estimating the expected rate of currency depreciation within the bands.

Exchange rates of currencies in the EMS are characterized by long periods of stability (low probability of realignment) interrupted by periods of extreme volatility (high probability of realignment). Consequently, a single normal distribution is not a good choice for EMS exchange rates. Therefore, we need an estimation procedure that allows us to deal with a mixture distribution generated by two possible situations: realignment and no realignment. For these reasons it seems plausible to use Hamilton's (1989) model for changes in regime.

We have applied this procedure to the estimation of the expected rate of realignment based on the traditional method. Nevertheless, the filtered probabilities derived from the implementation of a Markov-switching model to the three-month interest rate differentials of EMS currencies are the base of our credibility indicator.

The results show that, for most of the currencies, credibility improved transitorily after the widening of the bands. For the Spanish peseta and the French Franc the period between January 94 and December 94 presents small probabilities of state 2. However, there are some peaks in the probability graphs for the Portugese Escudo, the Danish Krone and the Belgian Franc during the same period of time. With no exception, the currencies analyzed show a probability of state 2 close to 1 at the end of the period (January-March 1995). Finally, it is also interesting to notice that for the Italina Lira, one of the currencies that left the EMS during the crisis of 92, the inferred probability of state 2 has returned to the level it was before the beginning of it and it has increased during the final months of the sample, like for the rest of the currencies. Therefore, it seems that the fact of getting into the EMS system or changing the rules of it (wider bands) may improve credibility but only in a transitory way. The EMS mechanism is not able "per se" of preserving the credibility of the currencies involved in it.

6 Tables.

Table 1								
Spot exchange rate: weekly changes								
	SP	PE	IP	StP	IL	FF	DK	BF
μ_1	0.014	0.109	0.001	0.004	0.012	-0.016	0.000	-0.004
	(0.033)	(0.055)	(0.012)	(0.070)	(0.023)	(0.018)	(0.020)	(0.006)
μ_2	0.717	0.364	0.090	1.923	0.252	0.093	0.039	-0.024
	(0.322)	(0.560)	(0.119)	(1.155)	(0.155)	(0.097)	(0.087)	(0.127)
σ_1^2	0.246	0.222	0.016	0.508	0.045	0.029	0.016	0.009
	(0.028)	(0.036)	(0.002)	(0.061)	(0.006)	(0.008)	(0.004)	(0.001)
σ_2^2	2.947	3.161	1.453	7.822	1.861	0.291	0.382	0.596
	(0.867)	(1.844)	(0.239)	(4.037)	(0.256)	(0.112)	(0.065)	(0.162)
p_{11}	0.974	0.923	0.954	0.985	0.987	0.968	0.915	0.985
	(0.016)	(0.042)	(0.026)	(0.011)	(0.010)	(0.028)	(0.035)	(0.010)
p_{22}	0.818	0.247	0.945	0.656	0.986	0.865	0.901	0.903
	(0.103)	(0.301)	(0.035)	(0.219)	(0.011)	(0.081)	(0.044)	(0.063)
π_1	0.87	0.91	0.54	0.96	0.52	0.81	0.54	0.87
π_2	0.13	0.09	0.46	0.04	0.48	0.19	0.46	0.13

Units of domestic currency per Deutsche-Mark. SP: Spanish Peseta; PE: Portuguese Escudo; IP: Irish Punt; StP: Sterling Pound; IL: Italian Lira; FF: French Franc; DK: Danish Krone; BF: Belgian Franc. Standard errors within parentheses.

Table 2						
Interest rate differentials: three-month euromarket rates						
	SP	PE	IL	FF	DK	BF
μ_1	2.784	5.235	2.808	0.540	0.717	-0.296
	(0.652)	(0.267)	(0.188)	(0.189)	(0.116)	(0.403)
μ_2	2.863	6.030	3.374	1.127	0.969	-0.049
	(0.676)	(0.368)	(0.223)	(0.263)	(0.170)	(0.406)
σ_1^2	0.024	0.143	0.047	0.015	0.032	0.014
	(0.004)	(0.031)	(0.005)	(0.001)	(0.003)	(0.001)
σ_2^2	0.769	4.918	0.878	0.633	5.716	0.462
	(0.152)	(1.213)	(0.252)	(0.128)	(1.269)	(0.114)
p_{11}	0.942	0.915	0.968	0.990	0.964	0.969
	(0.021)	(0.030)	(0.012)	(0.006)	(0.014)	(0.013)
p_{22}	0.844	0.827	0.772	0.974	0.866	0.825
	(0.054)	(0.068)	(0.089)	(0.022)	(0.054)	(0.080)
π_1	0.72	0.67	0.88	0.74	0.79	0.85
π_2	0.28	0.33	0.12	0.26	0.21	0.15

Differences between the domestic interest rate and the Deutsche-Mark interest rate. SP: Spanish Peseta; PE: Portuguese Escudo; IL: Italian Lira; FF: French Franc; DK: Danish Krone; BF: Belgian Franc. Standard errors within parentheses.

Table 3		
ER within the band		
	SP	FF
μ_1	1.138	0.076
	(0.922)	(0.201)
μ_2	-3.144	1.043
	(0.960)	(0.285)
σ_1^2	0.924	0.071
	(0.092)	(0.008)
σ_2^2		0.596
		(0.151)
p_{11}	0.965	0.989
	(0.014)	(0.008)
p_{22}	0.803	0.936
	(0.073)	(0.044)
π_1	0.85	0.85
π_2	0.15	0.15

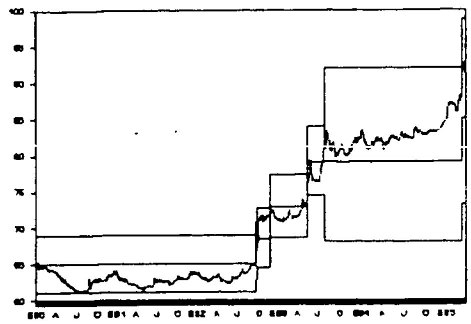
Table 4		
SWARCH (2,1,1)		
	SP	FF
δ_1	0.062	0.021
	(0.039)	(0.014)
δ_2	0.978	0.953
	(0.009)	(0.013)
α_0	0.871	0.569
	(0.223)	(0.153)
α_1	0.166	-0.094
	(0.134)	(0.103)
d_2	0.036	0.025
	(0.009)	(0.006)
p_{11}	0.980	0.995
p_{22}	0.919	0.975
π_1	0.80	0.83
π_2	0.20	0.17

Table 3:Three-month exchange rate depreciation, relative to the Deutsche Mark. SP: Spanish Peseta; FF: French Franc. Standard errors within parentheses.

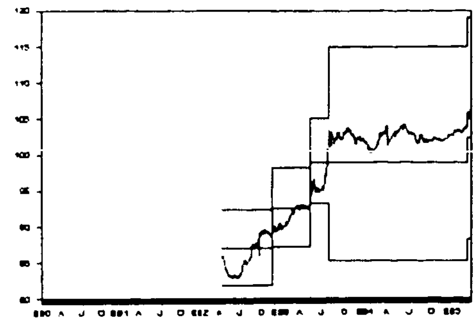
Table 4:Three-month interest rate differentials with respect to the Deutsche Mark. SP: Spanish Peseta; FF: French Franc. Standard errors within parentheses.

1. EXCHANGE RATES IN THE EMS.

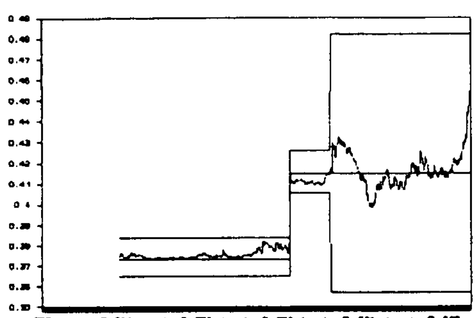
1.1. SPANISH PESETA/D.MARK



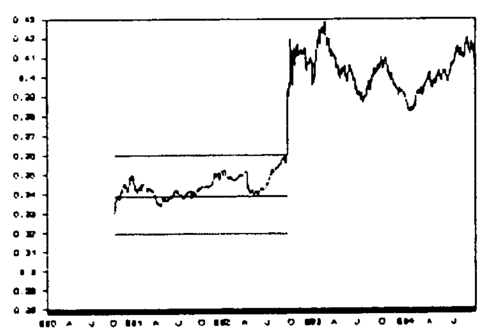
1.2. PORT.ESCUDO/D.MARK



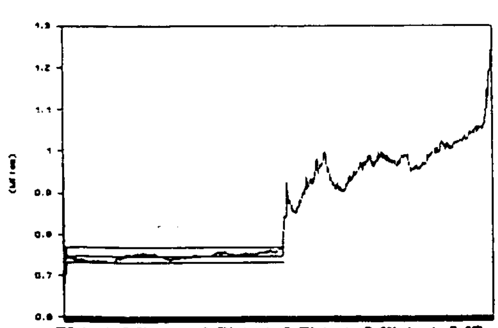
1.3. IRISH PUNT/D.MARK



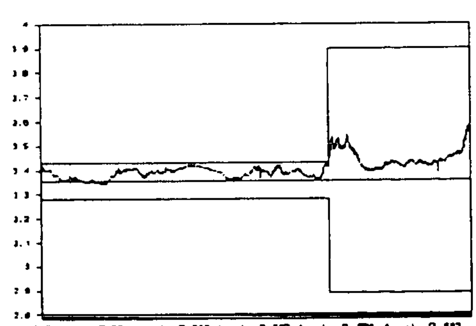
1.4. STERLING POUND/D.MARK



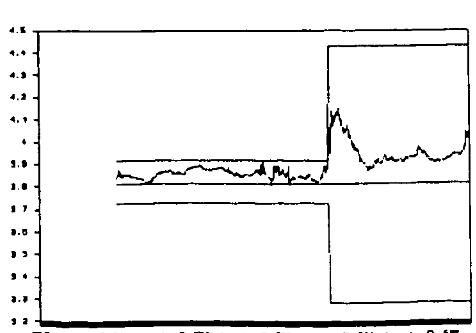
1.5. ITALIAN LIRA/D.MARK



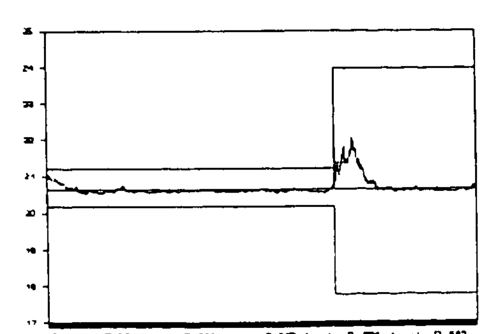
1.6. FRENCH FRANC/D.MARK



1.7. DANISH KRONE/D.MARK

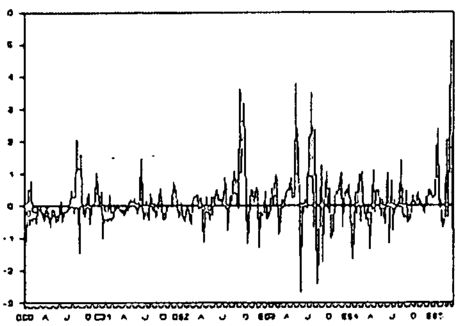


1.8. BELGIAN FRANC/D.MARK

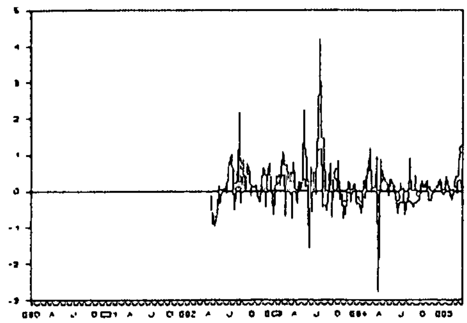


2. WEEKLY SPOT RATE CHANGES

2.1. SPANISH PESETA/D.MARK



2.2. PORT.ESCUDO/D.MARK



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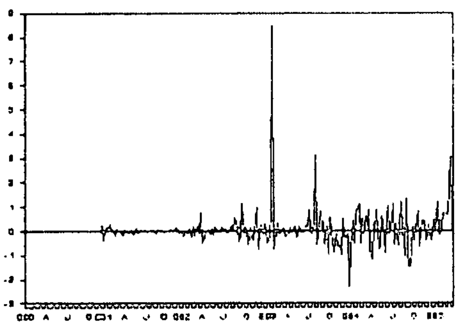
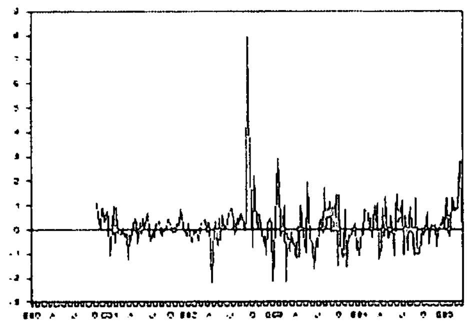
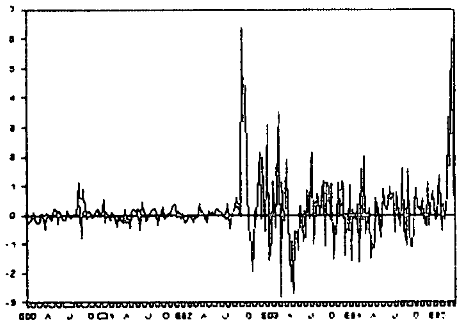


2.4. STERLING POUND/D.MARK



2.5. ITALIAN LIRA/D.MARK



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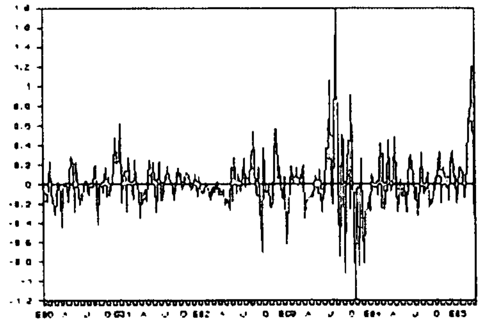

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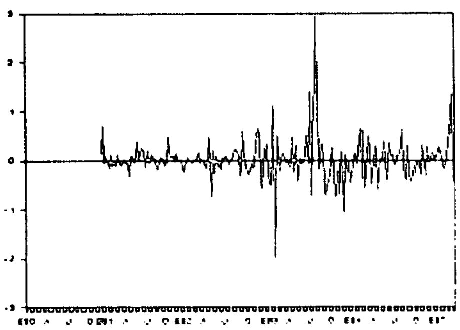
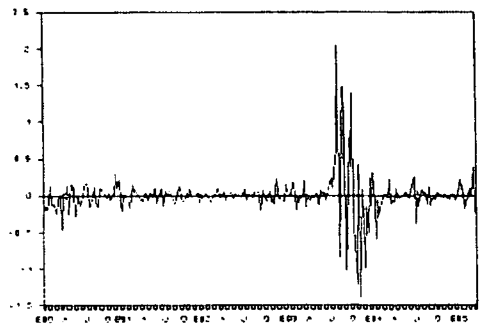
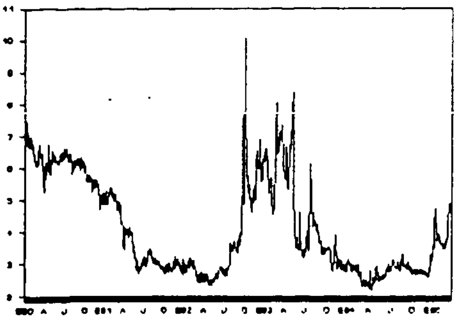


2.8. BELGIAN FRANC/D.MARK

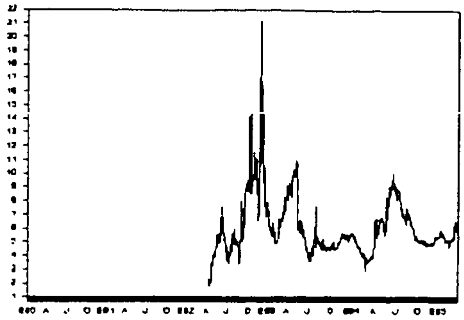


3. INTEREST RATE DIFFERENTIAL
THREE-MONTH EUROMARKET RATE.

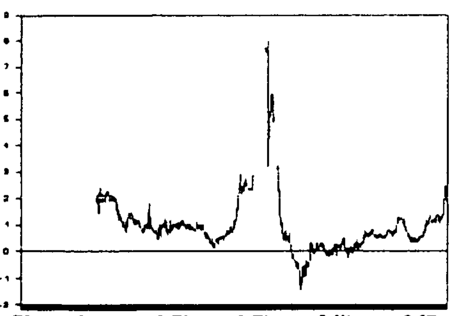
3.1. SPANISH PESETA-D.MARK



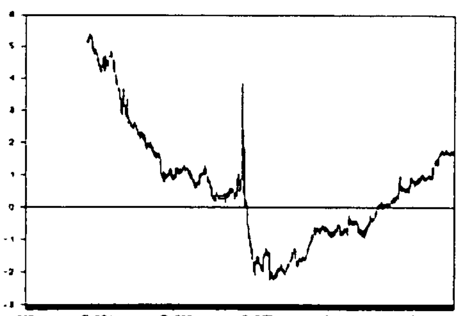
3.2. PORT.ESCUDO-D.MARK



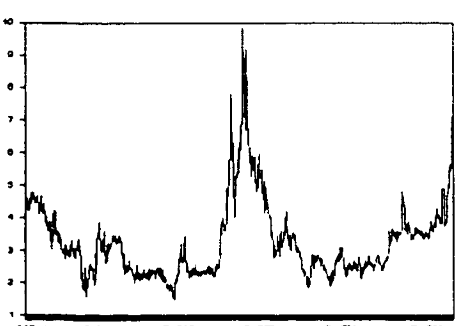
3.3. IRISH PUNT-D.MARK



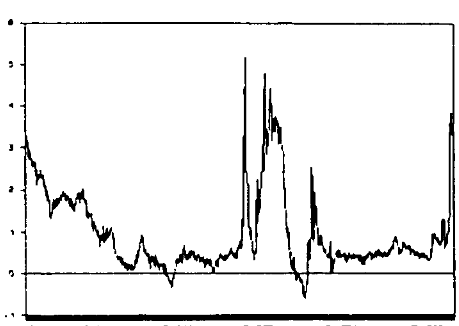
3.4. STERLING POUND-D.MARK



3.5. ITALIAN LIRA-D.MARK



3.6. FRENCH FRANC-D.MARK



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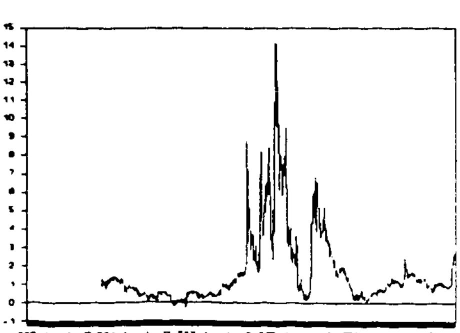
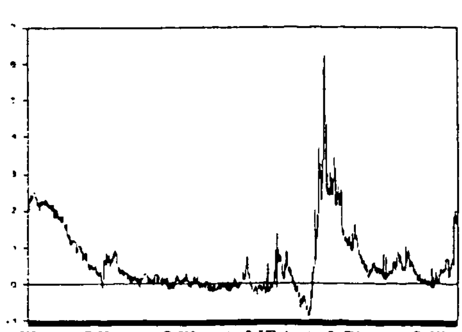
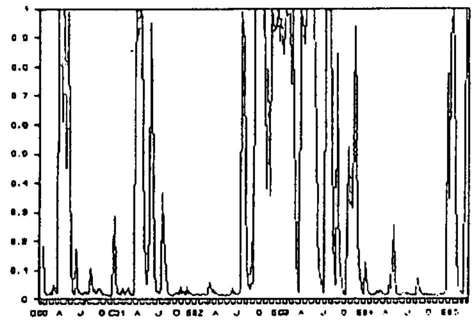


3.8. BELGIAN FRANC-D.MARK

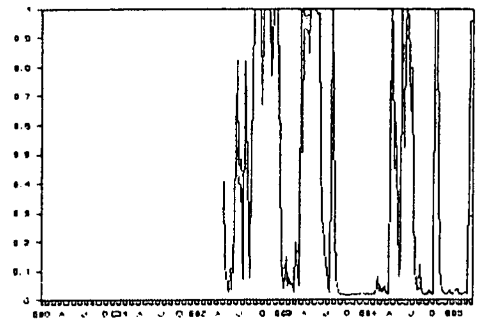


4. FILTERED PROBABILITIES STATE 2
THREE-MONTH INTEREST DIFFERENTIAL

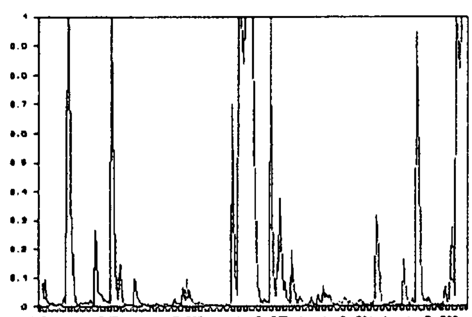
4.1. SPANISH PESETA-D.MARK



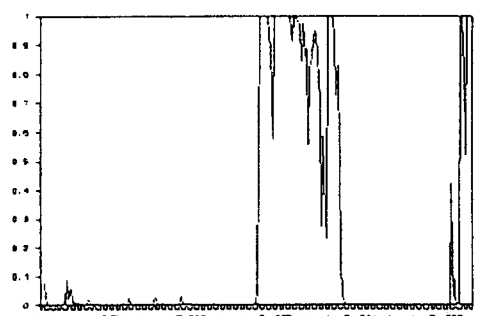
4.2. PORT.ESCUDO-D.MARK



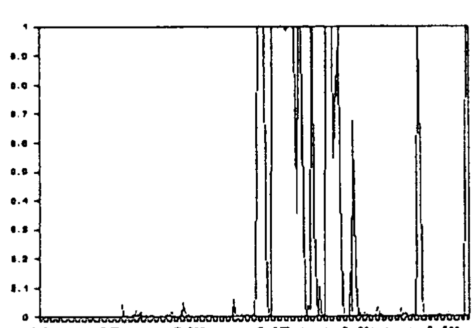
4.3. ITALIAN LIRA-D.MARK



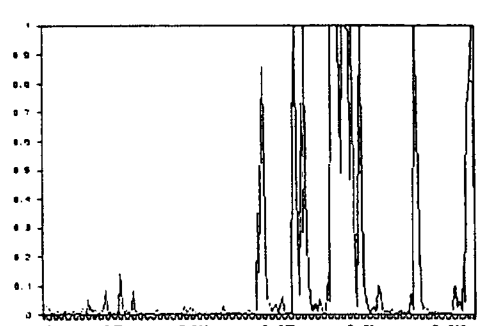
4.4. FRENCH FRANC-D.MARK



4.5. DANISH KRONE-D.MARK

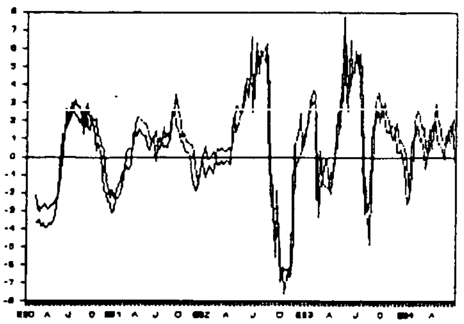


4.6. BELGIAN FRANC-D.MARK

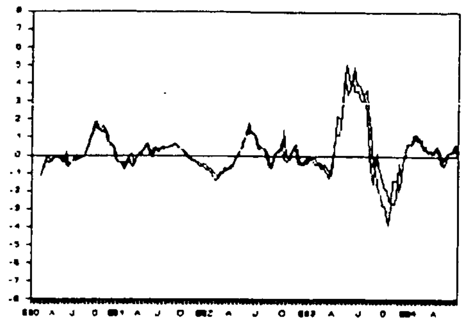


5. EXCHANGE RATE DEPRECIATION WITHIN THE BAND: 3 MONTHS. REAL AND PREDICTED VALUES

5.1. SPANISH PESETA/D.MARK

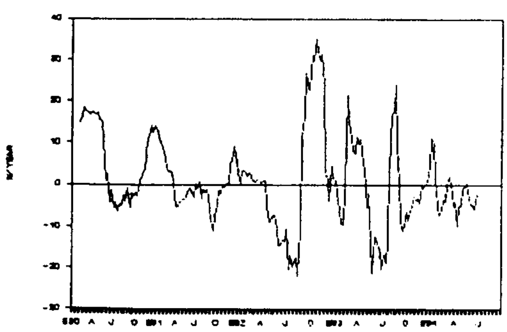


5.2. FRENCH FRANC/D.MARK

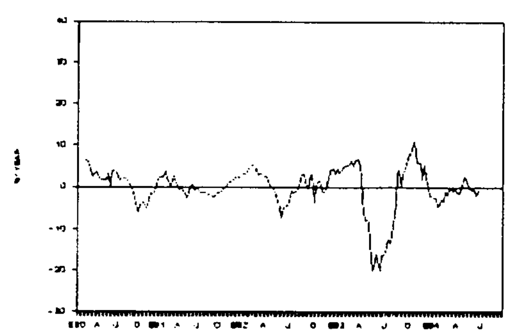


6. EXPECTED RATE OF REALIGNMENT: 3 MONTHS.

6.1. SPANISH PESETA/D.MARK



6.2. FRENCH FRANC/D.MARK



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