Documento de trabajo
E2003/33

On the credibility of a target zone: Evidence from the EMS

Francisco Ledesma-Rodríguez
Manuel Navarro-Ibáñez
Jorge Pérez-Rodríguez
Simón Sosvilla-Rivero

centrA: Fundación Centro de Estudios Andaluces

centrA: Fundación Centro de Estudios Andaluces

centrA:
Fundación Centro de Estudios Andaluces

Documento de Trabajo
Serie Economía E2003/33

On the credibility of a target zone: Evidence from the EMS[*]

Francisco Ledesma-Rodríguez
U. de La Laguna

Manuel Navarro-Ibáñez
U. de La Laguna

Jorge Pérez-Rodríguez
U. de Las Palmas de Gran Canaria

Simón Sosvilla-Rivero
FEDEA and UCM

RESUMEN
Se ofrece nueva evidencia sobre la credibilidad del Mecanismo de Cambios e Intervención del Sistema Monetario Europeo. Para ello, empleamos una batería de indicadores de credibilidad analizando la historia completa del SME. Se compara además la capacidad predictiva de los diferentes indicadores, y se aplican a la experiencia del nuevo MCI que relaciona el euro y las monedas nacionales de los países que no participan en la zona euro.

Palabras clave: Tipos de cambio, Sistema Monetario Europeo.

ABSTRACT
We provide some new evidence on the credibility of the Exchange Rate Mechanism of the European Monetary System. To that end, we use of several credibility indicators, analysing the complete EMS history. We also compare the prediction qualities of the different indicators, and apply them to the experience of the new ERM linking the currencies of non-euro area Member States to the euro.

Keywords: Exchange rates, European Monetary System.
JEL Classification: C32, F31, F33

[*] The authors would like to thank Beatriz Sanz (Bank of Spain) and Mayte Ledo (BBVA) for kindly providing us with the data set used in this paper, as well as a centrA anonymous referee for useful comments and suggestions

1. Introduction

The European Monetary System (EMS) was initially planned as an agreement to reduce exchange rate volatility for a Europe in transition to closer economic integration. Following its inception in March 1979, a group of European countries linked their exchange rates through formal participation in the Exchange Rate Mechanism (ERM). The essence of the ERM was that each participating country was assigned a specific range (target zone) within it its exchange rate could fluctuate with respect to the others. In order to keep the exchange rates within these margins, the participating countries were obliged to intervene in the foreign exchange market whenever their currency approached the limits of its band. Realignment of the parities by the monetary authorities was possible, provided that all the members of the EMS agreed.

The fluctuation bands were originally set at ±2.25%, but a ±6% band was set for Italy and the newcomers (Spain, the UK, and Portugal). After almost a year of turmoil unprecedented in the history of the EMS, the fluctuation bands of the ERM were broadened to ±15% in August 1993 (except for the Dutch guilder and the Deutschmark, which remained within the narrow bands of ±2.25%). There have been fifty-eight realignments during the 1979-1998 period, implemented in nineteen discrete adjustments. It should be noted that thirty eight of such realignments were made prior to the currency turmoil of 1992/93.

Researchers and practitioners alike were caught up with these institutional arrangements, and a number of exchange rate target zone models have been introduced. The ERM is the most prominent example of a target zone exchange-rate system. Starting with the seminal study by Krugman (1991), a large number of papers have examined the behaviour of exchange rates in target zones (see Kempa and Nelles, 1999, for a review). The main result of the target zone model is that, with perfect credibility, the zone exerts a stabilising effect (the so-called "honeymoon" effect), reducing the sensitivity of exchange rates to a given change in fundamentals. Nevertheless, in a target zone with credibility problems, expectations of future interventions tend to destabilise the exchange rate, making it less stable than the underlying fundamentals (Bertola and Caballero, 1992).

Credibility can be defined as the degree of confidence that economic agents assign to the announcements made by policymakers. In a context of an exchange rate target zone, like the EMS, credibility refers to the perception of economic agents with respect to the commitment to maintain the exchange rate around a central parity. Therefore, the possibility that the official authorities change the central parity could be anticipated by the economic agents, triggering expectations of future changes in the exchange rate that could act as a destabilising element of the system.

The aim of this paper is to provide empirical evidence on a set of alternative credibility indicators to detect certain main periods in the ERM history. The data employed have a weekly frequency and all ERM currencies are covered by the study. Most of these indicators were developed during the early 1990s and have been applied to various data sets for different currencies and data frequencies, but a comparative analysis has not yet been conducted. This is the major innovation of the paper and to that end we examine the ability of the credibility indicators in detecting exchange rate crisis. In addition, we explore the utility of this approach to other contexts by studying the credibility of the Danish krone and the Greek dracma *vis-à-vis* the euro in the new, modified exchange rate mechanism (the so-called ERM-II).

The structure of the paper is as follows. Section 2 presents the credibility indicators and the empirical results. In Section 3 we carry out a comparison among the credibility indicators used in this study. In Section 4 we extend our analysis to the currencies in the ERM-II. Finally, Section 5 offers some concluding remarks.

2. Measuring credibility

In this section we present the four credibility measures that we have used in this paper. Some of them have been widely employed in empirical literature, while others, like the marginal credibility indicator, have received much less attention.

2.1. Credibility indicators

2.1.1. Svensson's simple test

Svensson (1991) presented a simple test to study the credibility of a target zone exchange rate regime with fluctuation bands. There are two traditional versions of this test. In the first one, it is assumed that there is no arbitrage, while in the second version uncovered interest parity (UIP) is assumed to hold. In order to compare this indicator with the one based on the drift-adjustment method (see subsection 2.1.2), a more recent variant of the former is usually estimated**.**

To that end, we calculate a 100% confidence interval for the expected rate of realignment of the exchange rate under study *vis-à-vis* the German mark, using the three-month interbank rate. Taking into account the UIP hypothesis[1], the expected rate of realignment is bounded according to:

$$i_t - i_t^* - (\bar{x}_t - x_t)/t \leq E_t[\Delta c_{t+t}]/t \leq i_t - i_t^* - (\underline{x}_t - x_t)/t \qquad (1)$$

where x_t is the deviation of the log exchange rate s_t from the log central parity c_t, $\underline{x}_t$ and $\bar{x}_t$ are the lower and upper bounds of the exchange rate bands, τ is the maturity (valued at 3/12 for a 3-month maturity), i-i* is the interest rate differential, and E[·] is the expectation operator.

This more recent version of Svensson's simple test has been criticised because it only takes into account the possibility of realignments in the limits of the band, thus placing excessive weight on credibility. This is one of the reasons why the results obtained with this test might not be completely accurate.

2.1.2. The drift-adjustment method

This method, originally proposed by Bertola and Svensson (1993), computes an econometric estimate of the expectations of economic agents regarding the realignment

[1] Svensson (1992) and Ayuso and Restoy (1992) have estimated risk premia that are insignificant for the currencies in the ERM and, hence, the expected rate of depreciation is closely related to the interest rate differential.

in the ERM. These realignment expectations constitute an inverse measure of credibility. The drift-adjustment method also assumes UIP to hold.

In this method, the expected rate of devaluation g^{τ}_{t} is obtained from:

$$g_t^t = i_t - i_t^* - E_t\left[\Delta x_{t+t} / nr\right] / t \qquad (2)$$

This procedure implies estimating the expected rate of depreciation within the band in absence of realignment (nr) [the last term on the right-hand side of equation (2)], and then computing the expected rate of devaluation g^{τ}_{t}. Once g^{τ}_{t} has been estimated, the corresponding 90 percent confidence intervals can be calculated. These intervals can be directly compared with those of the more recent version of Svensson's simple test.

In this paper we have estimated the expected rate of depreciation within the band using a linear regression model where the exchange rate and the domestic and foreign interest rates are taken as explanatory variables[2]:

$$\frac{x_{t+t} - x_t}{t} = \sum_j a_j d_j + b_1 x_t + b_2 i_t^* + b_3 i_t + e_{t+t} \qquad (3)$$

where x_{t+t} and x_t are the exchange rate (log) deviation from the central parity in period $t+t$ and t, respectively, and where i_t and i_t^* are the national and German three-month interest rates, respectively. The variables d_j denote the dummies for the subperiods between the realignments and the widening of the bands[3]. Following a "general-to-specific" modelling methodology [see, e. g., Hendry (1995)], equation (3) was continuously simplified and re-parametrised until a parsimonious representation of the data generation process was arrived at[4].

The drift-adjustment method has been criticized. In particular, it has been pointed out that the selection of the explanatory variables is *ad hoc*, without an appropriate theoretical framework. Furthermore, the non-stationarity of the exchange rate may generate some problems when the expected rate of variation (Darvas,1998) is estimated. These problems depend on its position within the band. Thus, it is important to be careful when we are interpreting the results obtained from this method.

---

[2] When considering the practical implementation of the drift-adjustment method, the empirical studies that have computed this measure have used different econometric specifications for the expected rate of depreciation within the band. Lindberg *et al*. (1993), Svensson (1993), and Rose and Svensson (1994) have estimated a linear regression model where the exchange rate in $t+t$ depends on its value at moment t (and, in some cases, lagged exchange rates) and on the interest rate differential. On the other hand, Bertola and Svensson (1993) consider x_t as the only explanatory variable, assuming a mean-reverting model for the exchange rate within the band, as in Ayuso *et al*. (1994) and in Gómez and Montalvo (1997).

[3] We have also taken into account the widening of the bands, since this event produced a major change in the ERM, as can be observed in a greater fluctuation of the exchange rates before August 1993.

[4] Svensson (1993) eliminates from the sample the 65 observations corresponding to the three months before a realignment took place, given that he, like us, uses t= 3 months. Given the important reduction in the number of observations implied by this strategy, similarly to Gómez and Montalvo (1997) we use equation (3) to estimate the whole sample. In this way, we are estimating the expected depreciation rate within the band that includes possible jumps in each realignment. Therefore, we obtain the expected rate of realignment, but not the expected devaluation rate g_t^t (which, in addition, includes the expected jump in the exchange rate within the band in the realignments).

2.1.3. Models of discrete choice

This kind of model aims to estimate the probability of realignment by means of econometric techniques. To that end, explanatory variables are used to compute that probability, assuming normal or logistic distributions. Among the explanatory variables, it is usual to include the interest rate differential, the inflation differential, the current account balance, and the unemployment rate, leading to estimates using monthly or quarterly data[5].

We have introduced the exchange rate, the interest rate differential, and two target zone variables, i.e., the distance to the upper fluctuation band and to central parity. The selection of these stems from our interest in the estimation of credibility with high frequency data.

In this paper, we have estimated a logit model based on the following equation:

$$P_t = P(y_t = 1) = \Phi(z'_t d) = \frac{e^{z_t' d}}{1+e^{z_t' d}}; \qquad z_t' d = d_1 + d_2 z_{1t} \tag{4}$$

where $\Phi(\cdot)$ is the logistic distribution function ($\Phi(\lambda)$ is the probability that a normally distributed random variable with zero mean and unit variance does not exceed λ), z_{1t} denotes an explanatory variable, and $P(y_t=0)=1-P_t$. The parameters in equation (4) are estimated by maximising the logarithm of the likelihood function with respect to individual observations:

$$LogL = \sum_{t=1}^{T} y_t \log \Phi(\grave{}z'_t d) + \sum_{t=1}^{T} (1-y_t) \log\left[1-\Phi(\grave{}z'_t d)\right] \tag{5}$$

The drift-adjustment method estimates the 90% confidence interval (section 2.1.2). If both limits of the interval were simultaneously greater than, or less than, zero, the agents would have expected realignments with 90% confidence. Assuming that when $y_t=0$ there is no credibility and that when $y_t=1$ there is credibility, we use the drift-adjustment method to design the logit model. In other words, when $y_t=0$ the limits of the confidence interval for the expected rate of realignment are both simultaneously greater than or less than zero. When $y_t=1$ this does not occur[6]. This strategy allows us to obtain the probability that agents assign to the credibility of the exchange rate regime at each moment of time.

We have used different approaches to estimate the probability that national commitments towards the ERM were credible, defining z_{1t} as the explanatory variable: either the exchange rate, or the distance to the upper fluctuation band, or the distance to the central parity, or the interest rate differential.

---

[5] Edin and Vredin (1993) employ a two-step procedure suggested by Heckman (1976) to calculate both the probability and the expected size of the devaluation. In the first step of the estimation procedure, the probability of devaluation occurring at time *t+1*, based on information available at time *t*, is estimated. In the second step, the unconditional expectation of the rate of devaluation in period t is obtained.

[6] Note that this measure, when formulated in this manner, assigns credibility to any period when the lower bound is negative and the upper bound is positive.

2.1.4. Marginal credibility

This credibility measure proposed by Weber (1991a) focuses on the ability of policy announcements to influence the public's expectations. It measures the impact of official announcements on exchange rates and may be thought of as the weight placed on the announcement when the public forms their expectations. This credibility measure is equal to one if the policy-maker always makes fully credible announcements, and tends to zero as the announcements become non-credible. Marginal credibility (α_t) is defined as:

$$s_t - E_{t-1}[s_t] = \gamma + \alpha_t [c_t - E_{t-1}[s_t]] + u_t \qquad (6)$$

where the expectation operator is conditional on the information available in *t-1*, and u_t is a random disturbance.

A model of the public's expectation forming process is required in order to estimate α_t. We generate the expected exchange rate using the best ARIMA model for each exchange rate[7]. By applying the Kalman filter, α_t can be estimated, and so we obtain a different value of α_t for each moment in the sample period, thereby allowing the study of credibility through the evolution of α_t over time.

As is well known, the Kalman filter is an updating estimation method which bases the regression estimates for each time period on the previous period's estimates plus the data for the current time period (i.e., it bases estimates on data up to and including the current period).

The model estimated is the following:

$$y_t = w_t \beta_t + \varepsilon_t; \qquad \varepsilon_t \sim N(0, \sigma^2 h_t) \qquad (7)$$

$$\beta_t = T\beta_{t-1} + \eta_t; \qquad \eta_t \sim N(0, \sigma^2 \mathrm{Q}_t) \qquad (8)$$

where y_t is a vector of differences s_t-$E_{t-1}(s_t)$, w_t' is a row vector comprising ones and differences c_t - $E_{t-1}(s_t)$. Equation (8) is called the transition equation (which describes the evolution of a set of state variables), whereas equation (7) is the measurement equation (which describes how the data actually observed is generated from the state variables). b_t is the state vector that follows a random walk and T is a 2x2 identity matrix. The initial conditions are established by b_0~$N(b_0, P_0)$, where P_0 is a variance-covariance matrix for the initial conditions. Finally, h_t is the variance of the errors in the measurement equation and Q_t is the variance-covariance matrix for the errors in the transition equation.

The Kalman filter is a recursive method that computes the optimal estimate of the state variables in period *t*, based precisely on the information available in *t*. For each period, we use a conditional maximum likelihood for the information set-up for that period. The logarithm of the likelihood function is defined as follows:

[7] We employ an ARIMA model for its simplicity. On the one hand, the large variety of non-linear models makes it rather difficult to choose the best one and, on the other, previous experience indicates that although a non-linear model could improve on our predictions, the advantages are very limited [see, e. g., Clements and Smith (1999) or García and Gençay (2000)].

$$\log L = -\frac{T}{2}\log 2p - \frac{1}{2}\log s^{2} - \frac{1}{2}\sum_{t=1}^{T}\log f_t - \frac{1}{2}\sum_{t=1}^{T} x_t^{'} f_t x_t \qquad (9)$$

where σ^2 is computed from the recursive residuals, $f_t = w_t^{'} P_{t/t-1} w_t + h_t$ is a scalar, and $x_t = y_t - E_{t-1}[y_t]$

The use of an econometric technique that allows for changes in the values of the parameters over time may be appropriate for the study of credibility in a target zone. These changes in parameters could be explained by stabilising interventions by the central banks, speculative movements by private agents and realignments. In fact, this possibility was pointed out by Weber (1991a, 1991b) before the monetary turmoil of September 1992, and more recently by Darvas (1998).

2.2. Empirical results

The credibility indicators introduced in the previous subsection have been applied to weekly exchange and interest rate data from eight ERM countries (Belgium, Denmark, France, Ireland, Italy, the Netherlands, Portugal and Spain). Data restrictions led us to use weekly data (the highest frequency available). Nevertheless, the use of weekly rates facilitates comparisons with previous studies and avoids problems with the day-of-the week effects in the data. Wednesday spot rates and three-month interbank rates were obtained from the Bank of Spain and the Banco Bilbao Vizcaya Argentaria (BBVA). Given the central role of Germany in the European Union (see, e. g., Bajo-Rubio *et al.*, 2001), our exchange rates are expressed *vis-à-vis* the Deutschmark. The sample period runs from 13 March 1979 to 30 December 1998 (1034 observations), covering the complete EMS history. Figures 1a to 1h show the evolution of the exchange rates under study[8].

[Figures 1a to 1h, here]

The estimates for the indicators are presented in Tables 1 to 4 for each one of the currencies analysed. Regarding the drift-adjustment method, the results of the estimation for the expected rate of depreciation within the band obtained by ordinary least squares (OLS) are shown in Table 1, where the standard errors have been corrected for serial correlation and heteroskedasticity (which results from the "overlapping observations" problem) using a Newey-West covariance estimator. As can be seen, the estimated coefficients for x, i and i^* are clearly significant. The coefficients for x_t are negative, indicating mean-reversion of the exchange rate within the band. The associated t-ratio for these coefficients safely rejects the null hypothesis of a unit root, as in Svensson (1993). With the sole exception of the Dutch guilder, the estimated signs of i and i^* are in accordance with those reported by Svensson (1993) and by Rose and Svensson (1994). Finally, the dummy variables are significant, except those related to the Portuguese escudo, the French franc and the Belgium franc, suggesting the relevance of the different regimes in the history of the ERM.

[Table 1, here]

---

[8] The fluctuation bands were built following Honohan (1979). We took into account the lack of symmetry between the two intervention limits due to the requirement that the upper intervention limit for currency X with respect to currency Y equals the lower intervention limit for currency Y with respect to currency X.

The estimates of the probability of devaluation indicator based on the exchange rate, on the distance to the upper fluctuation band, on the distance to the central parity, and on the interest rate differential, are presented in Table 2. This table shows the results for each one of these four options, while in Table 3 we present the associated summary statistics of their estimated probabilities.

[Tables 2 to 3, here]

As can be seen in these tables, the estimated coefficients are all statistically significant, and the estimated (credibility) probabilities have a mean greater than 0.9, suggesting a subjective probability of realignment of 0.1. Time series of the probability of credibility have been calculated using the estimation results of Table 2. We only plot the results obtained using the interest rate differential with respect to Germany as the explanatory variable[9].

Lastly, the estimation of marginal credibility (α_t) is based on equation (6), where the random disturbance u_t is normal with a zero mean and a constant variance. Table 4 reports the estimation results. The upper panels in that table report OLS estimates of α_t as benchmarks for comparisons.

[Table 4, here]

Next we will discuss, country-by-country, the evidence provided by the various indicators for a given country's exchange rate, and we will compare the identification of crisis periods which the indicators provide with differing degrees of accuracy.

Belgium

The Belgian franc suffered three periods where a temporary crisis of credibility is detected: around its realignments in February 1982 and in April 1986, and after the widening of the ERM fluctuation bands in August 1993. These periods are detected for all indicators (except the Svensson's simple test –Figure2a- that in most of the sample cannot reject the hypothesis that the expected rate of realignment is zero).

The smooth improvement in credibility over time after 1986 is better captured by marginal credibility (Figure 5a), which also indicates more clearly the periods leading to the realignments in 1982 and 1983. For its part, the drift-adjustment method (Figure 3a) and the probability of devaluation (Figure 4a) detect the more general crisis that occurred in February 1990 (around the crisis in asset markets, and before the entry of the Italian lira in the narrow bands).

Denmark

Although its initial phase in the ERM was more unstable, the dynamics of the Danish krone were similar to those described for the Belgian franc. Thus the realignment in January 1987 placed the Danish krone near to parity (with respect to the

[9] Plots of the results obtained using the exchange rate, the distance to the upper fluctuation band, and the distance to the central parity as the explanatory variable are available from the corresponding author upon request.

German mark) at the end of the ERM. Moreover, the widening of the fluctuation band reduced the volatility of the exchange rate only after 1995.

The most critical periods detected by the indicators occurred around the dates of entry of Portugal and Spain in the European Community in October-November 1985, around the devaluations of 1986 and 1987, during the continuous market pressures against the Danish krone registered in December 1992, and when the band was broadened.

The Svensson's simple test in Figure 2b is less informative, and the probability of devaluation only indicates a fall in credibility before the widening of the ERM fluctuation band (see figure 4b). The drift-adjustment method, presented in Figure 3b, shows the pressures faced by the Danish krone during the first quarter of 1995 more clearly. In Figure 5b, marginal credibility clearly detects the continuous gains in credibility achieved by the devaluations in the eighties.

France

The general evolution mentioned above also characterises the French franc. What is more, in most of the sample period the Belgian franc, the Danish Krone and the Irish pound chose the soft currency option supplied by the Banque de France (Weber, 1991).

The main crises in credibility can be observed around the broadening of the band in August 1993 and around the devaluations of June 1982, March 1983, April 1986, and January 1987. Moreover, the French franc also suffered several attacks during the first quarter of 1995 that the drift-adjustment method registered as a greater increase in the expected rate of devaluation than the period around the widening of the band (see Figure 3c). The probability of devaluation presented in Figure 4c, shows the turmoils in the financial markets in January 1988 as a major crisis. Lastly, in Figure 5c, the marginal credibility displays a smoother and continous increase after a more unstable beginning (due to the crises in 1982 and 1983, before the austerity programme that was adopted after de devaluation in March 1983).

Ireland

The dynamics of this exchange rate is similar to the one associated with the currencies mentioned above. In this case, in spite of the broadening of the band the Irish pound presents more irregular behaviour. After the widening of the band we observe a depreciation until March 1996 followed by an appreciation period until March 1998, when the central rate of the Irish pound was revalued upwards by 3 per cent to a level consistent with sustained convergence.

The agents' confidence was reduced in the periods around the realignments of March 1983, August 1986, January 1987, and February 1993. Moreover, the end of 1992 (detected even by the simple test presented in Figure 2d) and the broadening of the fluctuation band are detected as major crisis periods.

As can be observed in Figure 5d, marginal credibility clearly recognizes the importance of the realignment in March 1983, the speculative attacks at the end of 1992 that led to the devaluation in February 1993, and the widening of the band in August 1993. This indicator also detects the stabilizing effect of the revaluation in March 1998. In Figure 3d, the drift-adjustment method clearly displays the crises around the devaluations that occurred in 1986 and 1987. On the contrary, the devaluation probability does not indicate any change in credibility around the critical periods in 1983 and before the realignment in March 1998 (see Figure 4d).

The Netherlands

From 1984 the Dutch guilder/German mark exchange rate moved quite close to its central parity, indicating a high degree of confidence by agents with respect to its evolution inside the band. Indeed the Netherlands chose the hard currency option, pegging its exchange rate to the German mark. This fact permitted it to gain credibility at the beginning of the ERM, and to maintain credibility for the rest of its history in the system.

The probability of devaluation indicator does not detect any reduction in credibility while the marginal credibility and the drift-adjustment method only register instability until mid-1982.

Spain

The Spanish peseta seemed to be the currency suffering the most speculative attacks after its entrance in the ERM in 1989. Contrary to the currencies analysed above, the Spanish peseta/German mark exchange rate was maintained between central parity and its upper limit of appreciation during the first three years in the ERM. In spite of this, the attacks forced two devaluations during the last quarter of 1992, the most dangerous crisis period of the ERM. The widening of the band on 1993 and the devaluation in May 1995 had a stabilizing effect that lasted until the introduction of the euro.

All the indicators reflect lack of credibility around the devaluations of September and November 1992, before the widening of the band, and prior to the realignment in March 1995. In Figure 5h, marginal credibility points out that the realignment in 1995 had its origin in financial market turmoil from June 1994. In addition, the drift-adjustment method estimates expected rates of appreciation between the devaluation in May 1993 and the broadening of the band in August 1993 (see Figure 3h). The probability of devaluation indicator, presented in Figure 4h, shows that after the instability which led to the realignment of March 1995 credibility only improved in March 1996, coinciding with the general elections.

Portugal

As can be observed in Figure 1c, the Portuguese escudo/German mark exchange rate fluctuated around central parity, and the devaluations occurred quite far from the upper band. This seems to indicate that this currency was not devaluated for domestic reasons but rather due to more intense attacks on other currencies of the ERM and the crises in international financial markets [see Ledesma *et al.* (1999b)]..

In spite of this, the credibility indicators detect transitory falls in credibility between September and November of 1992, and in mid-1993. In Figure 4g, the indicator based on the devaluation probability registers a confidence crisis in June 1994 around the time of the crack in international financial markets. The drift-adjustment method, in Figure 3g, provides an increase in the expected rate of devaluation during a small period at the beginning of 1995, and a sudden switch from a positive to a negative expected rate of devaluation between the realignment of May 1993 and the broadening of the fluctuation band in August. The marginal credibility, presented in Figure 5g, shows the relevance of the realignment of November 1992 in order to improve credibility.

Italy

The Italian lira/German mark exchange rate had a clear depreciation trend over time, except at the end of the period in which this currency did not belong to the ERM in 1995. During the eighties the lira was devaluated five times and the speculative attacks of September 1992 caused the suspension of its participation in the ERM. After re-joining ERM this currency moved closer to central parity.

The first period in the ERM was characterized by a low level of credibility until the devaluation of March 1983. The results also suggest that when the Italian lira re-joined ERM it experienced higher credibility levels than before it left. As can be seen in Figure 4f, the probability of devaluation indicator is less informative with a constant evolution along time. The marginal credibility provides some evidence of credibility gains for the Italian lira just before leaving the ERM as in Fernández-Rodríguez *et al.* (2003) .

3. Comparison among indicators

The primary purpose of this section is to explore the differences among the indicators studied in the previous section. To that end, and given that there does not exist an observed credibility time series to assess the ability of each indicator to mimic such a series, we consider two alternative approaches. Firstly, we assume that market participants observe the indicators and evaluate them in the light of their mean and variance, as these summary statistics constitute a good approximation to the level and the volatility in each indicator. Secondly, we consider that economic agents use some procedure to extract signals of such indicators in order to continually re-evaluate the exchange rate commitments. In both cases we try to assess the ability of each indicator to identify the main periods of speculative attacks and realignments in the ERM.

3.1. Analysing the mean and the variance

Here we present a simple graphical method in order to obtain a first approximation of the degree of efficiency associated with each credibility indicator. We have studied the changes of the first and second order moments prior to the main events of the sample period. In particular, for each indicator and for each exchange rate, we use information on location (mean) and spread (volatility) to assess its behaviour in the month prior to the main events: the realignments and the broadening of the bands (August 1993)[10].

Once we calculated the mean and the standard deviation for the whole period, as well as for the different subperiods before events, we measured the percentage changes between the values for each one of these subperiods and the corresponding values for the complete period. Then, we placed the six[11] indicators from the greatest to the smallest degree of detection of the selected events (i.e., from the greatest to the smallest percentage difference between the subperiods and the whole period). In this way, we assigned scores from 1 to 6 according to the place occupied by each measure in each event detected. For each exchange rate and each event, we have six scores, one for each indicator, corresponding to the changes in mean and six from the changes in standard deviation.

In Figure 6 for each one of the six indicators under study, we have considered the mean and the standard deviation separately. We have added the mean scores and the standard deviation scores across events and exchange rates. Therefore, the closer is the position of an indicator to the origin, the better is its ability to predict the events during the month before. As can be seen, the closest position to the origin (96, 147) corresponds to marginal credibility. This indicator seems to be the most accurate in predicting the events selected (i.e., the realignments of each exchange rate and the broadening of the bands). Marginal credibility presents a better balance between changes in mean and changes in standard deviation in the detection of events.

The crisis probability indicator, based on the exchange rate, for both mean and standard deviation has a worse position (96, 160) than marginal credibility due to a lower degree of detection in terms of the mean. The relative merits of the exchange rate could be explained if the level and the changes of this variable were closely followed by agents in the foreign exchange markets. The drift-adjustment method (238, 44) seems to be the best indicator with respect to the changes in the mean, but it is the worst one with respect to volatility. It is surprising that the indicators based on the existence of a target zone do not provide the best predictions. The credibility indicators based on the distances to the upper band and to central parity might have lost their relevance due to the great length of the period following the widening of the bands until December 1998. The great width of the fluctuation bands may have diminished the ability of these variables to capture the main events[12].

[Figure 6, here]

---

[10] The choice of a subperiod prior to each one of the selected events tries to capture the predictive quality of the different measures. Nevertheless, it must be pointed out that we are not taking into account the number of events registered by each indicator; this last element could have been an alternative criteria in order to carry out the comparison.

[11] Svensson's simple test was eliminated due to its sensitivity to the size of the fluctuation band.

[12] We have also used Data Envelopment Analysis (DEA) to compare the credibility indicators by simultaneously examining the variation in mean and in standard deviation in all the realignments in the history of the ERM and in the broadening of the bands (August 1993). The results, not shown here but available from the authors upon request, support those obtained from the simple graphic comparison.

3.2. Extracting signals

In our second approach, we consider that market participants make use of some procedure to extract signals of the credibility indicators, allowing them to dynamically revise their perception with respect to the commitment to maintain the exchange rate around a central parity. In this sense, and given the relevance of technical analysis in foreign exchange markets[13], it might seem natural to assume that market participants use moving averages (MA) to infer the likely course of future movements in the credibility indicators from its behaviour in the past. Indeed, a considerable amount of work has provided support for the view that technical trading rules are capable of producing valuable economic signals in foreign exchange markets [see, Dooley and Shafer (1983), Taylor (1992) and Levich and Thomas (1993), among others].

Private agents in financial markets use a variety of tools in order to capture the trends of the series. Drawing from previous academic studies and the technical analysis literature, in this paper we employ the simplest and most common trading rules (MA) as the signal-extraction procedure used by market practitioners, since empirical evidence suggests that they are able to create successful dynamic trading strategies. Alternatively, this signal-extraction procedure can be thought of as the mechanism used by the central banks in order to learn the perceptions of agents with respect to their commitment regarding the target zone. The signal is defined as

$$z_t = \frac{1}{n_1}\sum_{i=0}^{n_1-1} I_{t-i} - \frac{1}{n_2}\sum_{i=0}^{n_2-1} I_{t-i}$$

where I_t is a credibility indicator and n_1 (n_2) denotes the number of observations included in the short (long) window of the moving average signal. This procedure is assumed to capture the instantaneous momentum in the credibility indicator by comparing the average performance of the indicator over a short period with that over a longer period. Therefore, based on this signal, for each indicator and currency we construct a binary variable. Whenever the signal is positive, the credibility indicator would increase and a value 1 is assigned to that signal. Conversely, when it is negative, we would expect a reduction in the credibility indicator and a value 0 is assigned to that date[14].

In order to mitigate the danger of "data snooping" biases, we do not search for ex-post "successful" MA rules, but rather evaluate a wide set of rules that have been known to practitioners for at least several decades. In particular, we evaluate the following popular moving average rules: [1,4], [1,8], [1, 12], [1, 16] and [1,20], where the first number in each pair indicates the days in the short period (n_1) and the second number shows the days in the long period (n_2)[15].

---

[13] For example, Allen and Taylor (1990) and Taylor and Allen (1992) report that over 90% of participants in the London market rely on technical strategies when formulating short-term exchange-rate expectations.

[14] As can be seen, the moving average rule is essentially a trend following system because when prices are rising (falling), the short-period average tends to have larger (lower) values than the long-period average, signalling an increase (a reduction) in the credibility indicator.

[15] These MA rules are roughly the weekly equivalent to the daily rules examined by LeBaron (1992) and Levich and Thomas (1993) to show the statistical significance of the technical trading rules against several parametric null models of exchange rates.

For the indicators obtained from the models of discrete choice and marginal credibility, a reduction indicates a loss of credibility, whereas an increase can be interpreted as a credibility gain. Therefore, in this case we take a transition from a value 0 to a value 1 as a "realignment" (R) signal, while we interpret the change from 1 to 0 as a "no realignment" (NR) signal. The opposite is true for the indicators derived from the drift-adjustment method, since in this case an increase (decrease) in the indicator suggests credibility losses (gains). It should be noticed that there is a connection between our approach and the literature that models the exchange rates of the EMS as switching between two distributions [one that holds in stable times and the other that holds in volatile times [see Engel and Hakkio (1996)]. Indeed, the plots from the signals derived from our approach are very similar to the smoothed probabilities of being in different regimes implied by regime-switching models.

Following this procedure, and for each indicator and currency, we can classify each week in the sample as being either R or NR and therefore we can compare this classification with the realignments really observed. Table 5 reports the ratio of successfully identified cases, expressed in percentage terms, when identifying a particular week in the sample as R or NR.

[Tables 5, here]

As can be seen, the marginal credibility clearly outperforms the rest of indicators regardless of the MA we consider for extracting signals, except for the IRL where the DAM indicator yields the highest success ratio. These results suggest that the marginal credibility should be our preferred indicator[16]. The second best indicator is the probability of realignment based on the distance of the exchange rate to central parity (L4), except for the BFR where the DAM indicator is ranked in second place. These results could indicate the relevance of maintaining the exchange rate near to central parity in order to avoid system instability, as suggested by Bertola and Caballero (1992). Finally, note also that the success ratio increases in all cases with the days in the long period in the MA rule.

As a further comparison among indicators, we explore their behaviour in terms of efficiency by the application of DEA methods. Data Envelopment Analysis (DEA) allows the use of linear programming methods to construct a non-parametric piecewise surface over the indicators and the currencies.

The DEA method allows an efficient frontier to be achieved. We are interested in obtaining the maximum outputs by minimising the quantity of inputs. We have to solve this input-orientated linear programming problem[17]:

[16] We have also computed Fisher´s exact test that gives the probability of observing a table with as much evidence of association as the table actually observed (under the null of no association). The results from this test (not shown here but available from the authors upon request) also favour the marginal credibility indicator, since in general it yields the probability that is closest to 0, suggesting that the classification of R derived from this indicator is perfectly associated with the observed realignments

[17] A comprehensive description of these methods can be found in Seiford and Thrall (1990). In this paper we have used the DEAP 2.1.

$$
\begin{aligned}
&\min_{q,l}\ q_i \\
&subject\ \ to - y_i + Yl \geq 0 \\
&\qquad q_i x_i - Xl \geq 0 \\
&\qquad N1'\, l = 1 \\
&\qquad l \geq 0
\end{aligned}
$$

where q_i is the scalar that measures the degree of efficiency of each indicator, as proposed by Farrell (1957). A value of 1 tells us that this indicator is on the frontier (i.e., it is efficient, while a value less than 1 shows that is inefficient, where 1-*q* is the percentage in which inputs could be reduced in order to reach efficiency). l is a *Nx1* vector of parameters which allows us to obtain a fictitious and efficient credibility indicator from the observations. *X* is a *KxN* input matrix, and *Y* is a *MxN* output matrix, where *K* is the number of inputs, *M* is the number of outputs, and *N* is the number of indicators. x_i and y_i represent the vector of inputs and the vector of outputs associated to the *i*-th indicator, respectively. *N1'* is an Nx1 vector of ones. The first restriction fixes the output while the second one is an indication of the need to minimise the inputs used. The third restriction permits a variable returns to scale approach.

In particular, we use an input-oriented DEA method in which we have five inputs, each one being the average error associated with the use of each one of the five MA rules that we have analysed. Following a simplification similar to Cooper *et al*. (2000, p. 173), we can define an output with the value 1, since in our problem we have only five inputs: the average errors from each MA rule. Therefore, we have 42 elements generated by the six indicators and the seven currencies. The results are presented in Table 6.

[Table 6, here]

As can be observed, in four out of the five cases considered, the highest values of the efficiency parameter are those obtained for marginal credibility, the exception being again the IRL. Moreover, for three currencies (BFR, DKR and ESC) the marginal credibility indicator yields the maximum level of efficiency (i.e., a value of 1). These results reinforce our previous conclusion that marginal credibility is the best indicator in order to capture true signals of realignments and that it does not convey false signals. As before, the probability of realignment based on the distance of the exchange rate to central parity appears to be the second best indicator, since it returns satisfactory levels of efficiency (although always under 0.5).

As shown in Ledesma-Rodríguez *et al.* (1999a, 2000), daily data confirm the relevance of marginal credibility, and also point to a further advantage with respect to the rest of the credibility measures when the objective is to detect the main realignments that occurred during the sample period. This fact could be related to the capability of the marginal credibility indicator in capturing the volatility of the series. When using daily data, the information is processed more efficiently, avoiding the smoothing of the volatility curve when the frequency is reduced to the weekly level.

4. ERM-II

With the beginning of Economic and Monetary Union (EMU), the former EMS ceased to have effect. It was replaced by the new ERM-II. Under this mechanism, the four member states that did not introduce the euro for the time being were given the chance to prepare themselves for full incorporation in the euro area. Denmark and Greece took advantage of this option from 1st January 1999, while Sweden and the United Kingdom have stayed outside. Central and intervention rates are all defined in terms of the euro. A fluctuation margin of ±2.25% was set for the DKR and a standard margin of ±15% was agreed for the Greek dracma (GRD). Participation in the ERM-II is in principle voluntary, but it is a prerequisite for introducing the euro at a later stage.

The objective of ERM-II has been to ensure exchange-rate stability between the euro area and the EU members who have not introduced the single currency, adding another element of stability to the process of European integration. The ERM-II is also likely to be significant in the light of the enlargement of the EU to include a number of countries in central and eastern Europe. Once these countries have joined the EU, they will need to adjust their currencies to the euro by participating in the ERM-II.

On 19 June 2000, the EU Council, having assessed that Greece fulfilled the requirements of the Treaty, approved its accession to the euro area as a twelfth member from 1 January 2001. On the same day, the Council also decided that the conversion rate between the GRD and the euro should be equal to the dracma's central rate in the ERM-II. The convergence of the GRD towards its central rate was facilitated by a 3.5% revaluation of its central rate on 17 January 2000. Given that on 28 September 2000 a majority of the Danish electorate rejected the adoption of the euro, the Danish krone is the only currency currently participating in the ERM-II.

In this section we examine the ERM-II covering a period from January 1st 1999 to January 1st 2001 for the GRD and from January 1st 1999 to September 30th 2002 for the DKR. We study the credibility of both exchange rates *vis-à-vis* the Euro. The estimates for the different indicators are shown in Tables 7a-7d.

[Tables 7a-7d., here]

As can be seen in Table 7a, the variables used in the estimation of the expected rate of depreciation within the band (for the Drift-Adjustment Method) are significant and the signs of the parameters are those expected, except for those associated with the Danish interest rate. With respect to the devaluation probability, as can be seen in Table 7b, the estimated coefficients are all statistically significant. Again the estimated (credibility) probabilities for the GRD have a mean that is greater than 0.88, suggesting a subjective probability of realignment of 0.12. The Danish krone presents greater fluctuation due to the instability on 28 September 2000, when the majority of Danish voters rejected the adoption of the euro in a referendum. Lastly, the estimation of marginal credibility (α_t) is based on equation (6), where the random disturbance u_t is normal with a zero mean and constant variance. Table 7d reports the estimation results. The upper panel in that table shows OLS estimates of α_t as a benchmark for comparisons.

Danish krone

Danmarks Nationalbank chose to stabilise the DKR close to the central rate, as is shown in Figure 7. In spite of this, the indicators point out unstability in the run-up and the aftermath of the Danish rejection of the adoption of the euro on 28 September 2000. Indeed, these pressures were countered by foreign exchange interventions and key interest rate changes. The Drift-Adjustment Method, presented in Figure 7c, indicates a small expected rate of depreciation in July and September of 2000. In fact, Denmark's Nationalbank intervened in the markets in September 2000, purchasing foreign exchange to dampen an appreciation in the DKR.. The probability of realignment based on the interest rate differential detects this event more clearly from June to October of 2000, as well as in January 2001.

The Danish status in the EMU seems to be due to non-economic reasons, since the behaviour of its fundamentals would permit its accession to the euro as captured by the credibility indicators.

Greek dracma

Greece chose a ±15% fluctuation band in its two-year history in the ERM-II. As can be observed in Figure 8a, the GRD was perceived to enter the ERM-II with an undervaluated central parity in order to avoid speculative attacks. In this sense, the revaluation of January 2000 brought this exchange rate nearer to its central parity. In spite of this, the Drift-Adjustment Method (Figure 8c) and the probability of devaluation (Figure 8d) detect instability only around the realignment. The marginal credibility shows a slow reduction in credibility that only stops after the realignment of the GRD.

5. Concluding remarks

In this paper we have provided some new evidence on the credibility of the ERM. We differ from previous studies in the literature in four main respects. First, our main contribution is the use of several credibility indicators, some of which have never been applied before to all of the currencies under study. This allows us to strengthen the results obtained in this paper. Second, we analyse a longer period than that of previous studies, covering the complete EMS history. Third, we have carried out a comparison of the prediction qualities of the different indicators, in order to explore their ability to capture the main ERM events (realignments, changes in the fluctuations bands and speculative pressures). Fourth, we apply the indicators to the experience of the ERM-II, showing the relevance of this approach in the near future with the enlargement of the EU.

The country-by-country analysis made in this paper shows: (i) before the currency crisis in late 1992, for most of the countries, the exchange rate policy was credible, except for the Italian case (a similar conclusion is derived in Weber, 1991a); (ii) the 1992 currency turbulence was accompanied, in the first instance, by credibility losses in all countries, except Belgium and the Netherlands. This is consistent with the fact that the Dutch guilder and the Belgian franc, along with the Deutschmark, were the only currencies that were not affected by speculative attacks during the fall of 1992; (iii) after the widening of the fluctuation bands there was a gain in credibility for the currencies participating in the ERM, with the exception of the Belgian franc and the Irish pound. This is consistent with, and tends to confirm, the claims by both Ayuso *et al.* (1994) and Sosvilla-Rivero *et al.* (1999) that the broadening of the bands led to a decrease in volatility to levels comparable to those prevailing before the crisis.

Our results are consistent with the evolution of the nature of the EMS (see, e. g. De Grauwe, 2000). First, the relatively large fluctuation bands in the EMS (compared to those in the Bretton Woods system), together with relatively small and frequent realignments, helped to reduce the size of speculative capital movements and stabilised the system during the 1980s. In the early 1990s, however, the evolution of the EMS into a truly fixed exchange rate system with almost perfect capital mobility led to credibility losses in a context of policy conflict among EMS countries about how to face the severe recession experienced in 1992-93. Finally, after the crisis of 1993, the EMS changed its nature in drastic ways. The EMS gained credibility with the enlargement of the fluctuation bands to ±15% (reducing the scope for large speculative gains) and with the fixed exchange rate commitment among potential EMU-member countries. As a result, speculation became a stabilising factor and the market rates converged closer and closer to the fixed conversion rates, although the world was hit by a major crisis during the second half of 1998 (De Grauwe *et al.*, 1999).

We have also compared indicators according to their ability to detect the main events in the history of the ERM. The results suggest that marginal credibility is the best indicator in order to capture true signals of realignments and not to convey false signals. This could be due to the fact that this is an indicator that recognises the changing nature of central parities, the width of the bands and the realignment expectations in the history of the ERM. The probability of realignment based on the distance of the exchange rate to central parity comes in the second place in our comparative exercise.

We consider that our results are of interest, not only for the European experience in the 1979-1998 period, but also for the analysis of other possible target zones, such as the new ERM (ERM II), linking the currencies of non-euro area Member States to the euro, both current European Union Member States and future candidates (see ECOFIN, 2000). The EMS experience suggests that such an exchange rate system can only work within the framework of a temporary regime towards a full monetary union, since it is too fragile as a permanent monetary regime. The 1979-1998 period has shown us that the ERM-II could face similar problems to those experienced by the EMS during 1992-1993 (i.e., that if the prospect for a quick entry of the "out" members are weak, there could be speculative crises and a possible collapse of the arrangement). Therefore, participation in the ERM-II and future euro adoption could serve as a powerful anchor for economic, monetary and exchange rate policies in accession countries (guiding policy-makers as well as market participants), whenever the achievements in the areas of macroeconomic stabilisation and structural reforms would support the convergence process within the EU. Indeed, the ERM-II must be judged in the light of the planned EU enlargement once it is put to a test.

References

Allen, H. and M. P. Taylor (1990). Charts, noise and fundamentals in the London foreign exchange market. *Economic Journal* 100: 49-59.

Ayuso, J., Pérez-Jurado, M. and F. Restoy (1994). Is exchange rate risk higher in the ERM after the widening of fluctuation bands? Documento de Trabajo 9419, Banco de España, Madrid.

Ayuso, J. and F. Restoy (1992). Eficiencia y primas de riesgo en el euromercado de depósitos. Documento de Trabajo 9225, Banco de España, Madrid.

Bajo-Rubio, O., Sosvilla-Rivero, S. and F. Fernández-Rodríguez (2001). Asymmetry in the EMS: New evidence based on non-linear forecasts. *European Economic Review* 45: 451-473.

Bertola, G. and R.J. Caballero (1992). Target zones and realignments. *American Economic Review* 82: 520-536.

Bertola, G. and L.E.O. Svensson (1993). Stochastic devaluation risk and the empirical fit of target zone models. *Review of Economic Studies* 60: 689-712.

Clements, M. and J. Smith (1999). A Monte Carlo study of the forecasting perfomance of empirical SETAR models. *Journal of Applied Econometrics* 14: 123-141.

Cooper, W.W., Seiford L.M. and K. Tone (2000). *Data envelopment analysis: A comprehensive text with models, applications, references and DEA-solver software*. Boston Kluwer Academic Publishers.

Darvas, Z. (1998). Spurious correlation in exchange rate target zone modelling: Testing the drift-adjustment method on the US dollar, random Walk and chaos. CEPR Discussion Paper No. 1890. Centre for Economic Policy Research, London.

De Grauwe, P. (2000). *Economics of monetary union*, Fourth edition. Oxford: Oxford University Press.

De Grauwe, P., Dewachter, H. and D. Veestraeten (1999). Explaining recent European exchange-rate stability. *International Finance* 2: 1-31.

Dooley, M. P. and J. Shafer (1983). Analysis of short-run exchange rate behaviour: March 1973 to November 1981. In: D. Bigman and T. Taya (eds.), *Exchange rate and trade instability: Causes, consequences and remedies.* Cambridge: Ballinger.

ECOFIN (2000). Questions relating to the applicant countries' economic stability and exchange rate strategy: Conclusions, 2283rd Council meeting, Brussels, July 17 (available at http://ue.eu.int/newsroom/main.cfm1).

Edin, P.-A. and A. Vredin (1993). Devaluation risk in target zones: Evidence from the nordic countries. *Economic Journal* 103: 161-175.

Engel, C. and C. S. Hakkio (1996). The distribution of the exchange rate in the EMS. *International Journal of Finance and Economics* 1: 55-67.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of Royal Statistical Society*, Series A, General, 120: 253-281.

Fernández-Rodríguez, F., Sosvilla-Rivero, S. and J. Martín-González (2003). Credibility in the EMS: New evidence using nonlinear forecastability tests. *European Journal of Finance* 9: 146-168.

García, R. and R. Gençay (2000). Pricing and hedging derivative securities with neural networks and a homogeneity hint. *Journal of Econometrics* 94: 93-115.

Gómez, M. and J.G. Montalvo (1997). A new indicator to assess the credibility of the EMS. *European Economic Review* 41: 1511-1535.

Heckman, J. (1976). The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. *Annals of Economic and Social Measurement* 5: 475-492.

Hendry, D. F. (1995). *Dynamic Econometrics*. Oxford: Oxford University Press.

Honohan, P. (1979). A guide to the arithmetic of the EMS exchange-rate mechanism. *Central Bank of Ireland Quarterly Bulletin*, Autumn.

Kempa, B. and M. Nelles (1999). The theory of exchange rate target zones. *Journal of Economic Surveys* 13: 173-210.

Krugman, P.R. (1991). Target zones and exchange rate dynamics. *Quarterly Journal of Economics* 106: 669-682.

LeBaron, B. (1992). Do moving average rule results imply nonlinearities in foreign exchange markets? SSRI Working Paper No. 9222, University of Wisconsin-Madison.

Ledesma-Rodríguez, F., Navarro-Ibañez, M., Pérez-Rodríguez, J. and S. Sosvilla-Rivero (1999a). Una aproximación a la credibilidad de la peseta en el Sistema Monetario Europeo. *Moneda y Crédito* 209: 195-230.

Ledesma-Rodríguez, F., Navarro-Ibañez, M., Pérez-Rodríguez, J. and S. Sosvilla-Rivero (1999b). Una aproximación a la credibilidad del escudo en el Sistema Monetario Europeo. *Economia* 23: 69-95.

Ledesma-Rodríguez, F., Navarro-Ibañez, M., Pérez-Rodríguez, J. and S. Sosvilla-Rivero (2000). On the credibility of the Irish pound in the EMS. *Economic and Social Review* 31: 151-172.

Levich, R. and L. Thomas (1993). The significance of technical trading rule profits in the foreign exchange market: A bootstrap approach. *Journal of International Money and Finance* 12: 451-474.

Lindberg, H., Söderlind, P. and L.E.O. Svensson (1993). Devaluation expectations: The Swedish krona 1985-92. *Economic Journal* 103: 1170-1179.

Rose, A.K. and L.E.O. Svensson (1994). European exchange rate credibility before the fall. *European Economic Review* 38: 1185-1216.

Seiford, L.M. and R.M. Thrall (1990). Recent developments in DEA: The mathematical approach to frontier analysis. *Journal of Econometrics* 46: 7-38.

Sosvilla-Rivero, S., Fernández-Rodríguez, F. and O. Bajo-Rubio (1999). Exchange rate volatility in the EMS before and after the fall. *Applied Economics Letters* 6: 717-722.

Svensson, L.E.O. (1991). The simplest test of target zone credibility. *IMF Staff Papers* 38: 655-665.

Svensson, L.E.O. (1992). The foreign exchange risk premium in a target zone with devaluation risk. *Journal of International Economics* 33: 21-40.

Svensson, L.E.O. (1993). Assessing target zone credibility: Mean reversion and devaluation expectations in the ERM, 1979-1992. *European Economic Review* 37: 763-802.

Taylor, S. J. (1992). Rewards available to currency future speculators: Compensation for risk or evidence of inefficient pricing? *Economic Record* 68: 105-116

Taylor, M. P. and H. Allen (1992). The use of technical analysis in the foreign exchange market, *Journal of International Money and Finance* 11: 304-314.

Weber, A. (1991a). EMS credibility. *Economic Policy* 12: 58-102.

Weber, A. (1991b). Stochastic process switching and intervention in exchange rate target zones: Empirical evidence from the EMS. CEPR Discussion Paper No. 554. Centre for Economic Policy Research, London.

Fig 1a: BFR/DM exchange rate
(including ERM intervention limits)

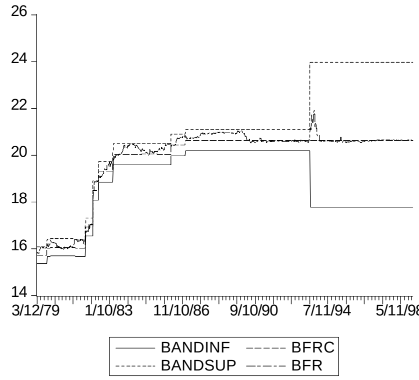


Fig 1b: DRK/DM exchange rate
(including ERM intervention limits)

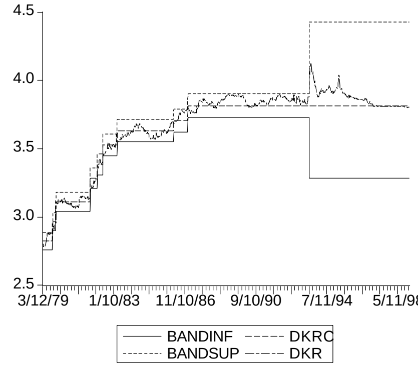


Fig 1c: ESC/DM exchange rate
(including ERM intervention limits)

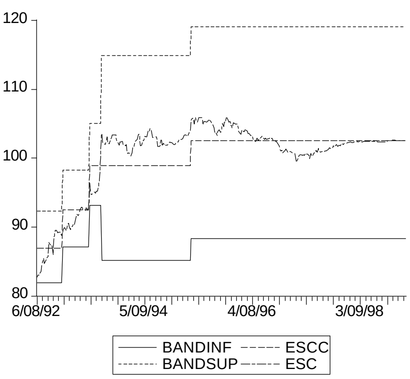


Fig 1d: FF/DM exchange rate
(including ERM intervention limits)

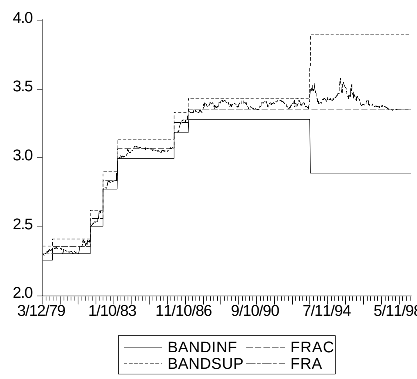


Fig 1e: HFL/DM exchange rate
(including ERM intervention limits)

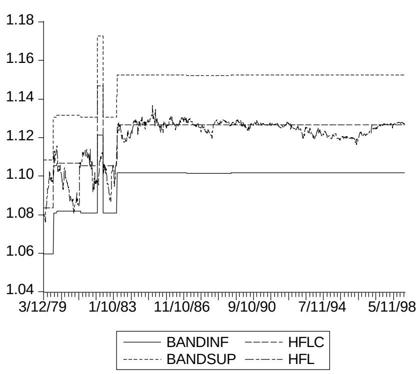


Fig 1f: IRL/DM exchange rate
(including ERM intervention limits)

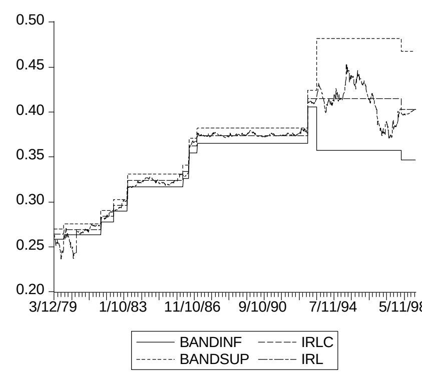


Fig 1g: ITL/DM exchange rate
(including ERM intervention limits)

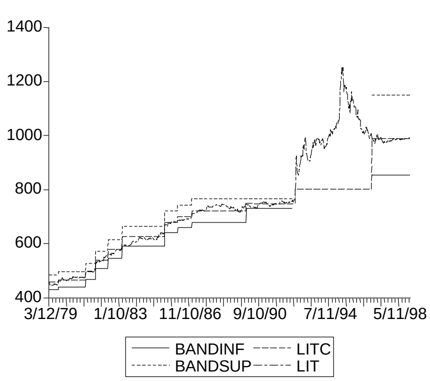


Fig 1h: PTA/DM exchange rate
(including ERM intervention limits)

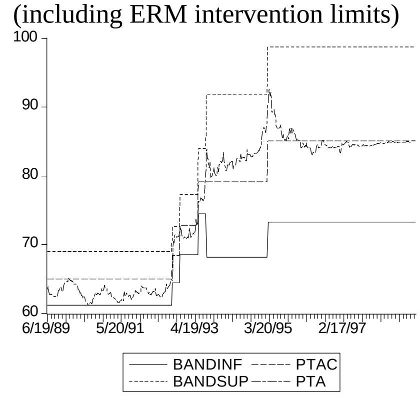
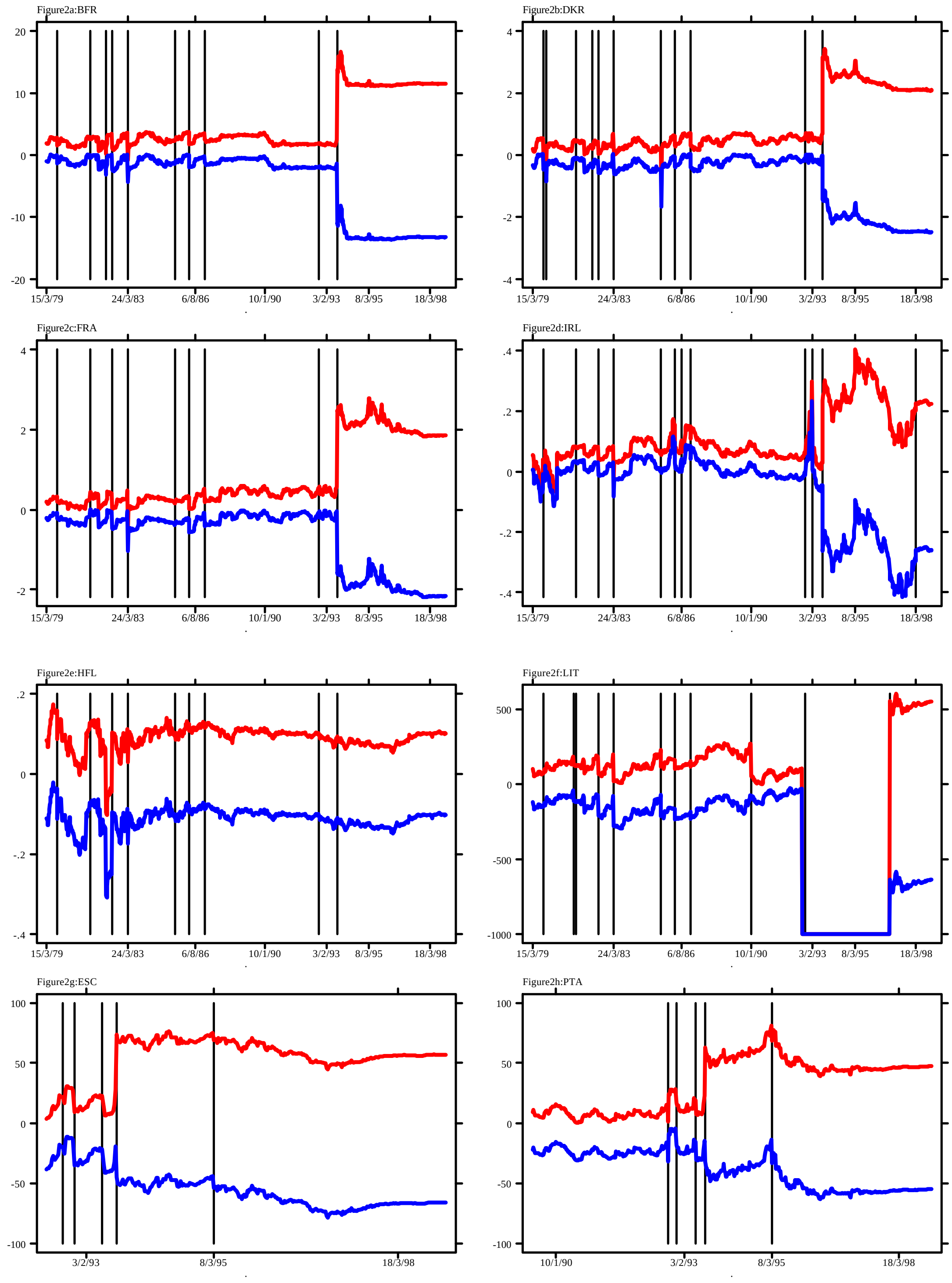


Figure 2: Maximum and Minimum Expected Rates of Realignment

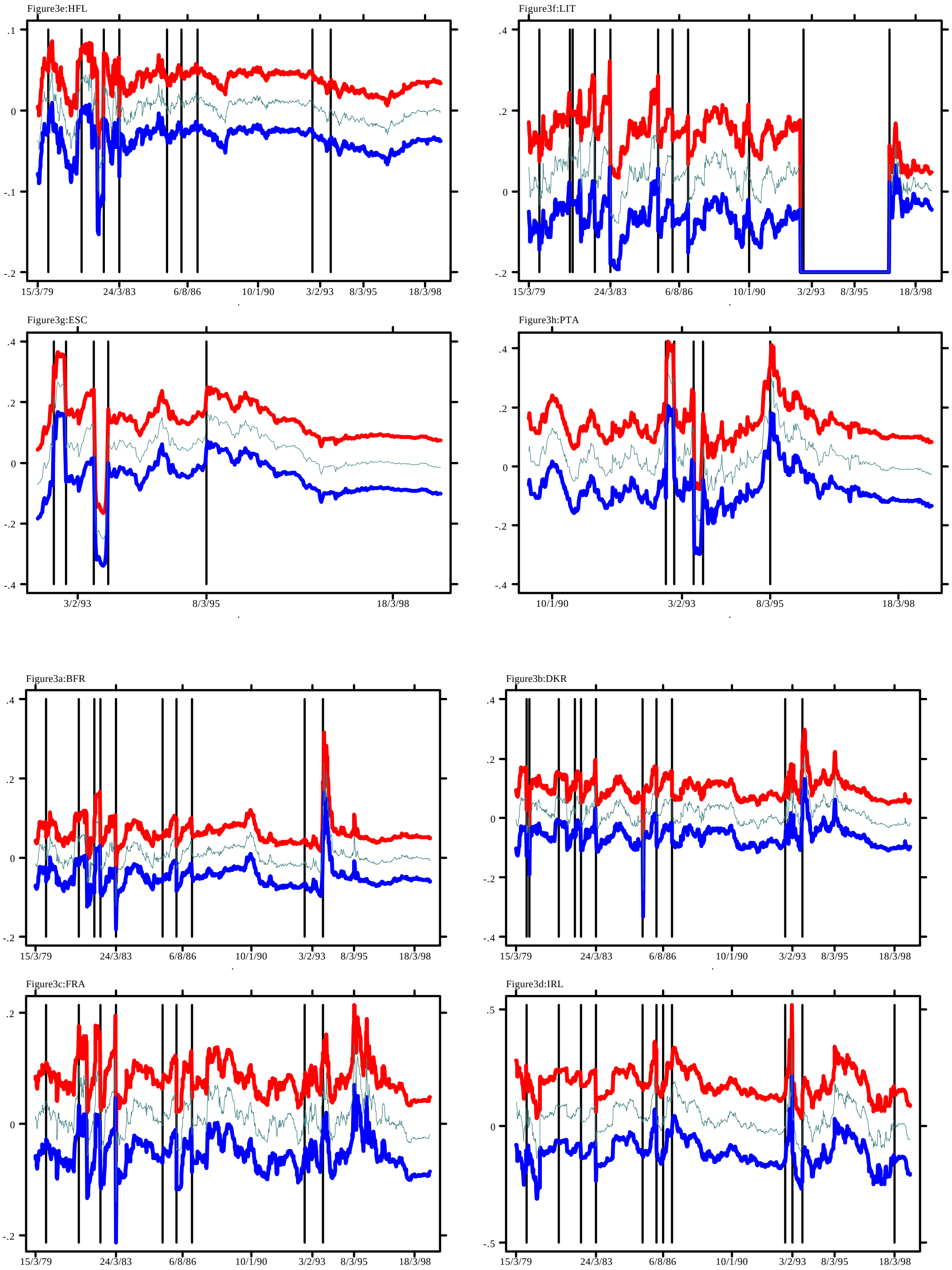


Notes: Blue line = minimum expected rate of realignment, based on Svensson's simple test.

Red line = maximum expected rate of realingnment, based on Svensson's simple test.

Vertical lines = actual ERM realignments and broadening of fluctuation bands.

Figure 3: Expected Rate of Realignment



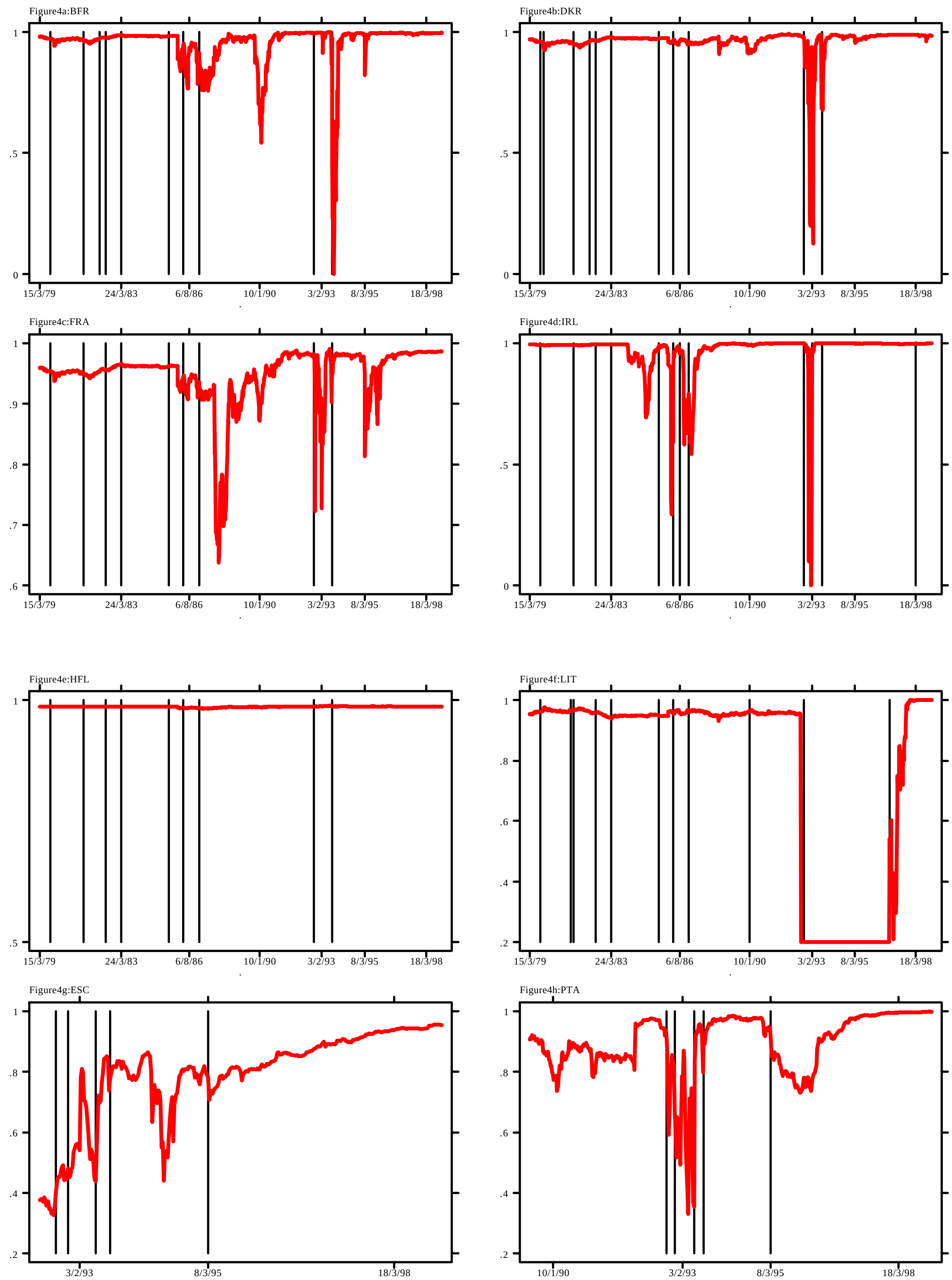
Notes: Green line = expected realignment rate, based on estimation results in Table 2.

Red line = 90 per cent confidence interval's upper limit.

Blue lien = 90 per cent confidence interval's lower limit

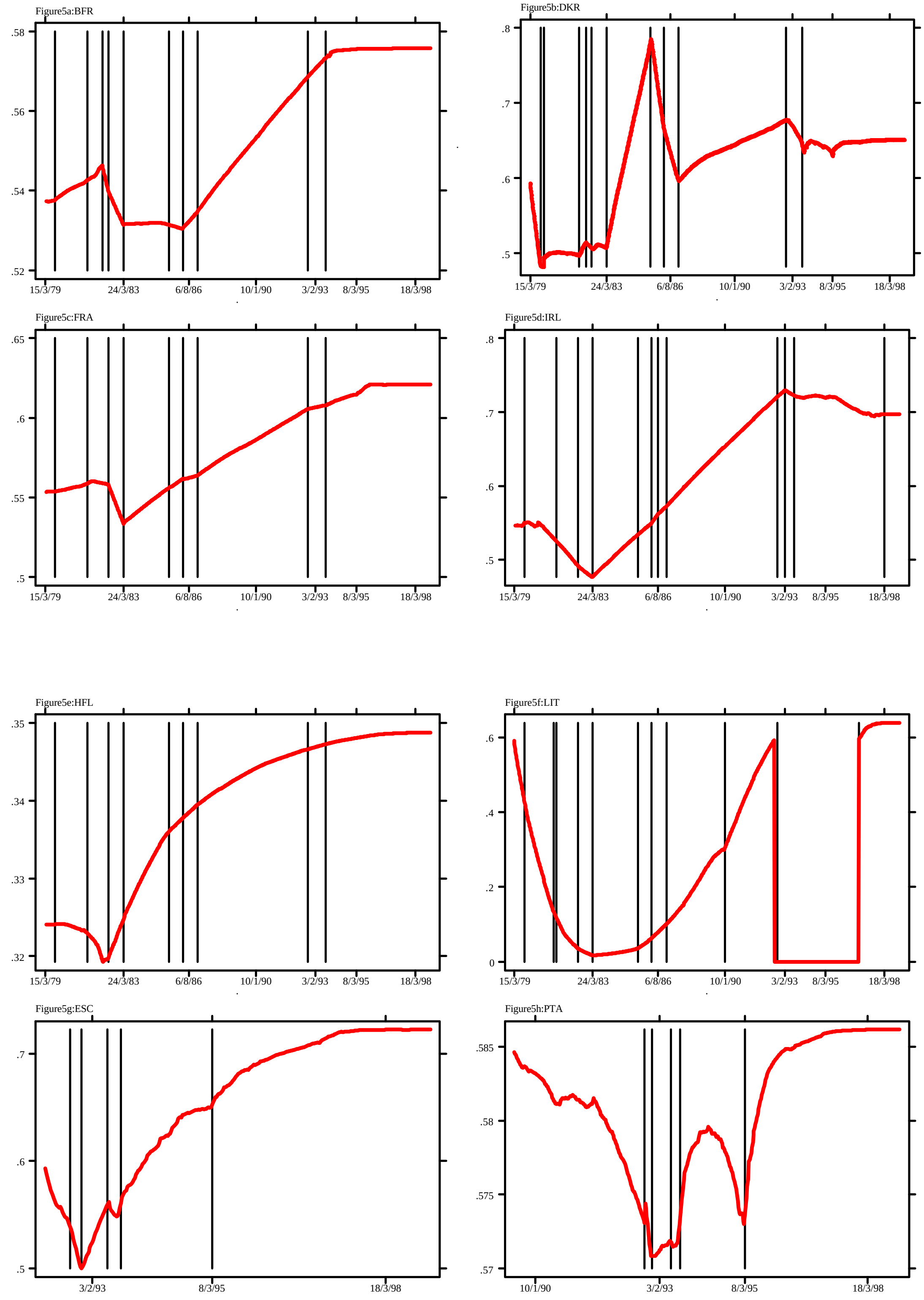
Vertical lines = actual ERM realignments and broadening of fluctuation bands.

Figure 4: Estimated Devaluation Probabilities



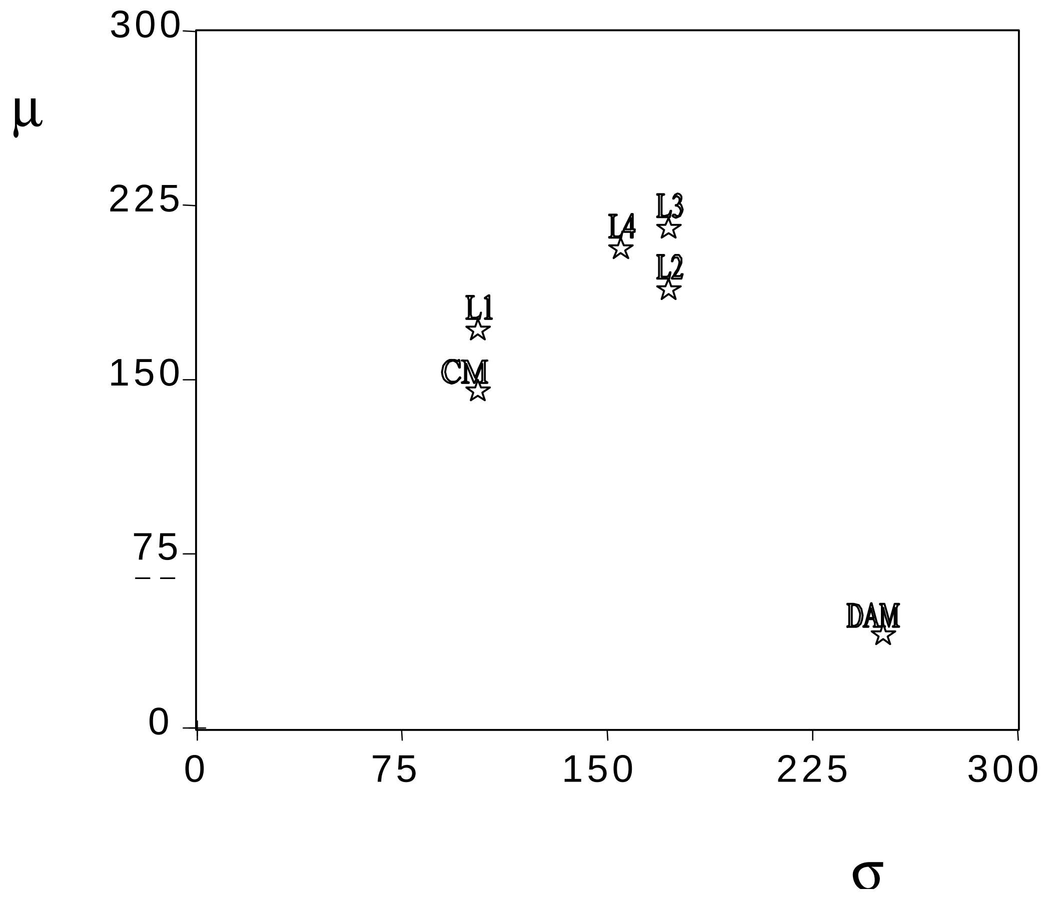
Notes: Inverse of devaluation probabilities, based on estimation results in Table 3, column 5. Vertical lines = actual ERM realignments and broadening of fluctuation bands.

Figure 5: Marginal Credibility



Notes: Credibility indicator based on estimation results in Table 5.
Vertical lines = actual ERM realignments and broadening of fluctuation bands.

Figure 6.- Comparison among indicators
in μ (order in changes of mean) and in σ (order in changes of standard deviation)



Note: DAM=Drift-adjustment method, L1=crisis probability from the exchange rate, L2=crisis probability from central parity distance, L3= crisis probability from upper band distance, L4=crisis probability from the interest rate differential, and MC=Marginal Credibility.

Figure 7. Credibility indicators for the DKR in the ERM-II

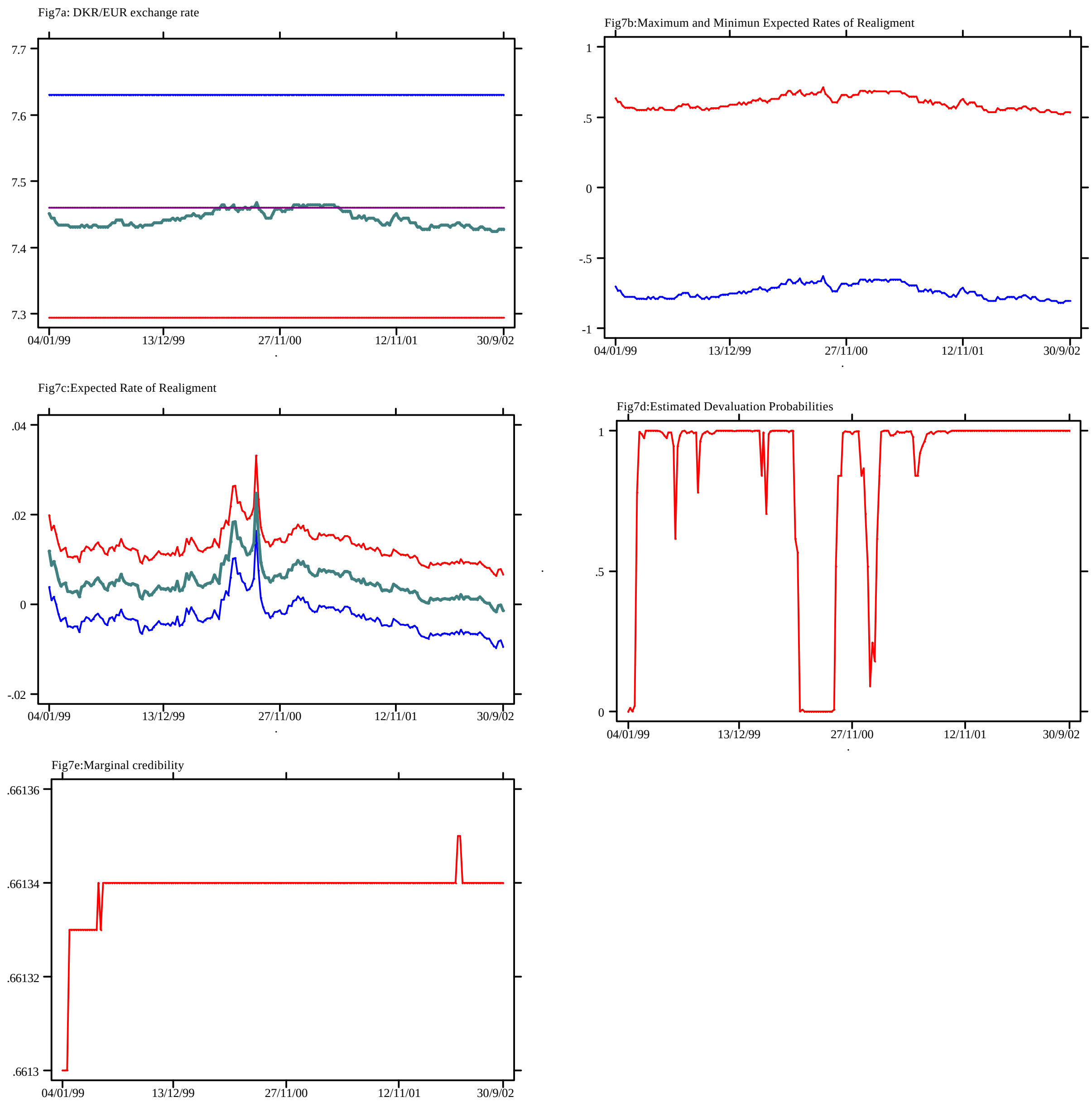


Figure 7. Credibility indicators for the GRD in the ERM-II

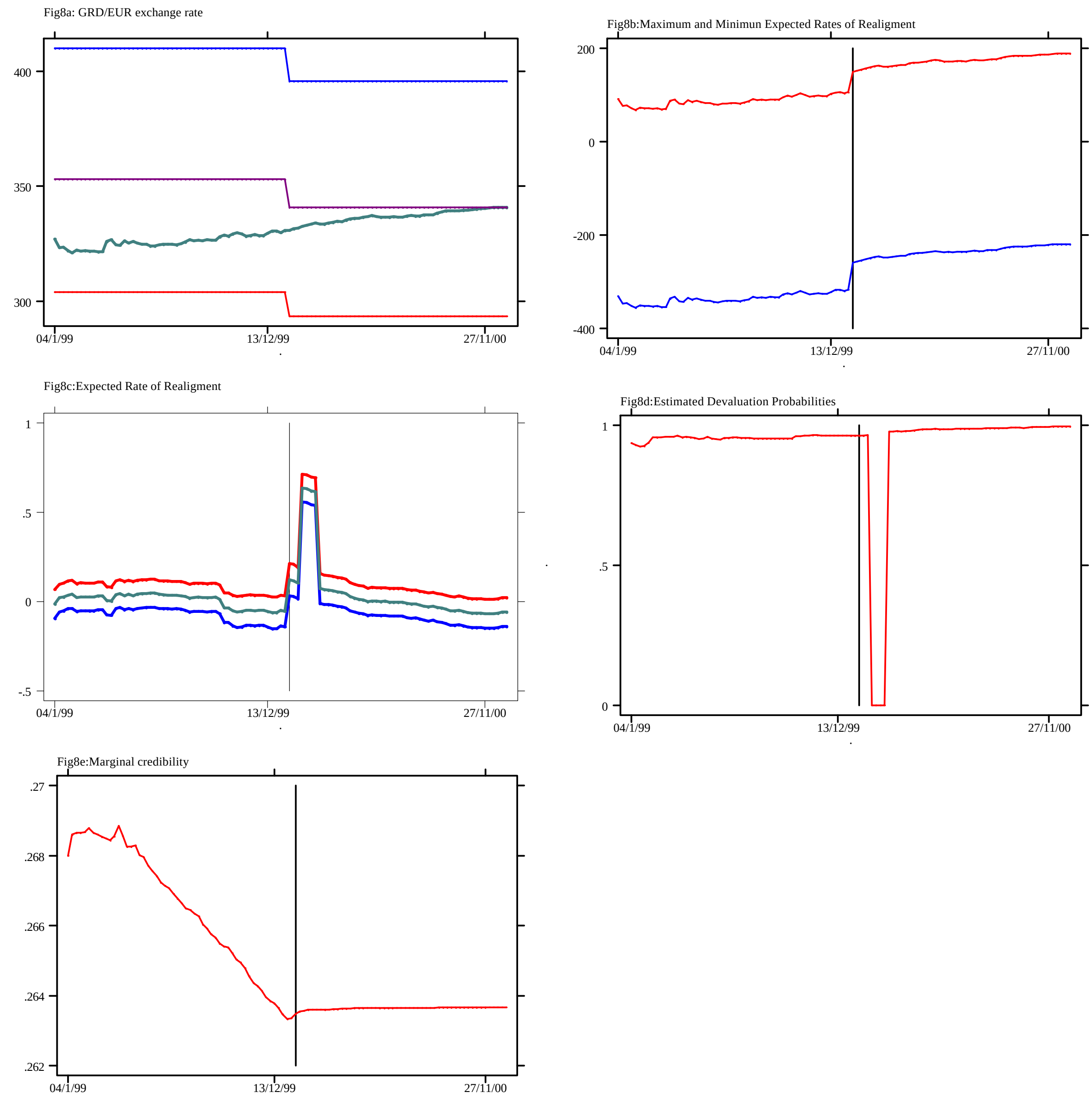


Table 1. Expected exchange rate depreciation within the band

	BFR/DM	DKR/DM	ESC/DM	FF/DM	HFL/DM	IRL/DM	LIT/DM	PTA/DM
D1		-0.0311			0.0541		-0.0298	-0.0641
		(0.0167)			(0.0173)		(0.2301)	(0.0216)
D2		-0.0216			0.0102		0.0218	-0.1254
		(0.0108)			(0.0164)		(0.2460)	(0.0231)
D3		-0.0554			0.0173		-0.0287	
		(0.0138)			(0.0099)		(0.2540)	
D4		-0.0584					-0.0282	0.1270
		(0.0185)					(0.2527)	(0.0219)
D5		-0.0521				0.0490	-0.0682	0.1448
		(0.0161)				(0.0171)	(0.2306)	(0.0223)
D6		-0.0364				0.1004	-0.0358	
		(0.0093)				(0.0177)	(0.2144)	
D7						0.0924	-0.0153	
						(0.0237)	(0.2136)	
D8						0.0347	-0.0208	
						(0.0147)	(0.2166)	
D9						0.0614	0.0509	
						(0.0321)	(0.2180)	
D10								
D11						0.0435	0.0056	
						(0.0151)	(0.2336)	
X	-3.9256	-2.5318	-1.9326	-3.8954	-2.8137	-1.4964	-2.7982	-2.7348
	(0.1285)	(0.2471)	(0.4240)	(0.1411)	(0.4281)	(0.3085)	(0.4210)	(0.2894)
i*	0.0598	0.0538	0.0964	0.0600	-0.0310	0.0903		0.0561
	(0.0178)	(0.0246)	(0.0513)	(0.0276)	(0.0106)	(0.0254)		(0.0286)
i	-0.0441	-0.0312	-0.0586	-0.0444	0.0185	-0.0870		-0.0489
	(0.0167)	(0.0205)	(0.0340)	(0.0239)	(0.0110)	(0.0217)		(0.0237)

Note: OLS estimation of equation (9). Newey-West standard errors within parentheses. Di (i=1,..,11) denote dummy variables for subperiods delimited by the realignments of the exchange rate and the widening of the bands.

Table 2. Logit estimation results

	BFR/DM	DKR/DM	ESC/DM	FF/DM	HFL/DM	IRL/DM	LIT/DM	PTA/DM
Exchange rates								
δ_1	37.4581	65.7825	39.3021	224.4180	-36.0372	8.7313	0.2057	9.4752
	(8.7702)	(8.6742)	(16.3266)	(22.8338)	(18.8494)	(1.7414)	(1.0346)	(1.7665)
δ_2	-1.6932	-16.3074	-0.3544	-65.1507	36.0384	-14.1500	0.0046	-0.0927
	(0.4238)	(2.2268)	(0.1582)	(6.6687)	(16.9258)	(4.5002)	(0.0017)	(0.0215)
Distance to upper band								
δ_1	13.8981	5.6266	53.3191	6.4758	4.4871	3.8118	3.6997	3.4820
	(1.6425)	(0.3974)	(13.3732)	(0.4652)	(0.3157)	(0.2432)	(0.3243)	(0.2881)
δ_2	-34.1012	-35.4790	-2.1896	-68.2629	-46.9208	-38.8093	-0.0564	-0.5875
	(4.3425)	(3.9583)	(0.5595)	(6.2563)	(23.3740)	(14.6986)	(0.0205)	(0.0904)
Distance to central parity								
δ_1	2.5048	3.2595	1.3961	3.2413	-2.3430	3.0123	0.6788	0.6043
	(0.1585)	(0.6119)	(0.7254)	(0.1978)	(0.8387)	(0.2307)	(0.4564)	(0.3623)
δ_2	0.2219	-1.0412	0.1268	-3.6656	279.3700	26.4156	0.0846	0.1785
	(0.1131)	(0.6119)	(0.0576)	(0.5312)	(40.7369)	(11.4170)	(0.0182)	(0.0435)
Interest rate differential with Germany								
δ_1	5.1489	4.7266	5.2382	3.7313	4.2384	7.18558	1.4431	6.2345
	(0.3524)	(0.3227)	(0.7250)	(0.2390)	(0.2726)	(0.6423)	(1.7229)	(0.7633)
δ_2	-2.1861	-0.6735	-0.3623	-0.7452	-0.1570	-0.6716	0.3554	-0.9615
	(0.2257)	(0.0967)	(0.0898)	(0.0964)	(0.5780)	(0.0829)	(0.3781)	(0.1581)

Note: Estimation of equation (10). Standard errors within parentheses.

Table 3. Summary statistics of the estimated probability

	BFR/DM	DKR/DM	ESC/DM	FF/DM	HFL/DM	IRL/DM	LIT/DM	PTA/DM
Exchange rates								
Mean	0.9381	0.9536	0.9534	0.9478	0.9855	0.9700	0.9555	0.8956
Median	0.9318	0.9750	0.9545	0.9567	0.9890	0.9686	0.9660	0.8683
Maximum	1.0000	1.0000	1.0000	0.9634	0.9928	0.9944	0.9766	0.9778
Mínimum	0.5884	0.1724	0.8492	0.9071	0.9398	0.9189	0.9061	0.7203
Std.Dev.	0.0446	0.0866	0.0337	0.0167	0.0084	0.0168	0.0220	0.0653
Skewness	-1.6486	-5.2411	-0.9148	-1.4770	-2.5042	-0.5518	-0.9012	0.0452
Kurtosis	12.6160	37.7665	3.9123	3.6892	9.2513	2.7323	2.4253	1.36222
Distance to upper band								
Mean	0.9381	0.9536	0.9534	0.9478	0.9855	0.9700	0.9555	0.8956
Median	1.0000	0.9878	1.0000	0.9778	0.9877	0.9744	0.9624	0.9288
Maximum	1.0000	0.9964	1.0000	0.9900	0.9889	0.9768	0.9758	0.9720
Mínimum	9.80E-14	0.0016	0.1406	0.1222	0.8885	0.9086	0.8528	0.1180
Std.Dev.	0.1861	0.1336	0.1328	0.1054	0.0085	0.0115	0.0227	0.1196
Skewness	-3.7514	-5.6536	-3.6566	-4.8736	-7.2734	-2.7485	-2.3304	-3.7853
Kurtosis	16.7110	36.6494	17.0534	29.0056	67.6254	10.6210	9.2270	19.9376
Distance to central parity								
Mean	0.9381	0.9536	0.9534	0.9478	0.9855	0.9700	0.9555	0.8956
Median	1.0000	0.9595	0.9605	0.9460	0.9934	0.9625	0.9703	0.9053
Maximum	1.0000	0.9630	0.9799	0.9543	1.0000	0.9983	0.9990	0.9717
Mínimum	9.80E-14	0.9312	0.8516	0.9445	0.3226	0.9511	0.7762	0.6804
Std.Dev.	0.1861	0.0113	0.0267	0.0034	0.0523	0.0149	0.0451	0.0628
Skewness	-3.7514	-1.0734	-1.8591	1.0004	-8.3636	0.7981	-1.4853	-0.6040
Kurtosis	16.7110	2.3452	6.2079	2.1805	80.0823	2.0093	4.8676	2.8880
Interest rate differential with Germany								
Mean	0.93881	0.9536	0.9534	0.9478	0.9855	0.9700	0.9555	0.8956
Median	0.9752	0.9696	0.9705	0.9610	0.9855	0.9949	0.9560	0.9240
Maximum	0.9988	0.9928	0.9947	0.9900	0.9878	0.9998	0.9757	0.9983
Mínimum	7.73E-05	0.0339	0.7288	0.6371	0.9819	4.45E-05	0.9321	0.3291
Std.Dev.	0.1122	0.0787	0.0566	0.0508	0.0010	0.0903	0.0074	0.1065
Skewness	-3.9836	-7.8390	-2.2292	3.3217	1.4972	5.8730	0.0517	1.9295
Kurtosis	23.2086	76.3020	7.3145	16.0281	5.7247	46.3832	2.3770	8.5444

Note: Estimation of equation (10). Standard errors within parentheses.

Table 4. Kalman filter estimates of marginal credibility

	BFR/DM	DKR/DM	ESC/DM	FF/DM	HFL/DM	IRL/DM	LIT/DM[1]	LIT/DM[2]	PTA/DM
α (ML)	0.7179 (0.1267)	0.6574 (0.2021)	0.7220 (0.2046)	1.1947 (0.2084)	1.2127 (0.5108)	0.8859 (0.3479)	0.6394 (0.0887)	0.6478 (0.1625)	0.4107 (0.1362)
Mean	0.6061	0.5591	0.6533	0.9318	1.0097	0.8723	0.2620	0.6319	0.4555
Median	0.5897	0.5429	0.6803	0.9469	1.0734	0.9479	0.2050	0.6377	0.4487
Maximum	0.7179	1.4908	0.7220	1.6412	1.7357	1.8274	0.6394	0.6394	0.5954
Mínimum	0.4596	-0.1030	0.4998	0.0168	0.0072	-0.0554	0.0166	0.5956	0.3726
Std.Dev.	0.0884	0.2406	0.0686	0.2900	0.3079	0.3512	0.2202	0.0114	0.0547
Skewness	-0.0436	0.4947	-0.6717	-0.2770	-1.1592	-0.5014	0.4987	-1.7388	0.9431
Kurtosis	1.5777	4.7415	2.0659	2.8684	4.2665	2.5205	1.7852	4.9695	2.8589

Note: Estimation by maximum likelihood (ML). Standard errors within parentheses.
[1]: From March 1979 to September 1992. [2]: From November 1996 to December 1998

Table 5a. Percentage of success when identifying realignments and no realignments: BFR

MA	DAM	L1	L2	L3	L4	MC
(1,4)	68.35	67.96	66.99	68.06	69.42	93.01
(1,8)	78.46	67.93	66.96	68.03	69.59	92.98
(1,12)	84.44	82.78	80.04	82.49	83.76	96.87
(1,16)	85.07	86.05	82.22	85.76	87.62	97.35
(1,20)	87.97	87.48	83.83	86.98	87.48	97.53
Average	80.86	78.44	76.01	78.26	79.57	95.55

Table 5b. Percentage of success when identifying realignments and no realignments: DKR

MA	DAM	L1	L2	L3	L4	MC
(1,4)	71.26	68.16	67.09	67.86	74.26	93.88
(1,8)	80.90	80.31	78.56	80.06	83.82	96.39
(1,12)	82.88	84.15	81.90	82.97	86.20	96.97
(1,16)	85.17	85.76	82.22	86.35	88.8	97.15
(1,20)	87.18	89.25	84.71	88.36	90.63	97.73
Average	81.48	81.53	78.90	81.12	84.74	96.42

Table 5c. Percentage of success when identifying realignments and no realignments: ESC

MA	DAM	L1	L2	L3	L4	MC
(1,4)	70.21	69.32	70.80	71.39	76.99	94.10
(1,8)	83.28	80.90	82.39	82.99	86.27	96.69
(1,12)	87.01	88.22	87.61	88.22	90.63	97.43
(1,16)	89.91	89.3	88.99	91.13	91.44	98.00
(1,20)	92.26	90.09	90.71	91.95	92.57	98.47
Average	84.53	83.57	84.10	85.14	87.58	96.94

Table 5d. Percentage of success when identifying realignments and no realignments: FF

MA	DAM	L1	L2	L3	L4	MC
(1,4)	73.50	71.65	71.26	71.84	72.43	78.74
(1,8)	82.26	83.14	81.09	83.53	81.77	84.41
(1,12)	84.83	86.01	82.78	85.81	86.79	88.36
(1,16)	86.25	87.72	84.09	88.11	88.51	89.88
(1,20)	88.17	88.46	85.31	88.86	88.76	90.04
Average	83.00	83.40	80.91	83.63	83.65	86.29

Table 5e. Percentage of success when identifying realignments and no realignments: HFL

MA	DAM	L1	L2	L3	L4	MC
(1,4)	70.04	67.90	65.86	69.07	70.43	74.12
(1,8)	79.04	78.46	74.95	78.27	80.9	82.26
(1,12)	81.70	80.53	78.08	80.92	82.78	85.23
(1,16)	84.77	83.01	80.16	84.58	85.27	87.52
(1,20)	86.79	85.70	84.02	86.29	86.98	89.15
Average	80.47	79.12	76.61	79.83	81.27	83.66

Table 5f. Percentage of success when identifying realignments and no realignments: IRL

MA	DAM	L1	L2	L3	L4	MC
(1,4)	73.59	70.68	69.22	70.97	70.87	71.65
(1,8)	83.04	78.95	78.17	78.65	82.46	82.07
(1,12)	87.08	83.95	81.41	84.64	84.64	85.23
(1,16)	89.88	87.23	85.07	87.92	89.78	86.15
(1,20)	90.24	87.97	85.6	88.86	91.03	89.15
Average	84.77	81.76	79.89	82.21	83.76	82.85

Table 5g. Percentage of success when identifying realignments and no realignments: PTA

MA	DAM	L1	L2	L3	L4	MC
(1,4)	69.03	72.47	71.26	73.68	71.46	84.01
(1,8)	81.22	80.00	80.20	82.04	83.27	89.80
(1,12)	88.89	85.6	85.39	87.24	87.45	91.36
(1,16)	89.00	86.93	85.89	88.59	89.21	94.19
(1,20)	89.33	87.24	87.03	88.49	90.38	93.31
Average	83.49	82.45	81.95	84.01	84.35	90.53

Note: DAM=Drift Adjustment Method, L1=crisis probability from the exchange rate, L2=crisis probability from central parity distance, L3= crisis probability from upper band distance, L4=crisis probability from the interest rate differential, and MC=Marginal Credibility

Table 6: Relative efficiency. DEA analysis.

	DAM	L1	L2	L3	L4	MC
BFR	0.224	0.243	0.206	0.228	0.273	1
DKR	0.226	0.254	0.202	0.234	0.3	1
ESC	0.34	0.288	0.321	0.444	0.385	1
FF	0.246	0.273	0.232	0.316	0.295	0.327
HFL	0.228	0.21	0.198	0.231	0.237	0.277
IRL	0.353	0.261	0.228	0.305	0.333	0.237
PTA	0.291	0.25	0.291	0.341	0.304	0.501

Note: DAM=Drift Adjustment Method, L1=crisis probability from the exchange rate, L2=crisis probability from central parity distance, L3= crisis probability from upper band distance, L4=crisis probability from the interest rate differential, and MC=Marginal Credibility

Table 7a. ERM-II: Expected exchange rate depreciation within the band

	DRAC/DM	DKR/DM
D1	-0.2719	
	(0.0862)	
X	2.6137	-0.9206
	(0.8744)	(0.3096)
i*	0.1774	0.0136
	(0.0522)	(0.0113)
I	0.035	-0.0139
	(0.0862)	(0.0102)

Note: OLS estimation of equation (9). Newey-West standard errors within parentheses. D1 denote dummy variables for subperiods delimited by the realignments of the exchange rate.

Table 7b. ERM-II: Logit estimation results

	DRAC/DM	DKR/DM
Exchange rates		
δ_1	14.8769	842.93
	(21.6508)	(160.17)
δ_2	-0.0368	-112.92
	(0.0651)	(21.4886)
Distance to upper band		
δ_1	1.8615	-0.6574
	(0.5251)	(0.3747)
δ_2	0.0645	249.92
	(0.0398)	(53.0306)
Distance to central parity		
δ_1	-1.6605	-30.006
	(2.4457)	(5.6444)
δ_2	0.06375	178.16
	(0.0375)	(32.5907)
Interest rate differential with Germany		
δ_1	5.7318	25.551
	(2.6544)	(6.8528)
δ_2	-0.3662	-39.7677
	(0.3862)	(11.3238)

Note: Estimation of equation (10). Standard errors within parentheses.

Table 7c. ERM-II: Summary statistics of the estimated probability

	BFR/DM	DKR/DM
Exchange rates		
Mean	0.9333	0.8567
Median	0.9361	0.9369
Maximum	0.9542	0.9897
Mínimum	0.9097	0.4212
Std.Dev.	0.0139	0.1562
Skewness	-0.2002	-1.1748
Kurtosis	1.6415	2.9989
Distance to upper band		
Mean	0.9333	0.8571
Median	0.9649	0.9841
Maximum	0.9807	0.9997
Mínimum	0.8655	0.3920
Std.Dev.	0.0431	0.2034
Skewness	-0.2392	-1.1275
Kurtosis	1.3058	2.6386
Distance to central parity		
Mean	0.9333	0.8571
Median	0.9678	0.9746
Maximum	0.9821	0.9986
Mínimum	0.8631	0.2473
Std.Dev.	0.0452	0.2077
Skewness	-0.2278	-1.4202
Kurtosis	1.2795	3.6035
Interest rate differential with Germany		
Mean	0.9333	0.8571
Median	0.9643	0.9983
Maximum	0.9965	1.0000
Mínimum	0.0000006	0.0000
Std.Dev.	0.1874	0.3167
Skewness	-4.7558	-2.1391
Kurtosis	23.857	5.8791

Note: Estimation of equation (10). Standard errors within parentheses.

Table 7d. ERM-II: Kalman filter estimates of marginal credibility

	DRAC/DM	DKR/DM
α (ML)	0.2636 (0.0557)	0.6614 (0.0726)
Mean	0.2651	0.6613
Median	0.2637	0.6613
Maximum	0.2688	0.6613
Mínimum	0.2633	0.6613
Std.Dev.	0.0019	0.00005
Skewness	0.8061	-5.316
Kurtosis	1.9924	36.26

Note: Estimation by maximum likelihood (ML). Standard errors within parentheses.