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Crises and Credibility in a Target Zone: A Logit from a Markov-Switching Model[*]

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Abstract

The 90's could be characterized as a time in which both developed and emerging countries have suffered important episodes of exchange rate instability; some of these periods have resulted in exchange rate devaluations and others, in important exchange rate depreciations. We are interested in the knowledge and explanation of such moments of turbulence in order to avoid or even forecast future crises.

This paper focuses on the study of the different moments of speculative pressure in Europe and particularly on the Spanish peseta during the target zone period. We use a Binary Dependent Variable Model (Logit Method) to estimate the readjustment probability in a target zone. Our dependent variable is calculated from a Markov-Switching model on the Spanish-German interest rate differential. We show that this methodology is appropriate.

Keywords: Target Zones, Markov-Switching Models, Currency Crises, Readjustment Probability.

JEL: F3 - International Finance

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1 Introduction

The last decade could be characterized as an intense period of events with respect to the International Financial System. Both emerging and developed countries have suffered important episodes of exchange rate instability resulting in realignment of parities or high volatilities. In either case, the monetary authority has been forced to intervene at the expense of huge losses in foreign reserves and/or large increases in interest rates. This turbulence has renewed the debate about the reform of the International Financial System, in order to avoid or lessen the virulence of currency crises.

In this paper, we study the different moments of speculative pressure in Europe focusing, in particular, on the Spanish peseta during the time it belonged to the ERM [European Rate Mechanism] target zone. We must, therefore, bear in mind the target zone, as it influences the behaviour of the exchange rate. An important contribution to the exchange rate literature, called "Target Zone", the best known paper being that of Krugman (1991), models the exchange rate in a target zone system. One of the more interesting aspects analyzed is that relating to the evaluation of the target zone credibility.[1] There are different methodologies which try to estimate the realignment expectations in exchange rate target zones. The first paper can be placed in the framework of "Classical Credibility Test", that includes the "Simple Test of Credibility or Svensson's Simple Test"[2] and the "Drift-Adjustment Method".[3]

Since the edition of Bertola & Svensson (1993), a lot of new methods for extracting information about market expectations have been developed. Worthy of mention as perhaps the most relevant are: Mizrach (1995), Gómez Puig & Montalvo (1997), Söderlind & Svensson (1997) or Bekaert & Gray (1998). All of them, study target zone models with stochastic devaluation risk. However, they

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[1] Gámez & Torres (1996) provide a survey of the Target Zones Literature.

[2] Svensson (1991), is a short version of the published paper with the same title in NBER, w.p., 3394, June, 1990.

[3] Svensson (1992) and Bertola & Svensson (1993) evaluate the realignment expectations by introducing the stochastic realignment risk in continuous time in the basic model of target zones [Krugman, 1991].

also distinguish [and this is one of the more outstanding issues for our purposes] between the size and probability of a jump, that will be constant or variable through time.[4]

There are other approaches, with non-structural features, to estimate the realignment probability which use a group of " fundamental" variables of the economy. We could point out two kinds of studies. First, Weber (1991), applies a Bayesian approach with Kalman multiprocessor filter.[5] Secondly, we could mention the following: Edin & Vredin (1993), Gutiérrez (1994) or Ayuso & Pérez Jurado (1997), who estimate a multinomial dependent variable model with a gaussian distribution,[6] so this is a probit model. If the distribution function used is a logistic one, the model will be a logit. This has been applied to the Spanish case by Ledesma et al. (1999), Campos (1999) and Campos & Rodríguez (2000).

In this paper, we try to study the readjustment probability of the Spanish peseta during the target zone period. However, not only do we need to bear in mind the influence of the band on the behaviour of the exchange rate, but also the moments of turbulence the peseta underwent during this time. The latter aspect requires that the contribution of the literature known as "Currency Crises" needs to be taken into account. Non-structural models of currency crises fall into two broad categories: those based on non-parametric tests e.g. Eichengreen, Rose & Wyplosz (1994),[7] Sachs, Tornell & Velasco (1996) or Kaminsky, Lizondo & Reinhart (1998); all of which try to identify crises by looking at an index of exchange market pressure;[8] and others based on binary

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[4] In recent works, the possibility of allowing the exchange rate to jump with realignments has been studied. It therefore underlines the jumps of the exchange rate but when there is no change in parity or devaluation.

[5] Alberola, López & Orts (1994) and Ledesma, Navarro, Pérez & Sosvilla (1999) in the Spanish case.

[6] The multinomial dependent variable models have the common feature that the dependent variable takes the values 0, 1, 2... If it could only take 0 or 1, then it is a binary dependent variable model.

[7] They use two non-parametric tests: the Kolmogorov-Smirnov Test for equality of the distribution functions and the Kruskal-Wallis Test for the equality of populations. They also report the traditional test for equality of first-moments.

[8] They compare the behaviour of macroeconomic variables during periods of speculative pressure to the behaviour of the same variables during periods of tranquility.

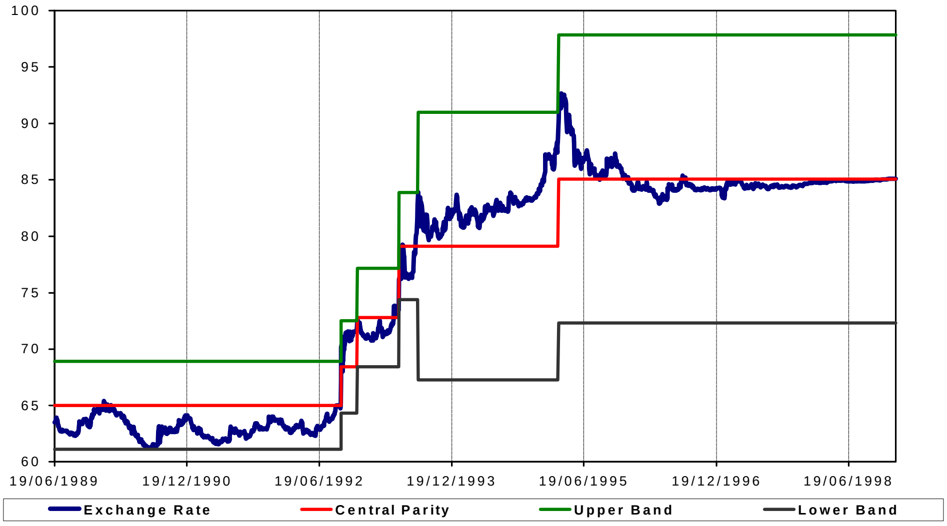
dependent variable models, logit or probit, e.g. Eichengreen, Rose & Wyplosz (1996), Frankel & Rose (1996) and Kruger, Osakwe & Page (1998). They applied this methodology using data for emerging and/or developed countries, and all of them try to associate speculative attacks with some exogenous variables, such as the output growth, domestic credit growth, foreign interest rates, current account or budget deficits. The first one and the third one also consider the possibility of contagion effects.

We also use a Binary Dependent Variable Model with a logistic distribution function. Our dependent variable is calculated from a Markov-Switching Model on the Spanish-German interest rate differential. We will use daily data from 19th June 1989 to 30th December 1998. The results suggest that this method could be suitable to explain the turbulence that Spanish currency suffered during the target zone period.

2 Binary Dependent Variable Model

2.1 Data and relevant dates

We use daily data for all the variables, e.g. the peseta/Deutsche mark and peseta/US dollar exchange rates, the interbank interest rate in Spain and Germany and EMS central parity data for the Spanish currency. The sample includes 2.326 daily observations from 19th June 1989 to 30th December 1998. In that period, the Spanish peseta suffered four devaluations: 17th September 1992, 23rd November 1992, 14th May 1993 and 6th March 1995, besides the shifts in wide bands on 2nd August 1993, from ±6% to ±15%. Daily peseta/Deutsche mark and peseta/US dollar exchange rates and Spanish interest rates have been obtained from the Spanish Central Bank, the Bundesbank provided the German interest rates and Cuentas Financieras de la Economía Española [Estadísticas Complementarias], published by the Spanish Central Bank, is the source for the rest of the series.



Daily Peseta/Mark Exchange Rate [1989/06/19 - 1998/12/30]

Figure 1 shows the evolution of the peseta/Deutsche mark exchange rate in the sample period. It also illustrates the central parity and the edges of the bands, both ±6% and ±15% wide. Only a glance at the figure leads us to think of different behaviours of the exchange rate depending on the band width. In the narrow band period, ±6% in the Spanish case, an initial phase can be found extending from joining the ERM of the European Monetary System to June 1992. During that time, the peseta was overvalued and it was grazing the lower band. This is the period previous to the monetary storm triggered in 1992, when the peseta was devalued three times.[9] The relative stability reached with the last readjustment in May 1993 could be kept only till the end of June. A new wave of attacks focused on the French franc and the monetary authorities had to intervene to stop the massive speculation against the currency. Those events led the Economy and Finance Ministers and the Central Banks Chairs

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[9] Sometimes this period has been defined as a paradox; The strongest currencies of the EMS were those belonging to economies with the worst fundamentals e.g. high inflation, current account deficits or budget deficits. It has been explained in relation to the British pound position in the System. This currency had joined ERM in October 1990 and stayed very weak from then on, leading the peseta to the maximum level of appreciation.

to decide the shifts in wide bands to ±15% for all the currencies, except the German mark and the Dutch guilder.

After the shifts in band widths, the Spanish currency showed a relative trend to depreciation, that became more intense in 1995. The Mexican peso crisis at the end of December 1994 provoked contagious effects in other countries with close trade links. The US dollar appreciated in value and it caused the mark to strengthen and the rest of EMS currencies to weaken. The Spanish currency depreciated in value and the risk premium increased not only due to the problems of the dollar, but also because of the political uncertainty in Spain at that moment and the bad evolution that inflation and the budget deficit were showing. At the beginning of March 1995, the pressures on the peseta increased and this resulted in the monetary authority approving a devaluation. The peseta suffered from another readjustment of 7% on 6th March. That devaluation was qualitatively different to the three previous ones because it happened before the peseta exchange rate reached the upper band. This realignment was therefore labelled as a "technical devaluation" because the evolution of the fundamental variables of the economy did not make it necessary yet it was basic in order to avoid the exchange rate from reaching the upper band.[10] One of the lessons from the monetary crisis in the autumn of 1992 was that, in some circumstances, a speculative attack could force a currency to the upper band thus triggering a wave of turmoil that makes the intervention of the monetary authorities insufficient.[11] The evolution of the peseta exchange rate in the following months endorsed this action and the markets corrected the excessive depreciation prior to the devaluation. Our period of study concludes with a last phase of relative stability that was influenced by a strong dollar and above all, the convergence in fundamental variables of those economies which had expectations of joining the future EMU. The evolution of long and short term interest rates was a clear indication of the convergence process.[12]

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[10] Spanish Central Bank Annual Report, 1995, p. 46.

[11] "Currency Crises" literature called these processes "Self-Fulfilling Attacks or Self-Fulfilling Crises".

[12] See Figure included in Appendix, which shows the daily interest rate differential between Spain and Germany.

Then, we shall now study whether a binary dependent variable model is adequate for explaining the crises and credibility periods of the peseta/Deutsche mark exchange rate during the sample target zone.

2.2 Econometric Specification

The application of a binary dependent variable model means we have to specify the moments in which the dependent variable will assume only two values $\{1;0\}$. Let j_t be our dependent variable and $j_t = 1$ if there is a lack of credibility and then a high probability of readjustment [storm period if we used the "Currency Crises" name], and $j_t = 0$ if it is a calm period with high credibility.

The logistic distribution function we shall use, $F(\{;\beta)$, is the following:

$$\mathrm{Prob}(j_t = 1) = F(\{;\beta) = \frac{\exp\left[\beta'\{\right]}{1 + \exp\left[\beta'\{\right]} \tag{2.1}$$

where $\mathrm{Prob}(j_t = 0) = 1 - \mathrm{Prob}(j_t = 1)$, and $\{$ is a vector of observed exogenous variables that we will use in the analysis, β being the parameter vector.

We use a Maximum Likelihood Estimation Method and the numerical optimization is reached through the iterative algorithm known as "Newton-Raphson". The log Likelihood function is given by:

$$\ln L = \sum_{t=1} j_t \ln F(\{;\beta) + \sum_{t=1} (1 - j_t) \ln[1 - F(\{;\beta)] \tag{2.2}$$

We must specify the exogenous variables considered in the estimation. If we are taking into account the different moments of speculative pressure along the sample with exchange rate readjustments as a result, we may consider real and/or monetary variables as "Currency Crises" literature does. However, we try to underline the fact that the Spanish currency belongs to the ERM of the European Monetary System and, therefore, the existence of a target zone. Because of this, we will use the following variables: the peseta/Deutsche mark nominal exchange rate, e_t, exchange rate deviations from the upper band,

$(e_{max} - e_t)$, nominal exchange rate deviations from the central parity, $(e_t - c_t)$, and the peseta/US dollar nominal exchange rate, s_t. We could justify using the last variable by bearing in mind the relationships between the US dollar exchange rate and the rest of the currencies in an integrated international finance market.[13]

We will show our results by calculating, as a first step, the dependent variable values. Then, we will estimate, by the maximum likelihood procedure, the readjustment probability of the exchange rate.

2.2.1 Dependent Variable Estimation

In a previous work, Campos (1999) the Classic Credibility Test [Svensson's Simple Test and the Drift-Adjustment Method] was applied to the peseta/Deutsche mark exchange rate from 19th June 1989 to 30th September 1998. The results showed a lack of credibility just at the moments before and after each devaluation, at the shift to wide bands and at the beginning of the sample, when the Spanish peseta joined the Exchange Rate Mechanism of the EMS, the instability lasting till the end of February 1991. During this last period, the Italian Lira was incorporated within the narrow EMS band [$\pm 2.25\%$] in January 1990 and in October, the pound Sterling joined the System. These tests have been criticized by the Target Zone and Currency Crises literatures; The first is said to be a necessary but not sufficient condition of credibility; and the Drift-Adjustment Method suffers from a non-structural character by choosing the exogenous variables to estimate the expected devaluation rate within the band.[14] Campos & Rodríguez (2000) tries to overcome these difficulties by applying a Binary Dependent Variable Model and using the Drift-Adjustment Method only as a complement for calculating the dependent variable values. They demonstrate that the existence of a breakpoint on 2nd

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[13] This interdependence is illustrated, for example, by the Mexican peso or the Asian countries Crises.

[14] The Drift Adjustment Method estimates the expected rate of devaluation by subtracting the estimate of the expected rate of exchange rate depreciation within the band from the interest rate differentials. The variables included in the OLS regression have usually been exchange rate deviations inside the band, and the national and foreign interest rates.

August 1993, date of the shift in the band width from §6% to §15% cannot be rejected. Because of the finding of a breakpoint, the study is carried out by sub-samples. The results suggest a Logit Model as a suitable option to explain the readjustment probability of the peseta/Deutsche mark exchange rate from June 1989 to December 1998. However, we posed two possible limits to that work. The first refers to taking the whole period by sub-samples. It is true that we get statistically better estimations of the readjustment probability but we are probably introducing some kind of bias with respect to the change in regime or jump probability just at the date of the shift in the band. The second issue we consider has already been pointed out in Gómez-Puig & Montalvo (1997),[15] and is related to the estimation procedure, the Drift-Adjustment Method, which relies on the “ex-post” knowledge of the realignment dates and will therefore lead to conditional distribution different from the “ex-ante” distribution. Then, we need an estimation method that allows us to deal with the mixture distribution generated by two possible situations: realignment and non realignment. It thus seems plausible to use the Hamilton (1989, 1994) model for changes in regimes.[16] This procedure is adequate when there are realignments and will allow us to obtain an appropriate indicator to calculate the dependent variable values to be used in a logit model.

In short, we shall estimate the expected devaluation rate using a Markov-Switching model, with constant transition probabilities. We take the nominal interest rate differential between Spain and Germany as the variable which changes with the state $m_t = 0$ in the calm state, and $m_t = 1$ if it is a crisis state. The Markov-Switching econometric procedure is included in the appendix to this paper.

Table 1 contains empirical estimates from Markov-Switching models with constant transition probabilities. All the estimated parameters are significant as the asymptotic standard errors indicate. In this way, we can specify a criterion to use in order to choose the dependent variable values for the Logit

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[15] [13, Gómez-Puig and Montalvo, 1997, p. 1517-1518]

[16] Gómez-Puig & Montalvo (1997) and Psaradakis, Sola & Tronzano (1999) consider this option as an adequate means of overcoming the problems of the Drift Adjustment Method.

Table 1: Markov-Switching Model on Spanish-German Daily Interest Rate Differential [Constant Transition Probabilities] [1989/06/19 - 1998/12/30]

Parameters	Coefficients
α_0	0.0222 (0.0111)
α_1	0.0031 (0.0146)
ϕ	0.9193 (0.0083)
σ_0	-0.0389 (0.0001)
σ_1	0.2168 (0.0041)
c_0	4.9049 (0.0061)
c_1	2.0143 (0.0297)
Log Likelihood	5416.795
P_{00}	0.9601
P_{11}	0.8023

Note: Asymptotic standard errors are tabulated in parentheses.

Model. That criterion will depend on the confidence percentage the economic agents assign to the readjustment expectations. We build a ± 1.65 standard deviation threshold.[17] We shall assign the dependent variable value $j_t = 1$ [lack of credibility and so high realignment probability] whether the threshold is above, or below, zero. Otherwise, we will consider $j_t = 0$.

3 Estimation Results

We have estimated the Log Likelihood function expressed in equation (2.2). We have used the chosen exogenous variables: the peseta/Deutsche mark nominal exchange rate, e_t, exchange rate deviations from the upper band, $(e_{max} - e_t)$, nominal exchange rate deviations from the central parity, $(e_t - c_t)$, and the peseta/US dollar nominal exchange rate, s_t, in different combinations, e.g. one by one, two and two, three by three and finally, all of them together. The results are set out in table 2, and the following figures show the same results.

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[17] As in Lindberg, Svensson & Söderlind (1993) [22, pp. 1175] we construct a 95 per cent confidence interval of the estimated rate of devaluation.

The purpose of this paper is to analyze whether a non-structural binary dependent variable model is a suitable method to adequately explain the turbulence and calm periods that the Spanish peseta has suffered during the target zone period. In addition, we suggest some exogenous variables which could help to explain the behaviour of the peseta/Deutsche mark exchange rate. It is possible to apply some Information Criteria as a guide in the model selection. We use AIC [Akaike Info Criterion].[18] Table 2 displays a goodness-of-fit calculated from the McFadden R-squared [likelihood ratio index].[19] The results of readjustment probability estimations suggest that in both cases, by using AIC criterion and MF-R^2, we should choose a Logit model with all our exogenous variables [e_t, $(e_{m\acute{a}x} - e_t)$, $(e_t - c_t)$, s_t]. If we analyze the results depending on the number of exogenous variables contained in the model, we could show that exchange rate deviations from the upper band should always be chosen. If we add exogenous variables, we should include the peseta/US dollar nominal exchange rate, the peseta/Deutsche mark nominal exchange rate and finally, nominal exchange rate deviations from the central parity. Our initial intuition about including the peseta/US dollar nominal exchange rate as an exogenous variable has been confirmed and it should be included in second place, only after including $(e_{m\acute{a}x} - e_t)$, one of the basic variables if we are analyzing a target zone.

The following figures illustrate the best models in each category and show the differences, in terms of readjustment probability, among periods of speculative attacks ending with realignment or those which ended without realignment. They also distinguish between the three first devaluations and the last one [6th March 1995] and finally, they clearly reflect the moment we could consider a breakpoint or a change in regime, 2nd August 1993, where the ERM of the European Monetary System became a quasi-flexible system. Therefore, the figure which includes the four exogenous variables is the one we suggest is the best[20]

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[18] We have calculated the Hannan-Quinn criterion (HQ) and the Schwarz criterion (SC) and the results are similar to using the Akaike criterion.

[19] In bold, the best models according to AIC and MF-R^2.

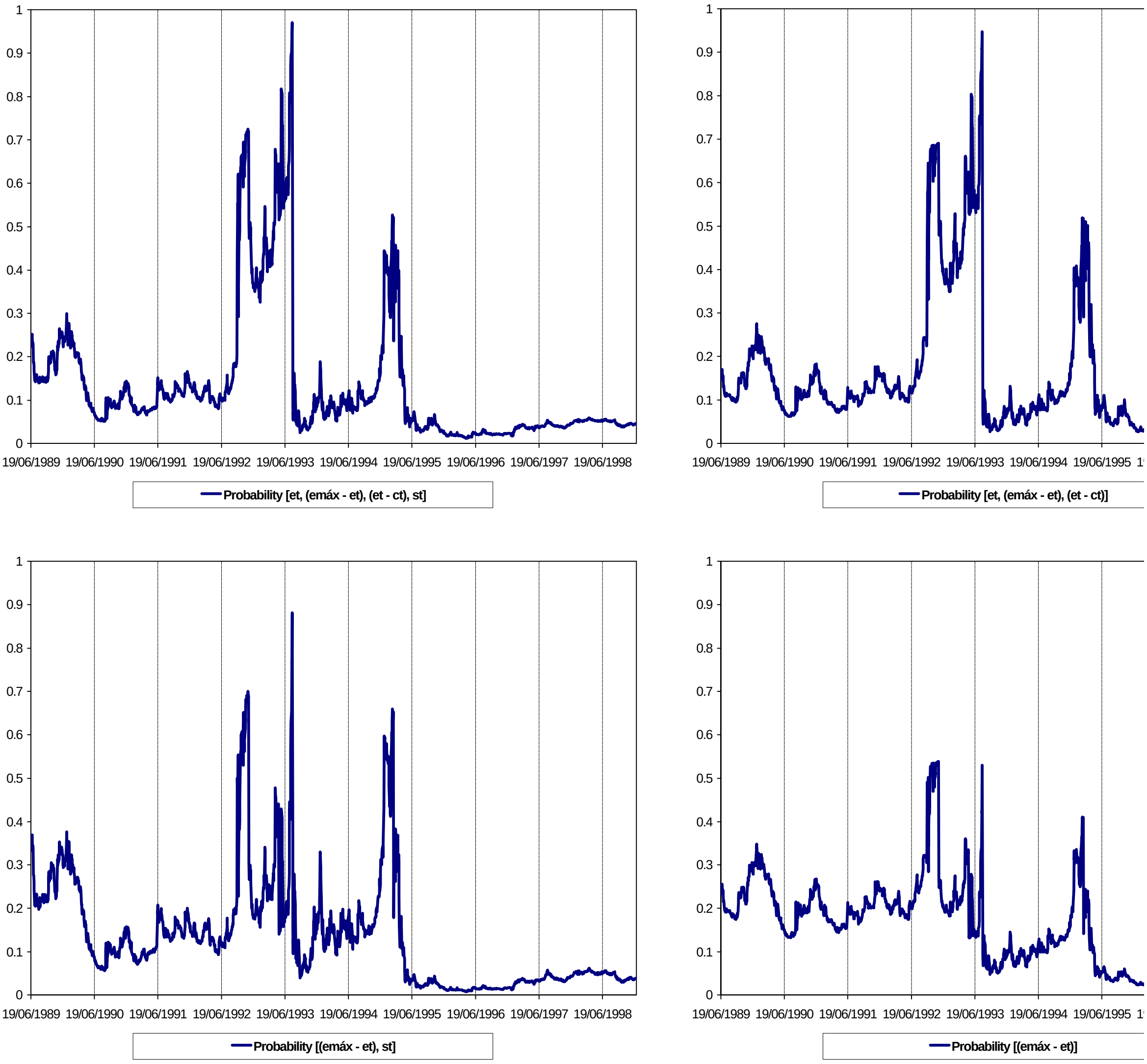
[20] Specially for countries in the narrow band of the ERM.

Table 2: Readjustment Probability using Logit Binary Model from a Markov-Switching Model [1989/06/19 - 1998/12/30]

Constant	e_t	$(e_{max} - e_t)$	$(e_t - c_t)$	s_t	AIC	MF.R^2
0.066 (0.148)	-0.026^{***} (-4.321)				0.776	0.010
0.435^{***} (2.601)		-0.302^{***} (-12.901)			0.686	0.125
-1.887^{***} (-30.547)			0.097^{***} (4.074)		0.777	0.009
0.089 (0.207)				-0.016^{***} (-4.550)	0.775	0.012
-2.816^{***} (-5.618)	0.054^{***} (6.971)	-0.397^{***} (-14.813)			0.666	0.152
3.611^{***} (5.576)	-0.074^{***} (-8.352)		0.281^{***} (8.722)		0.744	0.052
0.233 (0.509)	-0.009 (-0.880)			-0.011^{*} (-1.805)	0.775	0.012
0.407^{***} (2.421)		-0.298^{***} (-12.790)	0.068^{***} (3.039)		0.683	0.130
-3.459^{***} (-6.345)		-0.442^{***} (-14.544)		0.041^{***} (7.536)	0.661	0.159
1.474^{***} (2.902)			0.169^{***} (6.605)	-0.028^{***} (-6.534)	0.758	0.034
-12.527^{***} (-10.496)	0.219^{***} (10.993)	-0.722^{***} (-16.010)	-0.521^{***} (-9.064)		0.630	0.199
3.616^{***} (5.579)	-0.079^{***} (-5.441)		0.285^{***} (8.459)	0.003 (0.452)	0.745	0.052
-3.715^{***} (-6.579)	0.021^{*} (1.787)	-0.441^{***} (-14.692)		0.030^{***} (3.791)	0.660	0.160
-4.928^{***} (-6.883)		-0.508^{***} (-13.549)	-0.100^{***} (-3.221)	0.057^{***} (7.635)	0.657	0.164
-13.124^{***} (-10.694)	0.187^{***} (8.393)	-0.752^{***} (-16.035)	-0.508^{***} (-8.791)	0.026^{***} (3.185)	0.627	0.204

Note: The values in the parentheses are the t ratio. The superscripts *, ** and *** show that the corresponding parameter value is significant at 10, 5 or 1 per cent respectively. The Information Criterion as a guide in model selection is the Akaike info Criterion (AIC). The Goodness-of-fit is reported through McFadden R-squared.

Readjustment Probability [Peseta/Deutsche Mark Exchange Rate]



4 Conclusions

During the 90's, we have witnessed important episodes of exchange rate instability in both developed and emerging countries. Some of these periods have resulted in exchange rate devaluations and others, in important exchange rate depreciations. One of the most interesting purposes of this work has been to research and explain those moments of turbulence in order to avoid them or even forecast future crises.

We have analyzed whether a non-structural binary dependent variable model could be a suitable method to adequately explain the turbulence and calm periods that the Spanish peseta suffered during the target zone period. In addition, our aim has been to suggest some exogenous variables which could explain the behaviour of the peseta/Deutsche mark exchange rate during the sample time [1989/06/19 - 1998/12/30]. The methodology could be considered as a mixture of approaches which have studied and carried out research on currency crises and credibility. We refer to Target Zones and Currency Crises Literatures. On the one hand, this paper has applied a Markov-Switching model to the daily interest rate differential as a method in order to first, separate calm and crisis periods and then to be able to assign values to the dependent variable in our Logit model.

In that way, we have been able to show jumps in the exchange rate inside the band [high volatilities] and realignment of central parities. Our next step has been to estimate the readjustment probability using four exogenous variables, taking into account the existence of a target zone. The results suggest that it could be a suitable method and that we should always introduce the exchange rate deviations from the upper band as an exogenous variable in order to explain periods of currency crises and credibility in a target zone.[21] However, the results improve by including the rest of the exogenous variables. In addition, the intuition of including US dollar has been confirmed, and we suggest that this exogenous variable could be a basic one for analyzing currency crises with

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[21] Campos & Rodríguez (2000) suggest the same variable as being basic, but using the drift adjustment method to calculate the dependent variables values.

exchange rate systems other than a target zone.

We think the incorporation of real and/or monetary variables of the economy, as Currency Crisis literature proposes could be adequate, although the data are only available on a monthly basis. Therefore, it is impossible to work with them if we want to detect instability in a daily range of data.

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5 Appendix

5.1 Markov-Switching Model (Constant Transition Probabilities)

We have used the known Hamilton's Model to choose the values of the dependent variable of the logit model. Hamilton's model (1989, 1990) allows a variable to follow different time series processes depending on the sample considered. We try to separate two possible states or regimes of the economy. One of them is associated to high variance, the crisis state, and the other will be the calm state. Our state variable is a non-observed m_t random variable which follows a discrete time two state Markov chain, therefore the change or jump in the state is also a random variable. If $m_t = 0$, then the process is in calm regime without shocks or disturbances and there is a high credibility of the target zone. In contrast, if $m_t = 1$ the process is in crisis regime or there is a lack of credibility.

It is possible to model the dynamic of the nominal interest rate differential between Spain and Germany, using an autorregressive specification AR (1). We let mean and variance vary with the state. It is given by:

$$y_t - \mu_{m_t} = \phi_t \left(y_{t-1} - \mu_{m_{t-1}} \right) + \sigma_{m_t} \varepsilon_t \qquad t = 1 \ldots T \qquad \text{(A.1)}$$

where y_t represents the interest rate differential, ε_t are independent and identically distributed random variables with zero mean and unit variance $\sim N(0,1)$. We could parametrize linearly mean and standard deviation shift functions as follows:

$$\begin{cases} \mu_{m_t} = \alpha_0 + \alpha_1 m_t \\ \sigma_{m_t} = \sigma_0 (1 - m_t) + \sigma_1 m_t \end{cases}$$

As the economy could only be in one of two possible states, it is supposed the probability of being in one of them depends solely on the state it was in on the previous date, $(t - 1)$, thus:

$$P \left\{ m_t = i \mid m_{t-1} = j, m_{t-2} = k, \ldots \right\} = P \left\{ m_t = i \mid m_{t-1} = j \right\} = p_{ij} \qquad \text{(A.2)}$$

This equation describes a Markov chain with two states and $p_{i\,j} = 0,1$ transition probabilities. The transition probability matrix will be:[22]

$$P = \begin{bmatrix} p_{00} & p_{10} \\ p_{01} & p_{11} \end{bmatrix}$$

where, $(1 - p_{00}) = p_{01}$, and $(1 - p_{11}) = p_{10}$.

5.1.1 Econometric Specification and Optimal Inference

Let y_t be a $(T - 1)$ vector of daily interest rate differential between Spain and Germany. If the process at t is governed by the state $m_t = j$, the conditional

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[22] We assume the Markov chain is irreducible so $0 < p_{00}$, $p_{11} < 1$. If one of the transition probabilities is 1, then P matrix is triangular. Then, once the process enters that state, there is no possibility of ever returning to the other state. [17, Hamilton, 1994, ch. 22, p. 680] and [2, Avesani and Gallo, 1996, p. 12]

density function of y_t is given by:

$$f(y_t \mid m_t; \Omega_{t-1}; \alpha) \tag{A.3}$$

where $\Omega_t = (\Omega_t; \Omega_{t-1}; \ldots; \Omega_1)$ is the information vector through date t, and $\alpha = (\mu_0; \mu_1; \phi; \sigma_0^2; \sigma_1^2)'$ is a vector of parameters characterizing the conditional density function. With two regimes the densities represented by equation (A:3):

$$\eta_t = \begin{cases} f(y_t \mid m_t = 0; y_{t-1}; \alpha) = \frac{1}{\sqrt{2\pi}\,\sigma_0} \exp\left\{ \frac{-[(y_t - \mu_0) - \phi(y_{t-1} - \mu_0)]^2}{2\sigma_0^2} \right\} \\ f(y_t \mid m_t = 1; y_{t-1}; \alpha) = \frac{1}{\sqrt{2\pi}\,\sigma_1} \exp\left\{ \frac{-[(y_t - \mu_1) - \phi(y_{t-1} - \mu_1)]^2}{2\sigma_1^2} \right\} \end{cases} \tag{A.4}$$

We could define a new vector Ψ with all the parameters. We shall estimate $\Psi = (\mu_0; \mu_1; \phi; \sigma_0^2; \sigma_1^2; p_{00}; p_{11})'$, conditioned to the information through t.

Even assuming Ψ is known, we still do not know the regime the process is at on every date in our sample and if it belongs to calm or crisis. We form a probabilistic inference about the unobserved regime depending on all the observations available:

$$P\{m_t = i \mid \Omega_t; \Psi\} \qquad i = 0; 1 \tag{A.5}$$

We could collect in a (2×1) vector, denoted $\hat{\xi}$, these conditional probabilities that the analysis assigns to the possibility that the t^{th} observation is generated by regime i. The optimal inference for each date t could be found by iterating the equation:

$$\hat{\xi}_{t|t} = \frac{\left(\hat{\xi}_{t|t-1} \odot \eta_t\right)}{1'\left(\hat{\xi}_{t|t-1} \odot \eta_t\right)} \tag{A.6}$$

where 1 represents a (2×1) vector of 1s, and $\odot$ denotes element-by-element multiplication.

The log likelihood function $L(\Psi)$ for the observed data evaluated at the value of Ψ that is used to perform the iterations could be calculated as a by-product of this algorithm from:

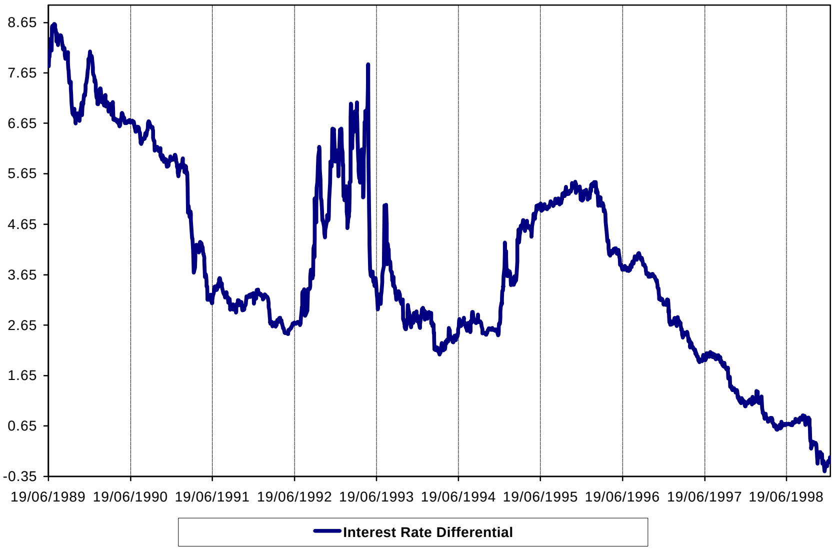
$$L(\Psi) = \sum_{t=1}^{T} \log f(y_t \mid \Omega_{t-1}; \Psi) \tag{A.7}$$

and where:

$$f(y_t \mid \Omega_{t-1}; \Psi) = 1'\left(\hat{\xi}_{t|t-1} \odot \eta_t\right) \tag{A.8}$$

5.1.2 Maximum Likelihood Estimates of Parameters

If we iterate equation (A:6), and it is completed for all the dates in the sample, then it is possible to find the log likelihood value through (A:7). The values of the parameters in Ψ, which maximizes the log likelihood function is obtained by numerical optimization using, in our case, the Newton-Raphson algorithm.[23] The results are shown in table1 and the following figure represents daily interest rate differential between Spain and Germany during the sample time.



Daily Interest Rate Differential between Spain and Germany [1989/06/19 1998/12/30]

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[23] [17, Hamilton, 1994, ch. 5, p. 133-142]

Readjustment Probability [Peseta/Deutsche Mark Exchange Rate]