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A MODEL OF REALIGNMENTS IN THE EMS

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The purpose of this paper is to formulate and estimate a model of the determinants of devaluations in target zones. The hypothesis is that a devaluation is related to «fundamentals». The target exchange rate will be treated as a censored variable. To handle the problem of selectivity bias, a two-step procedure is used. In this way it will be possible to calculate time series of both the probability and the expected size of a devaluation. The main economic conclusion is that macroeconomic fundamentals affect the probability of a devaluation, but do not influence too much the size of the realignment.

1. Introduction

Knowing the determinants of exchange rate movements is one of the enigmas of economic theory. As long as the exchange rate is a price, it seems reasonable to think that the economic policies will have an effect on it, as well as on the rest of prices in the economy.

In a context of target zone, where realignments are allowed, the stability of exchange rate, in the sense of stability of the central parity, will require a mid-term sustainable economic policy. After the 1992 crisis of the European Monetary System (EMS), an enormous literature has been developed. The main tours has been the credibility of the system before the fall. If the macroeconomic policies of the different EMS members are not convergent, achieving exchange rate stability will be almost impossible. The purpose of this paper is to test whether macro objectives affect the evolution of the central parity. To do so, a simple but in our opinion attractive model is formulated and estimated.

The workhorse model in many theoretical and empirical studies of exchange rate determination is some version of the monetary approach to the balance

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of payments and exchange rate determination. For example, Flood and Garber (1984) use the flexible exchange rate version of the monetary approach to solve for a «shadow exchange rate», which is assumed to materialize after a devaluation. In their paper, devaluations are assumed to take place whenever the shadow exchange rate exceeds the peg or whenever foreign exchange reserves hit a certain minimum level.

This paper's analysis is concerned with changes in the target zone itself: it is a study of how the central parity is determined. Following Baxter (1987), the target exchange rate (central parity) will be treated as a censored variable, a «shadow peg» which is observed only immediately after devaluations. When the exchange rate is a censored variable, standard econometric procedures will not yield unbiased estimates of the parameters of the reaction function determining the size of devaluations. Baxter therefore suggests that Heckman's (1976) two-step estimator be used.

In the paper of Edin and Vredin (1993), the central parity is treated as a censored variable, which is changed only if the shadow floating rate observed deviates too much from the prevailing central parity. It is also assumed that when a devaluation occurs the new central parity is the «equilibrium parity». This is an assumption that has been borrowed from the models which analyze the change from a fixed exchange rate system to a floating exchange rate system. In this kind of models, when the exchange rate abandons the discipline of a fixed system and it starts to float freely, it achieves its equilibrium value.

The model presented in this paper assumes that devaluations take place whenever the cost that the central bank has to bear in order to keep the prevailing central parity is bigger than a threshold. This is a model of the «escape-clause» kind. The idea behind this kind of models is the following: when a currency enters a target zone the central bank has to defend the prevailing parity. Let us assume that there is a high probability of a large adverse shock to the economy occurring in the next period. As long as the central bank has other macro economic objectives apart from the exchange rate, when these objectives are under threat, incentives to deviate from the agreement and devaluate appear. When a devaluation occurs a new central parity that depends on macro fundamentals is fixed, but in our model this new parity does not have to be the equilibrium one. Indeed the experience of the EMS shows us that a devaluation is not always enough to correct macro disequilibria and a new devaluation sometimes occurs a few months after the first one.

The model presented in this paper a generalization of the one formulated by Edin and Vredin, because it allows for different specifications of the selection equation, which determines the probability of a devaluation, and the reaction function determining the size of devaluations.

Maybe the best known approach to changes in exchange rates within target zones is the one suggested by Bertola and Svensson (1990). Svensson and

Rose (1993) use a new version of this approach. The starting point is the uncovered interest parity (UIP) condition. They distinguish between changes in the central parity and changes within the band. Using an autoregressive process, they estimate the expected intramarginal changes of the exchange rate. Subtracting this estimation from the differential of interest rates, they get the expected change in the central parity (an estimation of the product of the probability and size of the devaluation). In this case a strong implicit assumption is needed: the jump in the deviation of the exchange rate with respect to the central parity is equal to the size of the realignment. A similar procedure is used in Chen and Giovannini (1993). The main advantage of the approach used in this paper is that it allows us to get an estimation of time series of both the probability and the size of realignment, and that it does not have to rely on the UIP condition.

The model is formulated in Section [2]. Section [3] contains the results of the estimation. The main conclusions are summarized in Section [4].

2. An econometric model of devaluations

A simple policy rule for setting the central parity, S, can be defined as:

$$S_t = \begin{cases} S^*_t & \text{if} \quad C_t > c \\ S_{t-1} & \text{if} \quad C_t \leq c \end{cases} \qquad [1]$$

where C_t indicates the cost that the central bank has to carry in order to keep the prevailing parity S_{t-1}, and evolves according to the following process.

$$C_t = a + \beta' X_{t-1} + u_t \qquad [2]$$

where X_{t-1} is a vector of macroeconomic objectives. It is affected by a stochastic shock u_t, assumed to be independently and identically normally distributed. «c» is the threshold cost, that is, the cost that the monetary authority is willing to assume in order to defend the parity. We will assume that the central bank sets the target exchange rate according to the following rule.

$$S^*_t = S^*_\tau + \delta' \sum_{i=\tau+1}^{t-1} \Delta Y_i + v_t \qquad [3]$$

where S^*_τ is the target exchange rate fixed during the last devaluation, which took place at time τ. Given that no other devaluation has occurred since then, S^*_τ is equal to the prevailing exchange rate. The current target also depends on the rate of change of some fundamental variables, accumulated since the last realignment. Under the standard assumptions in monetary and target zone models, the vector Y is determined by factors affecting money supply and money demand. v_t is an iid random shock, also normally distributed. v_t and u_t are assumed to have a joint normal distribution.

Writing the model in terms of realignments, with $R_t = S_t - S_{t-1}$, and using [1] and [2] we get

$$R_t = \begin{cases} \delta' \sum_{i=\tau+1}^{t-1} \Delta Y_i + v_t & if\, I_t > 0 \\ 0 & if\, I_t \leq 0 \end{cases} \quad [4]$$

where $I_t = \alpha + \beta' X_{t-1} + u_t$ and $\alpha = a - c$. Using equation [4], the expected realignment is

$$E_{t-1}(R_t \mid I_t > 0) = \delta' \sum_{i=\tau+1}^{t-1} \Delta Y_i + E_{t-1}(v_t \mid I_t > 0) \quad [5]$$

The last term in equation [5] is non-null, which generates a sample selection problem.

In order to solve this problem, the probability of a devaluation is estimated in a first step. These first step estimates are then used to compute a correction term to account for sample selection bias in the second step, when observations with positive values of R_t are used to estimate the size of the devaluation. This procedure will now be briefly described.

The probability of a devaluation occuring at time t, based on the information available at time t_{-1} is:

$$Pr(I_t > 0) = Pr(u_t > -H_t) \quad [6]$$

where $H_t = \alpha + \beta' X_{t-1}$. Under the assumption of normality of u, [6] can be estimated as a Probit Model by Maximum Likelihood (ML). This constitutes the first step of the estimation procedure. Clearly, since $E_{t-1}(v_t \mid I_t > 0) = E_{t-1}(v_t \mid u_t > -H_t)$, the residual in a regression of R_t against the accumulated rate of change of Y_t, will be correlated with the explanatory variables. That is due to the fact that the disturbances affecting the cost of defending the parity will be correlated with the disturbances affecting the shadow floating rate. By using the formulae for the mean of a truncated normal distribution we can however rewrite [5] as

$$E_{t-1}(R_t \mid I_t > 0) = \delta' \sum_{i=\tau+1}^{t-1} \Delta Y_i + \sigma \lambda_{t-1} \quad [7]$$

where $\lambda = \varphi (H / \sigma) / \Phi (H / \sigma)$, Φ is the standard normal cumulative distribution function, φ the associated density function, and σ the ratio between the covariance of the disturbances v and u and the standard deviation of u. The correction term λ is often called «Heckman's lambda». To apply the Heckman two-stage procedure we thus start by obtaining estimates of $(\hat{H/\sigma})$ from [6], by the Probit method. These estimates are used to calculate $\hat{\lambda}_{t-1}$, which is used in place of λ_{t-1} in [7]. Using only observations with positive values of R_t, i.e. devaluations only, [7] can be estimated by Ordinary Least Squares (OLS) [1].

The unconditional expectation of the rate of devaluation in period t can obviously be obtained from the two-stage procedure discussed above as the product of the probability of a devaluation, given in the first step, and the conditional expectation of the rate of devaluation which results from the estimates of the policy rule in the second step.

$$E_{t-1} (R_t) = Pr (I_t > 0) E_{t-1} (R_t \mid I_t > 0) \qquad [8]$$

3. Empirical results

The empirical estimates of the model of devaluations are based on pooled monthly data for Belgium, Denmark, France, Italy and the Netherlands for the (maximum) sample period 1981: 2-1992: 9. These countries belonged to the EMS since its origin in 1979. Unfortunately, data for Irish Euromarket interest rates are not available until 1983, so data for this country have not been used for the estimation. The sample starts in 1981 because some data series are not available for previous years. All variables, except country dummies, interest rates and the current account balance as a percentage of GDP, are in logs. Since this paper is concerned with the realignments, central parity data are used instead of observed exchange rates.

Empirical estimates of the probability of a devaluation are presented in Table 1 for the period 1981: 3-1992: 10, moment at which the Italian Lira abandoned the EMS. The variables which are considered to be determinants of the cost assumed by the central bank in order to defend the central parity are: the rate of change of the money supply (Δm), the rate of change of the unemployment rate (Δu), both is terms of the rates of change of the same variables for Germany, the interest rate differential in monthly Euromarket interest rate ($i-i^*$), the rate of change of the real exchange rate against the Deutsche mark (Δq), current account balance as a percentage of GDP (Bcc), and the differential of inflation accumulated since the last realignment ($\Sigma (\pi-\pi^*)$). The reason for using this variable is that EMS countries try to use the discipline imposed by the system as a way to fight inflation, but if their cumulative rate of inflation does not converge to the

[1] Note that our formulation considers that both the cost that the central bank incurs in order to defend de parity, and the target central parity, depend on lagged macroeconomic variables. This assumption can be justified on the basis that unemployment, consumer prices, etc. are known with some delay.

German one, there will be a strong pressure to devaluate. Variables are used in growth rates instead of levels because it is thought that a central bank cares much more about the fact that its country's unemployment rate, for example, grows faster than German unemployment rate, than it does about its relative level.

These are, in general, the standard variables considered in a monetary model of determination of exchange rates. The typical equation on this model specifies the relative value of two currencies as a function of the difference between some macrofundamentals in the two countries. One of them is obviously the GDP. Unfortunately, monthly data are not available. We use unemployment as a proxy for this variable.

Countries are assumed to differ only in their intercepts. This is modeled by country dummies. This simplification is dictated by the small number of devaluations in the sample. A dummy that controls for the period known as the "New EMS" (1987: 2-1992: 6, dates of the last general realignment and of the Danish referendum on the Maastricht Treaty, respectively) is also used.

TABLE 1
Determinants of the probability of devaluation
Pobit estimation

Independent variables	$Pr\ (I_t > 0)$	Standard error
Intercept	2.3	0.384
New EMS	−0.994	0.387
Belgium	0.317	0.472
Denmark	0.318	0.469
France	−0.026	0.531
Italy	0.155	0.535
Δm_{t-1}	0.606	2.453
Δu_{t-1}	6.806	6.914
Δq_{t-1}	27.119	29.718
$(i-i^*)_{t-1}$	0.054	0.025
$(\Sigma\,\pi-\pi^*)_{t-1}$	0.055	0.027
Bcc_{t-1}	−0.055	0.007
Ln L	−90.686	
N	700	
No. of devaluations	27	

The variables which have a significant influence on the probability of a devaluation are the differential of interest rates, the differential of inflation accumulated since the last realignment, and the current account balance as a percentage of GDP. In all cases, even for the variables that do not appear to be significant, the signs of the parameters are those predicted by economic theory. The dummy of New EMS is also significant. An explanation for this fact is that during this period there is a stronger political pressure to defend the parity, so central banks are willing to bear a bigger cost in terms of macro objectives, and so the probability of a devaluation is lower (ceteris paribus).

Table 2 presents the results of a simulation that tries to show how the probability of a devaluation reacts when there is a change in some of the variables that affect it. For this an "average country" has been used, defined by the time and country means of the variables.

TABLE 2
Simulation of the probability of devaluation

	1981: 03 1987: 01	1978: 02 1992: 10 (New EMS)
Probability of a devaluation (percentage points)	2.05	0.24
Change of the probability when there is a 10% increase in macroeconomic variables.		
$\Sigma(\pi-\pi^*)_{t-1}$	3.8	3.9
$(i-i^*)_{t-1}$	4.8	4.9
Bcc_{t-1}	−0.46	−0.46

Looking at these results, one can see that the main macro determinant of the probability of a devaluation is the differential of interest rates, followed by the differential of inflation accumulated since the last realignment.

In the second stage, the variables which are considered to be determinants of the target central parity are basically the ones used by Edin and Vredin in their paper: the unemployment rate, and the money supply (both in terms of the same variables for the German Economy), the real exchange rate against the Deutsche mark and German interest rate.

The sum of the first differences of these variables, accumulated since the last realignment, and the estimation of λ obtained in the first stage, have been used to estimate equation [8]. Our sample includes 26 observations of devaluations. The results are presented in Table 3. The first column of this table shows the results of the estimation using country dummies, which try to control for institutional features different in each country. The second column shows the results of the estimation suppressing the dummies. Results are almost identical in both formulations.

TABLE 3
Determinants of the size of realignment
OLS estimation with correction term for sample selection

Independent variables	$S^{*}_{t} - S_{t-1}$	$S^{*}_{t} - S_{t-1}$
Intercept	0.064	0.07
	[7.112]	[5.599]
Belgium	−0.008	
	[−1.314]	
Denmark	−0.003	
	[−1.164]	
France	0.02	
	[2.013]	
Italy	0.011	
	[2.691]	
λ	−0.021	−0.022
	[−4.954]	[−3.748]
$\Sigma\Delta q$	−0.05	0.01
	[−0.955]	[−0.201]
$\Sigma\Delta m$	−0.014	−0.021
	[−2.032]	[−1.963]
$\Sigma\Delta u$	−0.018	−0.005
	[−0.926]	[−0.267]
$\Sigma\Delta i^{*}$	0.004	0.003
	[4.831]	[2.854]
Adjusted R^2	0.585	0.312
N	26	26
No. of devaluations	26	26

[ ] T-satistics constructed with White standard errors.

The variables which have a significant influence on the size of devaluations are the accumulated change of the German interest rate and the first stage estimation of lambda. The significant effect of the Heckman's lambda denotes the importance of accounting for sample selection in the model. Money supply is not significant at the 5% level, but it is at 10%.

The same equation was estimated using the accumulated differential of inflation instead of the accumulated change of the real exchange rate, and in no case was this variable significant. Looking at these results, it seems that monetary authorities do not use devaluations as a way to eliminate accumulated competitiveness losses. The negative sign of the money supply can be interpreted in two ways. It is likely that during the months previous to devaluations, the central bank undertakes tight monetary policies in order to defend the parity, but this negative sign could also be understood as a self-imposed penalty. If the problems with the exchange rate are due to a loose monetary policy, the central bank imposes self-discipline constraining the size of the devaluation.

We also estimated the size of realignment using the explanatory variables in levels, as in Edin and Vredin (1993). A priori, we did not see any advantage in using this specification. Economic intuition suggests that for estimating devaluations, we should look at the evolution of macrofundamentals since the last adjustment in the central parity, and not just to what happened in the previous month. Econometrics results confirmed this intuition. Country dummies were the variables with the biggest explanatory power. If removed from the estimation no economic variable was significant[2].

Times series of the probability of a devaluation, and the unconditional expectation of the size of realignment have been calculated. Using the estimations in Tables 1 and 3 (with country dummies). The unconditional expectation of the size of realignment is calculated as specified in equation [8], ie the product of the probability of devaluation and the expected size of the realignment. These estimations have been plotted in Figures 1-10. The profile of the estimates seems to track reasonably well the evolution of the central parity.

The fact that macro fundamentals do not appear to have a significant influence on the devaluation size[3], reinforces the idea that the new central parity is different from the equilibrium one. Adjustments within the EMS have been usually done using more than one devaluation, like a partial adjustment process, so this is a potential reason explaining why the probability equation works better than the equation determining the size of the devaluation, since the latter does not depend very much on macro fundamentals. This is not a surprising result. If realignments depend somehow on macro fundamentals, it seems reasonable to think that this relationship appears via probability of devaluation. The size of realignment can be smaller than the one required to reequilibrate fundamentals since exchange rate can move within the band.

The empirical results of this paper are in accordance with Bertola and Svensson (1990), Edin and Vredin (1993), Svensson and Rose (1993) and Ayuso *et al.* (1993). Fundamentals seem to play a role in the determination of realignments although results are not very encouraging. A difference with

[2] Dummy variables control for the "fixed effects". Nevertheless we are interested in estimating the coefficients of the macrofundamentals. Differencing the equation allows us to get an alternative consistent estimators without the dummies.

[3] We estimated the size of realignment using alternative sets of variables. In all cases the estimation of lambda from the first stage was significant, but the fit of the second stage regression was always poor.

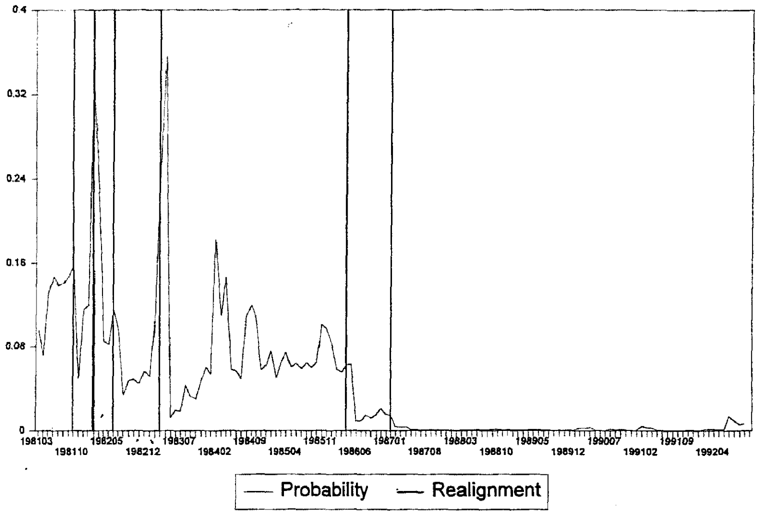

Figure 1
Estimated probability of realignment
Belgium

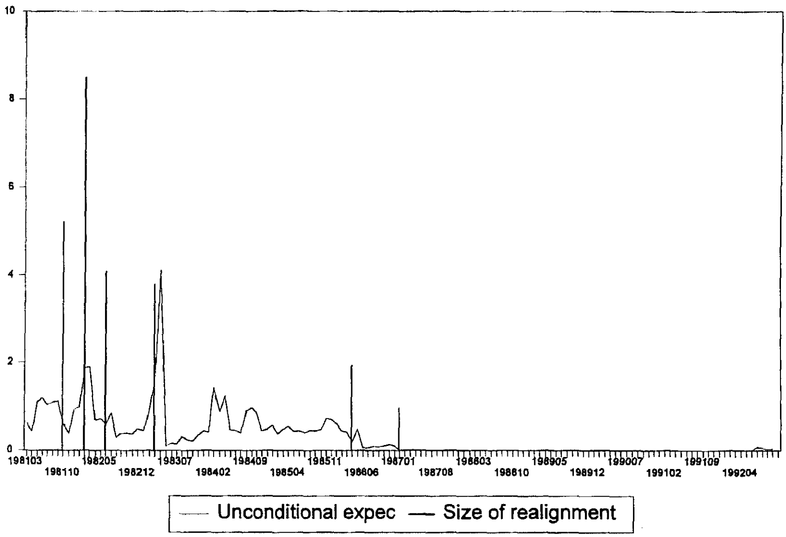

Figure 2
Expected size of realignment
Belgium

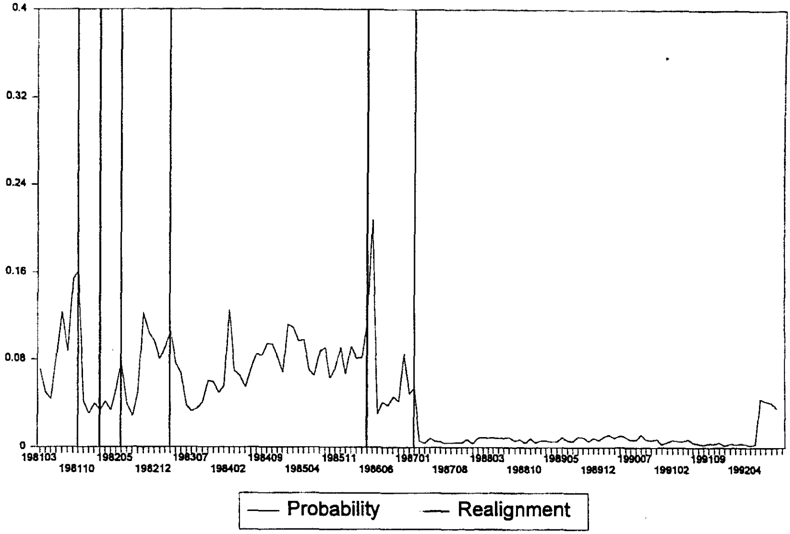

Figure 3
Estimated probability of realignment
Denmark

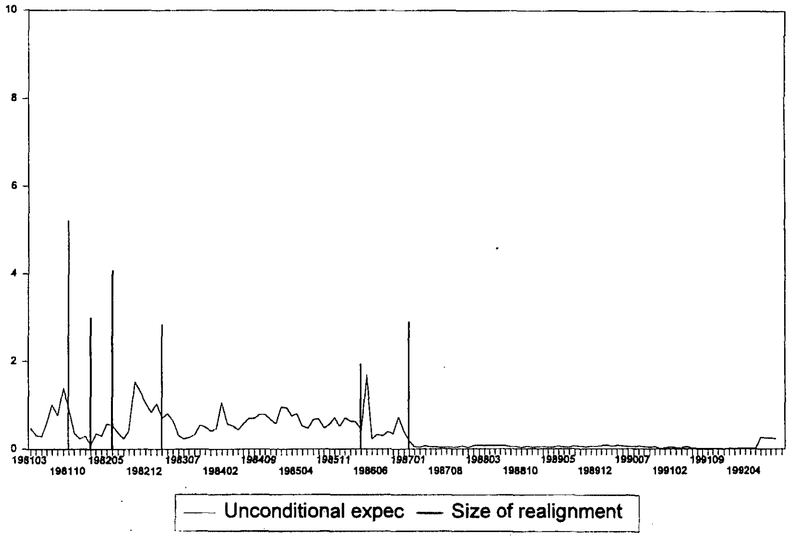

Figure 4
Expected size of realignment
Denmark

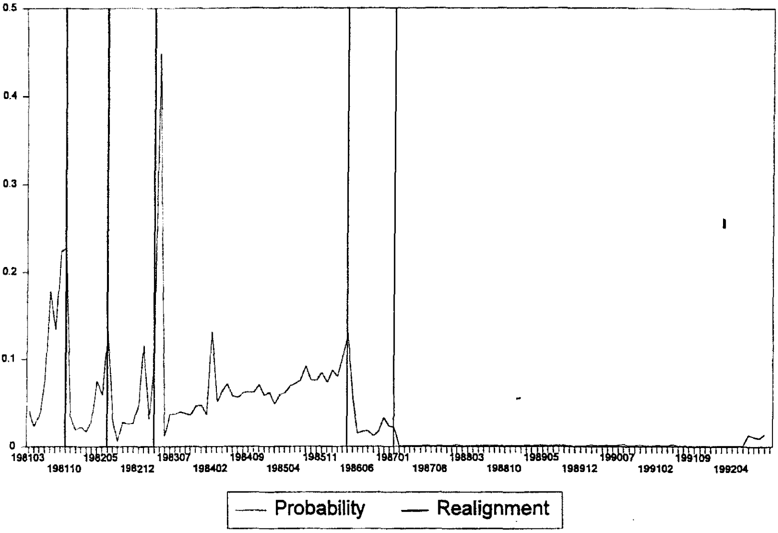

Figure 5
Estimated probability of realignment
France

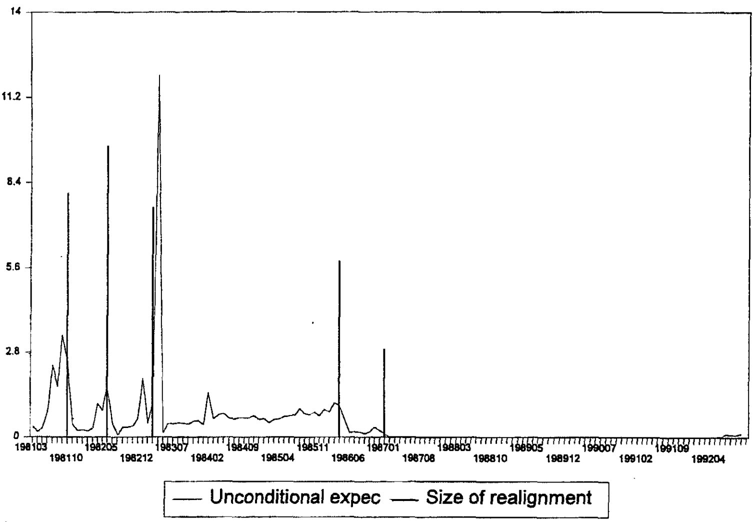

Figure 6
Expected size of realignment
France

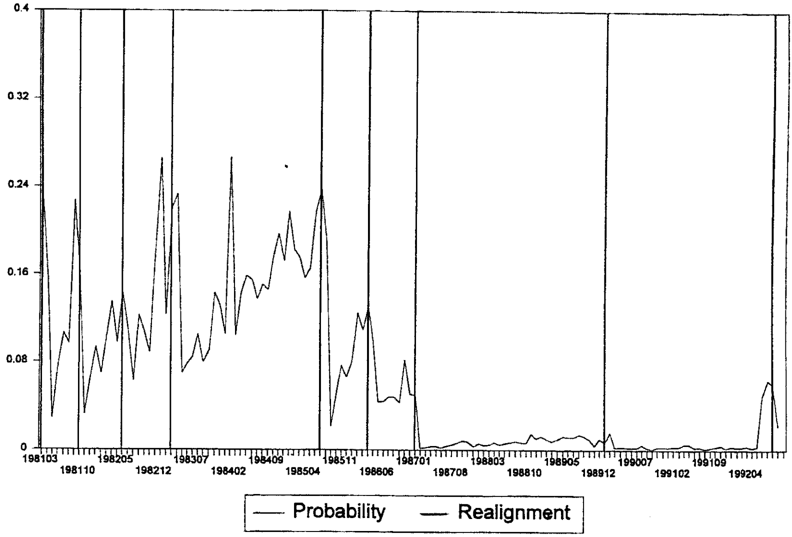

Figure 7
Estimated probability of realignment
Italy

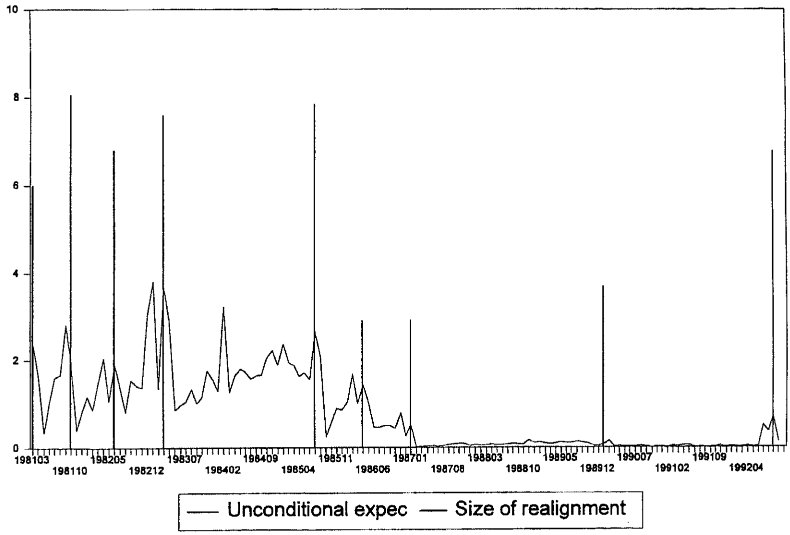

Figure 8
Expected size of realignment
Italy

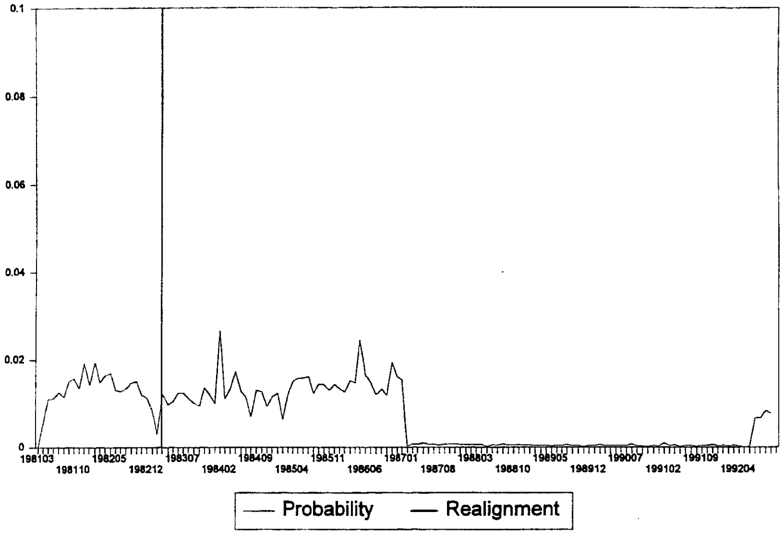

Figure 9
Estimated probability of realignment
The Netherlands

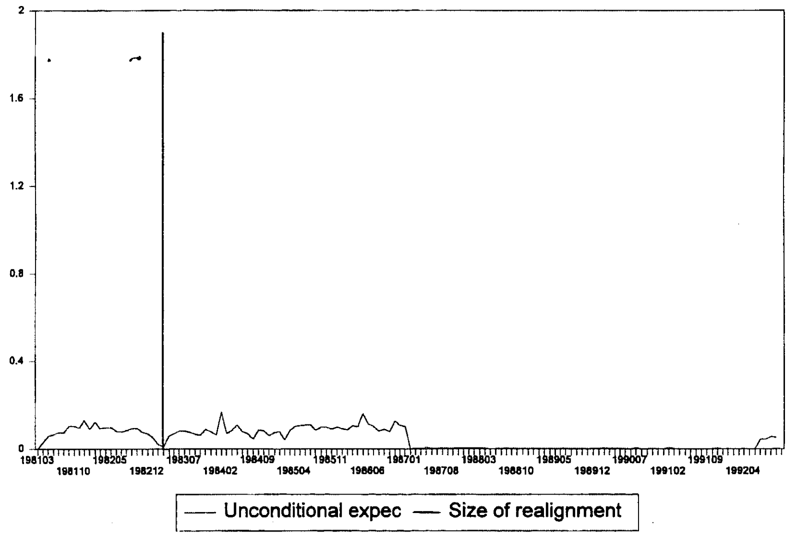

Figure 10
Expected size of realignment
The Netherlands

some of these papers is that since we distinguish between probability and expected size of the realignment, we suggest they affect devaluations via the probability equation.

4. Conclusions

From the results obtained we can infer that the use of a two stage procedure seems to be a correct approach to model devaluations. Nevertheless, the theoretical framework of this kind has some limitations. These are partial equilibrium models because devaluations are decided only by central banks. A richer model would include the other side of the market, that is, private investors who try to maximize the expected value of their investments in foreign currency, and who can force monetary authorities to devalue. Devaluations can have their origin not in macro desequilibria but in speculative attacks, which are left out of this model.

As previously noted, the main advantage of the approach used in this paper is that we can get an estimation of time series of both the probability and the size of devaluations, without relying on the UIP condition. Nevertheless this is not made at no cost. In particular, the assumption of normality of the disturbances is needed.

One of the innovations of this paper is that different rules for the probability and the size of a devaluation are allowed for. This modification enriches the econometric estimation by considering different sets of variables in the two equations. On the other hand, estimating the model in terms of rates of change accumulated since the last realignment improves the empirical results.

The main economic conclusion of this paper is that fundamentals seem to play a role in the determination of realignments-although results are not very encouraging. In particular, our results suggest that they affect devaluations via the probability equation. Devaluations in the EMS seem to follow a partial adjustment process. This could be the reason why macro fundamentals do not appear to be relevant for the size of the devaluation. Central banks do not correct all the disequilibria in the exchange rate with just one devaluation, and so they typically have to devaluate again.

Appendix 1

The data used in this paper have been kindly provided by the Banco de España, and they come from different databases; the OCDE, the BIS, etc.

Real exchange rate series have been built using the series of nominal exchange rates and prices (real exchange rate increases mean real appreciations). Interest rate and central parity data are monthly means of daily observations. Price indices have a base 1985=100. Series of prices, unemployment, real exchange rates, GDP and current account balance have been seasonally adjusted using an ARIMA X11 procedure. The main reason for doing this is that some series provided by the Banco de España were seasonally adjusted and some others were not. In any event, in this context this kind of adjustment seems reasonably. The idea is that central banks do not devalue when there is a seasonal change in macro variables. When the frequency of observations was not monthy, the data have been transformed by dividing by three in case of quarterly series (current account balance and GDP series), and dividing by twelve in case of annual series (GDP series for some countries).

References

Ayuso, J.; Pérez Jurado, M. and Restoy, F. (1993): «*Credibility indicators of an exchange-rate regime: the case of the peseta in the ERM*», Boletín Económico, Banco de España, July.

Baxter, M. (1987): «Rational expectations models with censored variables», University of Rochester, Working Paper 89 (revised August 1990).

Chen, Z. and Giovannini, A. (1993): «The determinants of realignment expectations under the EMS: Some empirical regularities», Center for Economic Policy Research, Discussion Paper 790.

Edin, P. and Vredin, A. (1993): «Devaluation risk in target zones: evidence from the Nordic countries», *Economic Journal* 103, pp. 161-175.

Flood, R. P. and Garber, P. M. (1984): «Collapsing exchange rate regimes. Some linear examples», *Journal of International Economics* 17, pp. 1-13.

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, pp. 475-492.

Rose, A. and Svensson, L. (1993): «European exchange rate credibility before the fall», National Bureau of Economic Research, Working Paper 4495.

Resumen

El objetivo de este artículo es formular y estimar un modelo de devaluaciones en un contexto de bandas de tipo de cambio. La hipótesis principal es que los realineamientos en la paridad central son consecuencia de la evolución de los fundamentos macroeconómicos. La paridad objetivo es una variable censurada, sólo observable cuando se produce una devaluación. La estimación se realiza usando un procedimiento bietápico, que proporciona estimadores insesgados y permite calcular series temporales de la probabilidad y tamaño de los realineamientos. El resultado de las estimaciones indica que los fundamentos macroeconómicos afectan principalmente a la probabilidad de devaluación, pero no parecen excesivamente relevantes en la determinación del tamaño de la misma.

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