MEMORANDUM

No 16/2002

A DRIFT OF THE "DRIFT ADJUSTMENT METHOD"

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ISSN: 0801-1117

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A DRIFT OF THE "DRIFT ADJUSTMENT METHOD"*

by

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JEL classification: F31
Key words: Currency bands; realignments; drift adjustment method; regime switches.

This version: 8 May 2002

ABSTRACT

This paper shows why regressing the realised rates of depreciation within the exchange rate band on a given information set and conditional on (ex-post) actual no-realignment (à la drift adjustment) still encounters a "Peso Problem". Such a procedure generally gives inconsistent estimates. The main reason is that the frequency of realignments in the data need no coincide with the frequency of the subjective (even small) probabilities that a realignment may take place. These probabilities cause jumps in the exchange rate even when it is conditional on actual no-realignment. When using an alternative approach that takes care of the peso problem and provides consistent estimates of the expected rate of realignment, we find that our estimates of the expected realignment (devaluation) rates are always greater than the ones obtained using the drift adjustment method.

* I would like to thank an anonymous referee for very useful comments that led to a great improvement of the paper, and to Jon Strand for comments and suggestions. I benefited from the comments of Oded Stark to an earlier version of this paper. I would also like to thanks people at Citigroup, Citibank, specially Mohsen Enayatollah and Robert R. Cox, for providing the data on option prices, and to Hetty Colchester for discussions on option markets.

1. Introduction

Countries in the ERM and the Nordic countries have had over the period 1979-1993 essentially exchange rate systems of fixed but adjustable parities. Reasonably, market participants must have assigned subjective probabilities to the event that realignments could have taken place. Studies of monetary regimes, even past ones, will always be important for assessing the degree of credibility of these regimes and the predictability and anticipation of crises in such regimes. This is useful for policy makers and the public in order to establish certain criteria for succeeding in future monetary arrangements. By now, most countries have adopted other monetary policy regimes (i.e.inflation targeting), but studies measuring realignment/devaluation expectations of past regimes are still of interest and are being done. For example, Hallwood, MacDonald and Marsh (2000) estimate the dollar-sterling exchange rate expectations for the years between 1890 and 1908. One of the purposes of this paper is to suggest a methodology for estimating the expected exchange rate depreciation within its band for exchange band regimes. We draw attention to a possible drawback of the widely used drift-adjustment method. This is used to obtain estimates of the expectations about realignment/devaluation and depreciation within the band in exchange rate band regimes. We show that this method cannot give consistent estimates.[1] An alternative procedure that provides consistent estimates is here then suggested. At the outset, we should mention that our estimates of the expected realignment (devaluation) rates are always greater than the ones obtained using the drift adjustment method.

The "drift-adjustment" method, suggested by Bertola and Svensson (1993) has been applied widely, to mention just a few, by Caramazza (1993), Chen and Giovannini (1995), Lindberg, Svensson and Söderlind (1993), Svensson (1993), Rose and Svensson (1991, 1994). Hallwood

[1] An estimator, t_n, is consistent if by increasing the sample size it can be made to lie arbitrarily close to the true value, Θ, with a probability arbitrarily close to one. This is often denoted by $\text{plim}_{n\to\infty} t_n = \Theta$ where plim stands for probability limit.

et. al (2000) argue that they used the drift adjustment method to estimate realignment or devaluation expectations of the exchange rates in the classical gold standard period in the context of the target zone literature, because Svensson (1992) has suggested that all important regimes of the international monetary system in which exchange rate fixity are the *modus operandi* can be analysed using a target zone framework.[2]

The literature on the target-zone model, initiated by Krugman (1991), explains the exchange rate dynamics in regimes where the authorities could credibly commit themselves to an explicit exchange rate target zone.[3] Credibility, in this context, means that the target zone stabilises expectations on the existing parity because the market expects the monetary authorities to wish and be able to defend the exchange rate parity. That is, if the exchange rate moves toward the weak (strong) end of the band, the market participants will expect the authorities to intervene (either by selling (buying) foreign currency or changing domestic interest rates) to drive the exchange rate in the direction of the central parity.[4] Moreover, Svensson (1991) showed that under the assumption of uncovered interest parity (UIP) and perfect credibility, there will be a negative and deterministic relationship between the exchange rate position in the band and the interest rate differential. A weak (strong) exchange rate close to the upper (lower) boundary of the band will give rise to expectations of appreciation (depreciation), and we should therefore observe a negative (positive) interest rate differential. The empirical literature has contradicted many of these results and found that exchange rate band regimes in many countries have often not been credible as the theory predicts.[5]

Later on, Bertola and Svensson (1993) argued that the relationship between interest rate differential and exchange rate is not deterministic. They pointed out that the interest rate differential

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[2] This implies that the drift-adjustment method should be also use to estimate realignment expectations.
[3] Svensson(1992a) and Bertola(1994) give good surveys of the literature.
[4] This is the so called mean reversion effect.

[5] Lysebo and Mundaca (1994) for example show that the relationship between the interest rate differential and the

itself may be a misleading measure of realignment expectations and credibility because they also include the expectations of depreciation (appreciation) within the band. They suggest that with their drift adjustment procedure, the interest rate differential should be adjusted for the expected rate of depreciation within the band, to obtain then a measure of devaluation expectations in an exchange rate band regime. The expected rate of depreciation within the band is obtained by regressing the realised rates of depreciation within the band conditional on no-realignment,[6] on for example, the exchange rate deviation from its central parity, and the domestic and foreign interest rate.

In contrast to the studies using the drift-adjustment method, we first assume that market participants form expectations about future changes in the exchange rate within the band and consequently about realignment rates, conditional on the full information set: With realignment and no-realignment possibilities and realisations. Second, the market considers that either of two equilibrium outcomes (states) for the exchange rate may occur with certain probabilities. Third, we realistically assume that changes in monetary policy and in the economic fundamentals may cause expectations to shift, and thus induce switches between possible states of the stochastic process of the exchange rate. The states considered here are a high-volatility state (regime 1) and a low-volatility state (regime 2).[7] The probabilities of the transition from one equilibrium to another are modelled as endogenous, contrary to what is more commonly assumed.[8] To test the role

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exchange rate depends on the width of the currency band that the central bank is actually defending.

6 This implies that the observations at which a realignment of the currency band occurs should be excluded from the sample used to estimate the expected changes of the exchange rate within the band conditional on no-realignment. We will explain below more about this issue.

7 The characterisation of the regimes may sound arbitrary. As it will clear later, the name of the regimes is not as crucial as the qualitative characteristics of the regimes as such since these lead us to the relevant conclusions. Moreover, at this point we do not need to characterise high-volatility with non-credible exchange rate band (Bertola and Caballero (1992). It will be rather our empirical results that will lead us to find out which of the exchange rate bands of the countries we study here are credible or not.

8 Diebold, Lee and Weinbach (1994) introduced the modelling of transition probabilities as endogenous.

of monetary policy, these probabilities will depend on interest rate differentials. For Britain, these probabilities will also depend on the implied volatilities that represent the daily price quotes of over-the-counter (OTC) European-style options expiring in one month and three months on the British pound against the German mark. Unfortunately for the countries and periods we here consider no data on cross-rate options are available.

The methodology presented here is the one of Hamilton (1989). As explained in the next section, it effectively takes into account the “peso problem” that arises when estimating expected changes in the exchange rate within the band. This is an issue that has been disregarded in the relevant literature. In particular, Chen and Giovannini (1992) and Svensson (1993) only briefly mention how the peso problem arises when one wishes to estimate the expected depreciation of the exchange rate within the band and realignment rates. [9]

That the market can switch expectations about the realisation of the exchange rate process is in line with the second-generation models of currency crises pioneered by Obstfeld (1986, 1994). (See Eichengreen et. al (1996) for a survey on this type of modelling.) These models embody the possibility of multiple equilibria whereby one equilibrium with a stable exchange rate exists alongside with another equilibrium where the peg or the currency band is abandoned. Thus, the government is either successful in defending the exchange rate regime against speculative attacks and then maintains it, or immediately and ultimately succumbs the attack, resulting in a change in the exchange rate regime. The latter is the case when devaluation expectations are reinforced, and validated or self-fulfilled by the monetary policy authorities.

The model is tested using daily data on the French Franc, the British pound, the Norwegian Krone

[9] Chen and Giovannini (1992) have also argued that the conditional expectation of the exchange rate cannot, in general be correctly estimated from the data even with realignment observations excluded from the sample. This is so because the possibility of a future realignment should be "priced" by the market under rational expectations, and the sample of the exchange rate is conditional on both realignment and no-realignment possibilities or states.

and the Swedish Krone, their corresponding interest rate differentials and the cross-rate between the pound and the mark option. We here consider the relevant currency band for each currency to be one defended against the monetary anchor. For Nordic currencies outside the EMS such as the Swedish Krone and the Norwegian Krone until the turmoil of the European currency markets in the fall of 1992, the monetary anchors were during our first period of study, a basket of currencies, thereafter the ECU. This paper builds on a commonly accepted feature of the ERM, that the German Mark was used as the anchor for the ERM participants.[10]

Foreign exchange options provide a significant expansion in the available risk-control and speculative instruments for a vital source of risk, namely foreign currency values.[11] The options approach uses current market-determined prices that reflect the market's volatility future forecast or the so-called implied volatility. Thus, the price of currency options depends on the exchange rate's second moment rather than on its first. If the options market is efficient and the option-pricing model is correct, the implied volatility then provides an unbiased estimate of ex ante spot exchange rate volatility. The implied volatilities of the OTC options price the market's most traded instrument: At-the-money-forward straddles. A straddle consists of a call and put with the same strike price and equal to the forward exchange rate of the same maturity.[12]

The structure of this paper is as follows. Section 2 reviews the relevant literature. Section 3 discusses briefly the drift adjustment method. In section 4, we present our econometric model. Section 5 explains the data and the empirical results for the chosen ERM and Nordic currencies. Section 6 concludes.

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[10] See for example Giavazzi and Giovannini (1989).

[11] Options are derivatives or contingent claims. The simplest option gives the holder the *right* to trade in the future at a previously agreed price but takes away the obligation. So if the stock falls, we don't have to buy it after all. A ***call (put)*** option is the right to ***buy (sell)*** a particular asset for an agreed amount at a specified time in the future.

[12] ***Over-the-counter*** contracts imply that some options are an agreement between two parties, often brought together by an intermediary. The agreements can be very flexible and the contract details do not need to satisfy any conventions. ***At-the-money*** is a call or put with a strike that is close to the current asset level. The ***strike price*** is the

2. Background to the literature

Regime switching in foreign exchange markets has been modelled by Engel and Hamilton (1990), Bekaert and Hodrick (1993), Weinbach (1998), Mundaca (2000), among others. Estimations of realignment/devaluation expectations have mostly been done using the drift-adjustment methods. Lately, such estimations have been also done using data on over-the-counter options for different European currencies by means of other methodologies, e.g. Malz (1996), and Campa and Chang (1996,1998). The only theoretical papers modelling option prices in credible target zones are Dumas, Jennergren and Näslund (1993) and Ingersoll (1996); while option prices in target zones with realignment risk are studied by Dumas, Jennergren and Näslund (1995) and Ball and Roma (1990).

Girardin and Marimoutou (1997) also analyse empirically the credibility of the French franc-German mark from January 2, 1989 to February 1, 1993, using daily data. They show that the error term in any regression for estimating the expected change of the exchange rate within the band (even conditional on no realignment) is necessarily regulated by upper and lower bound of the currency band. This error term will then be correlated with policy variables that are used to maintain the exchange rate away from the edges of its band (e.g. interest rate differentials). To correct for this, they estimate the expected rate of depreciation inside the band by maximising a likelihood function of a rational expectations censored Tobit model. The truncation of the exchange rate is on the upper bound of the currency band. Note however that in spite of the truncation, a peso problem is still present in their estimates. Market may have had expectations that the upper bound will change and this is not taken into account in their estimates. Their estimates then depend on having no-realignment expectations. They find that a substantial increase in the expected rate of devaluation

amount for which the underlying (i.e.currency) can be bought (call) or sold (put) (Wilmott (2000)).

occurred due both to a fall in the expected rate of depreciation, and to a rise in the interest rate differential. Between January 1989 and the early fall of 1992, the expected rate of devaluation was highly stable but credibility collapsed in September 1992.

Campa and Chang (1996,1998) introduce arbitrage-based tests of target-zone credibility using prices on intra-ERM cross-rate options, covering September 1991 to August 1994. They use daily price quotes of OTC European-style options expiring in 3 and 6 months on the British Pound-German Mark, German Mark-French Franc, German Mark-Italian Lira and German Mark-Spanish peseta exchange rates. They derive a minimum bound on the market's perceived "intensity of realignment", a composite of future exchange rate realisation outside the band, weighted by their respective probabilities.

The tests in Campa and Chang (1996) indicate that for certain periods the mark ceiling against the lira was not fully credible, but they are unable to reject credibility of the pound-mark band until a few weeks before the pound’s devaluation in September 1992. For the mark-franc, credibility is rejected for just over one month around September 1992, and for 4 months between late November and early April 1993. Campa and Chang (1998) find that option data best support a model with endogenous realignment risk where the volatility is greatest at the edges. They regress their minimum "intensity of realignment" against some macroeconomic fundamentals (the same as the one used by Rose and Svensson (1994)). They find, as Rose and Svensson do, that macroeconomic variables are unable to explain patterns in the realignment intensity. They argue that their tests are based on arbitrage rather than on any specific model. This may be an advantage as their tests are then not vulnerable to specification or estimation error. It is important though to notice that their empirical exercises are based only on arbitrage conditions and that no assumptions were made regarding the distribution of the exchange rate.

Malz (1996) uses a jump-diffusion option model to estimate the risk neutral ex-ante realignment probabilities in the pound-mark exchange-rate band. Some structure on the behaviour of the underlying exchange rate is then imposed and a procedure for estimating the market's perceived probability distribution of future exchange rate from prices of risk reversals, strangles and other currency options is suggested. His estimated realignment probabilities for the pound-mark were zero in the spring of 1992, and rose sharply in the second half of August, peaking on September 16. He concludes, as we do also here, that there was probably a shift from one self-fulfilling set of expectations to another as the second-generation models of currency crises suggest. In contrast to Malz (1996), we however find what causes expectations and equilibria to shift. We have no evidence of sunspot equilibria. We find that interest rate differentials explain why there were shifts between self-fulfilling expectations.

3. Inconsistent estimates with the "drift adjustment method"

The drift adjustment method defines:

$$E_t\Delta c_{t+\tau} = \delta_t(\tau) - p_t(\tau)\, E_t[\Delta x_{t+\tau}/\tau dt|I_t,R] - (1 - p_t(\tau))\, E_t[\Delta x_{t+\tau}/\tau dt|I_t,NR]; \qquad (1)$$

$\delta(\tau)$ the interest rate differential between the domestic and foreign interest rates with maturity τ; τ is the maturity such that τdt represents the fraction of the year that corresponds to the maturity. Between time t up to and including time t+τ, there will be expectations of change in (log) of the central parity of the exchange rate band ($E_tc_{t+\tau}$), and expectations of depreciation of the exchange rate within its band ($E_tx_{t+\tau}$),[13] and a probability of realignment $p_t(\tau)$. I_t is the information set available at time t that normally includes all realignment possibilities. R and NR stand for realignment and no-realignment, respectively. Uncovered interest rate parity (UIP) is assumed.[14]

[13] x_t is the deviation of the (log of the) exchange rate (say e_t), from c_t

[14] UIP implies that if the domestic currency is expected to depreciate, interest rates on assets denominated in terms of this currency will exceed those abroad by the expected rate of depreciation.

Note that (1) is derived from the expected realignment:

$$E_t\, \Delta c_{t+\tau}/\tau dt = \delta_t(\tau) - E_t\, \Delta x_{t+\tau}/\tau dt. \quad (2)$$

Whereas data on $\delta(\tau)$ are usually available, data on $E_t\Delta x_{t+\tau}/\tau dt$ are not, and thus estimation of (2) will normally encounter a "Peso Problem". This problem arises because the market may perceive a small probability that realignment may take place inducing a likely jump in $x_{t+\tau}$. $E_t\Delta x_{t+\tau}/\tau dt$ may then contain information about subjective probabilities of realignment. In addition, the data typically show relatively few actual realignments, and the sample distribution of actual realignments may not be representative so as to capture the discrete changes in $x_{t+\tau}$ caused by a non-zero subjective probability of realigment (even when, in fact, no realignment has taken place). Note that those jumps in x cannot be observed directly in the data. It is this Peso Problem which makes estimation of the expected rate of depreciation within the band, and consequently, of the expected realignment rate, difficult.

Rearranging (1) provides:

$$E_t\Delta c_{t+\tau} + p_t(\tau)\ \{E_t[\Delta x_{t+\tau}/\tau dt|I_t,R] - E_t[\Delta x_{t+\tau}/\tau dt|I_t,NR]\} = \delta_t(\tau) - E_t[\Delta x_{t+\tau}/\tau dt|I_t,NR] \quad (3)$$

The left-hand side is termed the expected rate of devaluation. The method mainly consists in how to obtain $E_t[\Delta x_{t+\tau}/\tau dt|I_t,NR]$, the expected depreciation within the band conditional on no realignment occurring between t and t+τ. The method uses the following "trademark" for allowing us to obtain $E_t[\Delta x_{t+\tau}/\tau dt|I_t,NR$:

$$[\Delta x_{t+\tau} \mid NR] \equiv E[\Delta x_{t+\tau} \mid I_t, NR] + \varepsilon_{t+\tau} \mid NR \quad (4)$$

$[(\Delta x_{t+\tau}/\tau dt)|NR]$ is the vector with realised depreciations of the exchange rate within the band but excludes observations around the time when an actual realignment of the exchange rate took place.[15] It is argued that $\varepsilon_{t+\tau}|NR$ is then the error term conditional upon no realignment occurring

[15] In practice, sometimes the observation at the time of realignment is excluded, but observations previous to the time of

between t and $t+\tau$ and should be consequently orthogonal to I_t. I_t may be affected by realignment *possibilities,* but it *does not include* whether or not there will be an *actual* realignment between t and $t+\tau$.[16] $E_t[\Delta x_{t+\tau}/\tau dt|I_t,NR]$ in (4) can be then obtained by regressing ($[\Delta x_{t+\tau}/\tau dt|NR]$ in (4)) on an information set I_t. It is claimed that the "Peso Problem" is not encountered because of the conditionality on no-realignment.

Two comments to relation (4) are in order. *First*, the regression of $[\Delta x_{t+\tau}/\tau dt|NR]$ on I_t would yield the estimated rate of depreciation within the band conditional upon *actual no-realignment* but not conditional upon *no-realignment possibilities* or expectations. Such regression can hardly yield the *expected* changes of the exchange rate conditional on no-realignment taking between t and $t+\tau$, in spite of the rational expectations assumption. Unless we assume that the market and the economist know with probability one when a realignment would have taken place between t and $t+\tau$. The latter assumption is although far from realistic. One cannot guarantee that $[\Delta x_{t+\tau}/\tau dt|NR]$ (as well as $\varepsilon_{t+\tau}|NR$ and $E_t[\Delta x_{t+\tau}/\tau dt|NR,I_t]$) have some information about expectations or possibilities of realignment when none in fact took place. By simply looking at the data we cannot know whether or not there have been such expectations. Thus, $[(\Delta x_{t+\tau}/\tau dt)|NR]$ (à la drift adjustment) is nothing else than changes of the exchange rate when actual realignments did not occur. In order to correctly obtain E_t $[\Delta x_{t+\tau}/\tau dt|NR,I_t]$, the conditioning should also be made on ex-ante (a priori) expectations. The market can have expectations of realignment over extended periods without one actually occurring. The economist cannot turn a blind eye to the possibility that x may jump due to such expectations and

realignment may also be excluded. This is done in order to net out the jump of the exchange rate within the band that usually occurs at the point of realignment (Svensson (1993)). If no realignment takes place during the studied period, no observations are excluded.

[16] I_t is usually assumed to include variables such as, exchange rate deviation from parity, domestic and foreign interest rates.

this should be taken into account and resolve the "peso problem".

Second, even if $E_t[\Delta x_{t+\tau}/\tau dt|NR,I_t]$ (in (4)) does not include information on the possibilities of realignment, from the argument made above, $\varepsilon_{t+\tau}|NR$ need not be orthogonal to prospective realignments and consequently either to I_t. Estimates of $E_t[\Delta x_{t+\tau}/\tau dt|NR,I_t]$ à la drift adjustment method cannot be consistent. An alternative procedure that takes into account the peso problem is needed in order to obtain a consistent estimator of $E_t[\Delta x_{t+\tau}/\tau dt|NR,I_t]$. This should be done independent of whether τ is large or small. As far as we are aware, no related studies have addressed this potential problem. In the next section, I suggest a method for this purpose.[17]

4. An alternative estimation procedure

$E_t[\Delta x_{t+\tau}/\tau dt]$ (in (2)) will be estimated conditional on the full information set (actual and possibilities of realignment). Using Lindgren's (1978) and Hamilton's (1989) model, we assume that there exists an unobserved random variable, s_t, that follows a Markov chain and governs switches between equilibria/states in the exchange rate and takes on the value 1 or 2, with certain probabilities.[18] The values of s_t correspond to the state of high volatility and the state of low volatility, respectively, and characterise the depreciation of the exchange rate within the band at each state and t. We assume that changes in monetary policy and/or economic fundamentals may generate shifts between state 1 and state 2 in the stochastic processes of the exchange rate, as the second generation models of currency crises predict.

At time t, the market knows that the current depreciation within the band is drawn from a

[17] Arguing also that if the period in question contains a "sufficient" number of realignments it should not matter whether $\Delta x_{t+\tau}/\tau dt$ is estimated conditional on realignment or not is troublesome since what is a sufficient number of realignments will always be a subjective judgement.

[18] Consideration of more states will be highly demanding computationally.

mixture of two normal distributions with the following means:

$$\Delta x_t/\tau dt = (x_t - x_{t-\tau})/\tau dt = \mu_i + \eta_t \qquad \text{if } s_t = 1,2; \tag{5}$$

μ_i is the mean in s_t=i while η_t is drawn from a distribution $N(0,\sigma^2_\eta)$.

Assume now that the market observes the current state (either state 1 or 2) and the following two informational possibilities: (a) the market knows exactly when the equilibrium switch will take place (say with probability 1); or (b) the market does not know with certainty when the equilibrium switch will take place, but it does know the current regime s_t.

If (a) were true, taking conditional expectations in (5), we obtain white noise, zero mean forecast errors:

$$\Delta x_{t+\tau}/\tau dt - E_t\Delta x_{t+\tau}/\tau dt = \eta_{t+\tau}, \tag{6}$$

In this specific case, there is no "Peso Problem" to be concerned with. $E_{t-\tau}\Delta x_t/\tau dt$ can be estimated without even needing the conditioning on no-realignment (à la drift adjustment).

However, it is more realistic to assume that the market participants do not know with certainty when the equilibrium switch will take place.[19] We assume that s_t not only follows a two-state, first-order Markov process but also that the transition probabilities that govern its value are affected by certain market fundamentals:

$$p_{11}(t) = p_t(s_{t+\tau} = 1 \mid s_t = 1) = \frac{\exp(\alpha_{10} + \alpha_{11}Z_t)}{1 + \exp(\alpha_{10} + \alpha_{11}Z_t)}$$
$$p_{22}(t) = p_t(s_{t+\tau} = 2 \mid s_t = 2) = \frac{\exp(\alpha_{20} + \alpha_{21}Z_t)}{1 + \exp(\alpha_{20} + \alpha_{21}Z_t)} \tag{7}$$

$p_{11}(t)$ is the probability of remaining in the state of high volatililty (state 1) from date t up to and including $t+\tau$, given being in state 1 at time t, and $p_{22}(t)$ is the probability of remaining in the low

[19] Kaminski's (1993) model, which is an extension of Hamilton's model may also be used. Kaminsky assumes that the market participants do not observe the current regime directly so that the probabilities of being in a certain regime at a certain time need to be estimated as well. This consideration does not affect our argument.

volatility state (state 2) from date t up to and including $t+\tau$, given being in state 2 at time t. If α_{11} and α_{21} are numerically or statistically insignificant, we will have the usual and most common used Markov Switching Model with exogenous probabilities. Equations (7) are logistic functions of the α parameters, while Z_t is the explanatory variable. For all countries considered, Z is the interest rate differential. However for Britain, we also use as explanatory variable the implied volatilities with 1- and 3-month expiration date.[20]

From (5), the exchange rate depreciation process will be in state 1 when it is drawn from the distribution $N(\mu_1,\sigma_1)$; and in state 2 when drawn from the distribution $N(\mu_2,\sigma_2)$. Thus the density function of $\Delta x_t/\tau dt$ conditional upon s_t is:

$$f\left(\frac{\Delta x_t}{\tau dt}\middle| s_t = i;\theta_i\right) = \frac{1}{\sqrt{2\pi\sigma_i^2}} e^{\left(\frac{\{(\Delta x_t / \tau dt) - \mu_i\}^2}{2\sigma_i^2}\right)}; \qquad (8)$$

where $\theta_i = \{\mu_1, \mu_2, \sigma_1^2, \sigma_2^2, \alpha_{10}, \alpha_{11}, \alpha_{20}, \alpha_{22})$, i=1,2.

This conditional density (8) and the transition probabilities defined in (7) are all that is needed to describe the stochastic structure of the switching process. The Exponential Maximisation (EM) algorithm is used to obtain maximum likelihood estimates of the parameters of the model. This algorithm is well documented in Diebold, Lee and Weinbach (1994).

The conditional expectations of the future changes in the exchange rate within the band for the two states are given as follows:

If $s_t=1$: $$E_t (x_{t+\tau} - x_t)/ \tau dt = [p_{11}(t)\, \mu_1 + (1-p_{11}(t))\, \mu_2] \qquad (9.a)$$

If $s_t=2$: $$E_t (x_{t+\tau} - x_t)/ \tau dt = [p_{22}(t)\, \mu_2 + (1 - p_{22}(t))\, \mu_1] \qquad (9.b)$$

In contrast to the drift-adjustment method, there are then two equilibria for the expected depreciation within the band. The forecast errors arising from the conditions above described:

[20] Note that $p_{12}(t) = p(s_{t+\tau}=2|s_t=1)=1-p_{11}(t)$ and $p_{21}(t) = p(s_{t+\tau}=1|s_t=2) = 1-p_{22}(t)$.

$$\Delta x_{t+\tau}/\tau dt - E_t \Delta x_{t+\tau}/\tau dt = \begin{cases} (\mu_2 - \mu_1)(1-p_{22}(t)) + \varepsilon_{t+\tau} & \text{if } s_{t+\tau}=2, s_t=2 \\ (\mu_2 - \mu_1)p_{11}(t) + \varepsilon_{t+\tau} & \text{if } s_{t+\tau}=2, s_t=1 \\ (\mu_1 - \mu_2)p_{22}(t) + \varepsilon_{t+\tau} & \text{if } s_{t+\tau}=1, s_t=2 \\ (\mu_1 - \mu_2)(1-p_{11}(t)) + \varepsilon_{t+\tau} & \text{if } s_{t+\tau}=1, s_t=1. \end{cases} \quad (10)$$

(10) shows us clearly how the error term depends on the agents' subjective assessment of the probability of future realignment, be it p_{11} or p_{22}. These characteristics hold independent of whether or not $\Delta x_{t+\tau}$ is being conditioned on actual no realignment (à la drift adjustment). Such characteristics should be taken into account to get consistent estimates of the expected changes of the exchange rate within the band.

5. Data and empirical results

5.1 The exchange rate regimes in the ERM

The period covered in our empirical analysis of the ERM starts with the 9th realignment of the ECU parities, on 22 July 1985, and ends with the 17th realignment, on 23 November 1992 [21]. See table 1. Only two currencies out of a maximum of eleven participants in the ERM are here chosen: The French Franc and British Pound, both against the German mark.[22] In the period we study, there was high political activity due to the establishment process of the European Monetary Union (EMU), and until 1987 realignments in the ERM were frequent. During the period from July 1985 to November 1992, the French Franc had a ±2.25% official bilateral bandwidth against the German Mark. It experienced two realignments, on the 7 April 1986 when

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[21] The ECU parities were also changed on 17 September 1984 and 21 September 1989, when the Greek Drachma, panish Peseta and the Portuguese Escudo (the two latter at the same time) were included in the EMS without affecting the bilateral parities. See Ungerer et al. (1990) for history of ERM realignments before 1985.

[22] The ERM began operations on March 12, 1979 and consisted of (a) a grid of bilateral central parities; (b) rates for compulsory intervention, or fluctuation limits, set until August 2, 1993, at ±2.25% or ±6% from their parities; and (c) the obligation of central banks on both sides of a currency pair to purchase or sell unlimited amounts of currency at the fluctuation limits.

the central parity changed from 3.06648 to 3.25617, and on the 12 January 1987 establishing a central parity equal to 3.35386.

Table 1. Realignments in the ERM countries. 1985-1992.

Period	# observ. until next realignment[23]	Realignment at the start of the period. (Some chosen currencies)
9th realignment 22.07.85	0001-0125 125 obs.	The Lira is devalued by 8%. Technically through a 6% realignment of the Lira and a 2% revaluation of the other currencies in the ERM.
10th realignment 07.04.86	0180-0261 82 obs.	The German Mark and the Dutch Guilder are revalued 3%, Danish Krone is revalued 1%, the Italian Lira remained unaffected. The Franc is devalued 3% against its former central parity, that is 6% against the Mark.
11th realignment 04.08.86	0262-0373 112 obs.	Irish Punt is devalued by 8%.
12th realignment 12.01.87	0374-1128 755 obs.	The German Mark and the Dutch Guilder are revalued 3% against the other ERM currencies. The Peseta and the Escudo are joining the EMS 21.09.89. This does not affect the bilateral parities of the system.
13th realignment 08.01.90	1129-1316 188 obs.	The Lira is devalued by 3.68% at the same time as the official bandwidth is reduced from ±6% to ± 2.25%.
14th realignment 08.10.90	1317-1802 486 obs.	Not an usual realignment, but a redefining the weights of the ECU produces new bilateral parities
15th realignment 14.09.92	1803-1805 3 obs.	The Italian Lira is devalued 7%, technically this is done through a 3.5% realignment of the Lira and a similar revaluation of the other currencies of the ERM (including the Pound Sterling).
16th realignment 17.09.92	1806-1852 47 obs.	The Spanish Peseta is devalued by 5%. The Italian authorities suspend their participation in the ERM.

Table 2 Realignment periods

	22.7.1985	6.4.1986	12.1.1987	8.1.1990 (8.10.1990)	14.9.1992 (17.9.1992)	21.11.1992
Danish Krone	Start of time series	Realignment of the Krone	Realignment of the Krone			End of time series
French Franc	Start of time series	Realignment of the Franc	Realignment of the Franc			End of time series
Italian Lira	Realignment of the Lira	Realignment of the Lira	Realignment of the Lira	Realignment of the Lira, band is narrowed	Realignment, suspended, end of series.	
Dutch Guilder	Start of time series					End of time series
Pound Sterling				Starts participation in ERM	Realignment, suspended, end of series	

[23] This column serves to illustrate when realignments in figures 1-4 occur.

The United Kingdom brought the pound into the ERM, with a ±6% bandwidth on October 8, 1990 and a central parity equal 0.3389831 (British Pound against the German Mark). The 16 September 1992, the Bank of England responded to the speculation against the pound by raising its minimum lending rate, first from 10 to 12 percent and three hours later to 15 percent. That evening, the UK suspended its participation in the ERM.

Figures 1-4 show the exchange rate, the annualised quarterly change of the exchange rate and the interest rate differential for France and Britain. Note there that *the interest rate differentials decreased over time and independent of whether the exchange rate was weak or strong*.

Fig.1 GBP/DEM and [i(Great Britain) - i(Germany)]

8 October 1990 - 16 September 1992

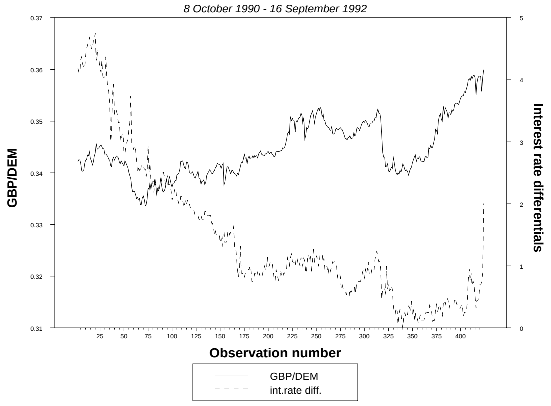


Fig.2 Annual change in GBP/DEM and [i(Great Britain) - i(Germany)]

Period: 8 October 1990 - 16 September 1992

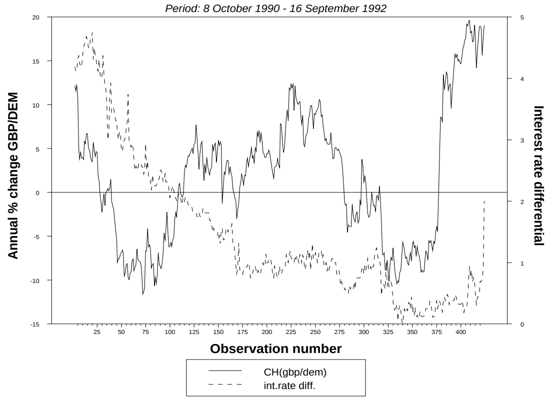


Fig.3 FRF/DEM and [i(France) - i(Germany)]

22 July 1985 - 20 November 1992

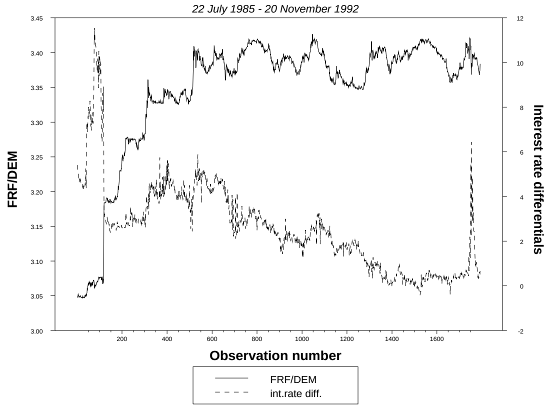


Fig.4 Annual change in FRF/DEM and [i(France) - i(Germany)]

22 July 1985 - 20 November 1992

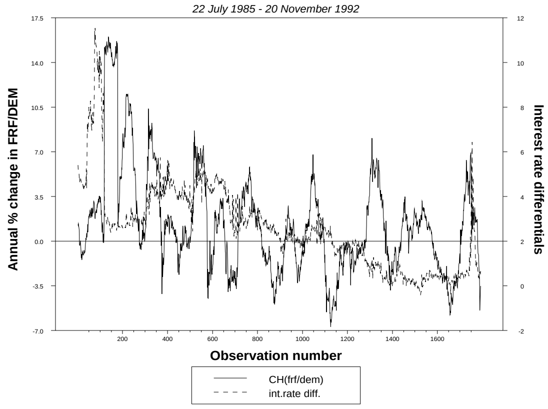
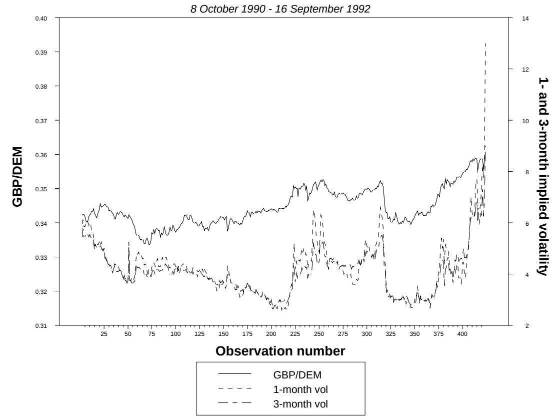


Fig.5 1- and 3-month implied volatility, and GBP/DEM

8 October 1990 - 16 September 1992



It then seems that there was no obvious negative and deterministic relationship between the exchange rate position in the band and the interest rate, as the original target zones models predict. It is well recognised that *all country participants in the ERM system aimed to have their interest rates converge toward the low German interest rate*. We should keep in mind the above general empirical observations when we relate our estimates of the expected realignment of the exchange rate to the interest rate differential. The development of the implied volatilities of the cross-rate between the pound and the mark pand the pound against the mark are shown in figure 5. T*hey reached their high levels whenever the pound was weakest.* It is also clear that the 1-month volatility was larger after 1991.

The parameter estimates of our empirical model are presented in table 2. These are the mean (μ_i) and variance (σ_i) for each state i (i=1,2) and the parameters of the transition probability functions. We first concentrate on the British Pound and the French Franc. State 1 is characterized by positive changes (depreciations) in the exchange rate and a relative large variance, in comparison with state 2 that is characterized by mostly negative changes (appreciations) in the exchange rate and a relatively small variance.

Note that the mean and variance of the stochastic process of the pound in each state are invariant to the explanatory variables entering the transition probability functions. These explanatory variables though affected the transition probabilities. For the British pound for example, we find that a lower interest rate differential reduced the probability of leaving state 1, once the pound was in that state as viewed by the market. On the other hand, higher implied volatility of 1- and 3-month pound/mark option prices reduced the probability of the pound continuing in state 1, once it was in that state. Thus, α_{11} is in all cases negative. α_{21} was however statistically significant only when we study the effect of the option prices expiring in one-month.

Table 2. Parameter estimates (Standard errors in parentheses.)

	B. Pound *(i.r.d.)*	**B. Pound** *vol(1-month)*	**B. Pound** *vol(3-month)*	**French Franc** *(i.r.d.)*	**NOK/basket** *(i.r.d)*	**NOK/ecu** *(i.r.d.)*	**SEK/basket** *(i.r.d.)*
μ_1	5.341 (0.0268)	5.3430 (0.0254)	5.347 (0.0258)	6.843 (0.00632)	3.518 (0.0114)	0.320 (0.0045)	2.340 (0.0018)
μ_2	-7.441 (0.0368)	-7.4387 (0.0399)	-7.435 (0.0351)	-0.437 (0.1767)	-6.273 (0.0078)	-0.309 (0.003)	-2.134 (0.0018)
σ_1	32.567 (0.2053)	32.557 (0.2208)	32.532 (0.1907)	13.72 (0.0329)	24.747 (0.0818)	0.1032 (0.0016)	3.595 (0.0048)
σ_2	3.027 (0.0769)	3.0367 (0.0957)	3.046 (0.0998)	4.501 (0.0088)	4.876 (0.0512)	0.197 (0.0014)	2.680 (0.0091)
α_{10}	5.672 (0.471)	7.9015 (1.3704)	10.13 (1.6393)	3.459 (0.1873)	12.007 (0.8238)	2.736 (0.1349)	3.018 (0.1404)
α_{11}	-0.301 (0.1643)	-0.612 (0.2453)	-1.132 (0.3098)	0.2009 (0.0613)	-1.144 (0.1264)	0.485 (0.3509)	0.5603 (0.0598)
α_{20}	3.767 (0.5367)	6.794 (1.0996)	1.765 (1.4578)	5.815 (0.1109)	2.044 (0.7912)	3.192 (0.1267)	4.427 (0.1236)
α_{21}	0.125 (0.193)	-0.548 (0.1938)	0.488 (0.2901)	-0.231 (0.0273)	0.393 (0.1206)	-0.969 (0.2968)	0.00047 (0.0293)
Max. Lik	-122.08	-122.02	-121.96	-423.26	-218.41	-25.29	-429.87

Now, if the implied volatilities reflected actual market expectations about future developments of the pound, our results implied that when the option markets estimated high volatility of the exchange rate, they did not expect the pound to continue in state 1 but instead to switch to state 2, in 3 months time. Note that at this point, we are not characterising high-volatility (at the edges) with non-credible currency bands (Bertola and Caballero (1992)). Decreases in the interest rate differential could however have offset such effect, leading instead to higher probabilities of continuing in state 1. This is perhaps an empirical evidence that monetary policy could cause a shift in market expectations.

Regarding the French Franc, we find that a lower interest rate differential reduced the probability of the franc continuing in state 1, that is α_{11} is positive. A lower interest rate differential must also have reduced the probability of leaving state 2, whenever the exchange rate was in that state as viewed by the market. Thus α_{21} is negative. In contrast to the British Pound, a lower interest rate differential did not then cause the market to expect the French Franc to continue in state 1.

Figures 6-8 show the expected British Pound depreciation within its band in the two states when the transition probabilities (equation 7) depend on the interest rate differential, 1-month implied volatility and 3-month implied volatility, respectively.

Fig. 6 Expected annual % change in GBP/DEM within the band

Effect of int.rate diff. Period: 8 October 1990 - 16 September 1992

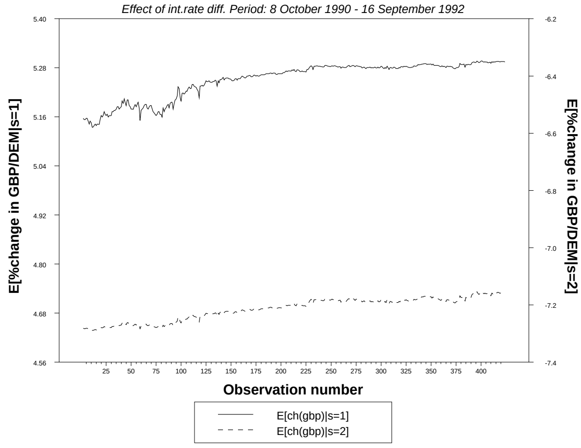


Fig.7 Expected annual % change in GBP/DEM within the band

Effect of 1-month vol. Period: 8 October 1990 - 16 September 1992

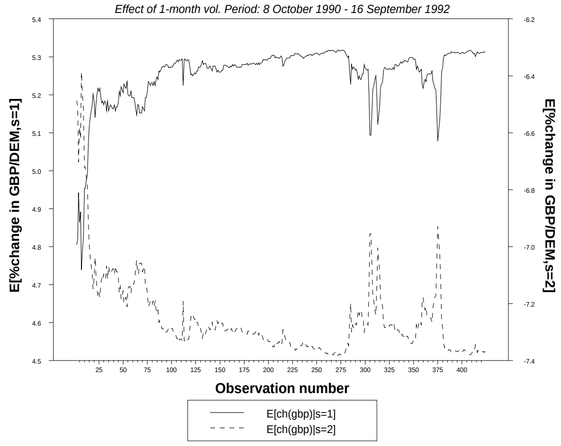


Fig.8 Expected annual % change in GBP/DEM within the band

Effect of 3-month vol. Period: 8 October 1990 - 16 September 1992

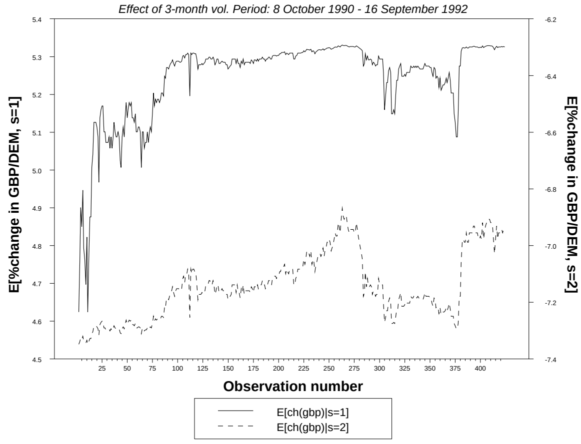
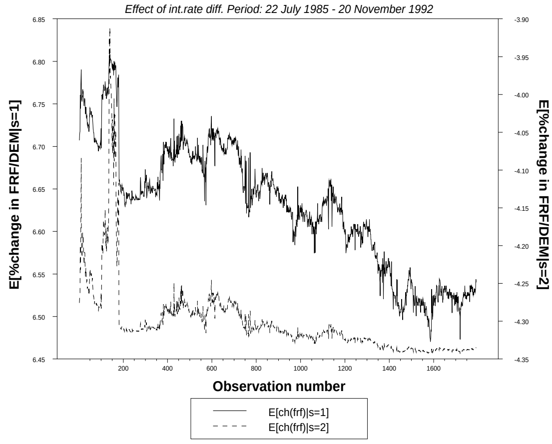


Fig.9 Expected annual % change in FRF/DEM within the band

Effect of int.rate diff. Period: 22 July 1985 - 20 November 1992



It is clear that in state 1, where the observed mean and variance of the exchange rate depreciation are larger, the expected depreciation of the pound within its band is also larger. In state 1, the market expected the pound to depreciate between 4.6% and 5.3% annually, depending on the explanatory variable of the transition probability. On the other hand, in state 2 the market expected an annual appreciation between -7.3% and -6.4%, depending also on the explanatory variable of the transition probability. Now notice that the interest rate differential in the period of concern decreased from 5% to almost 0% until the pound entered the crisis of 1992. For the French Franc, we have also estimated its expected depreciation within the band for each state. As for the British pound, this expected depreciation was also larger in state 1 (between 6.45% and 6.85%) than in state 2 (between –3.9% and –4.35%). These figures were relatively larger than for the British pound but they were decreasing over time (see figure 9). *As for Britain, the interest rate differential was also of the size between the expected depreciation for each state.* We will later present and explain our estimates of the expected realignment rates.

5.2 The Nordic countries

We also use daily data and study the period between 1 October 1986 and 15 February 1990 when the Norwegian Krone was pegged to a basket of currencies and the bandwidth was ±2.25%. The central parity was 112 and the upper and lower bounds were 114.5 and 109.5, respectively. Before that date, the krone was last devalued in May of 1986.[24] The interest rate differential is the difference between the 3-month Norwegian rate and the 3-month basket of foreign interest rates of the same currencies included in the basket. We also analyze the period from 22 October 1990 until 12 December 1992 when the krone was pegged to the ECU and the bandwidth also was ±2.25%. Here the central parity was 7.994, and upper and lower bounds 8.1739 and 7.8141, respectively. The krone began to float on 12 December 1992 after massive speculative attacks. The interest rate differential is here between the 3-month Norwegian interest rate and the 3-month market ECU

[24] See Edin and Vredin (1993) for a chronological listing of the devaluations before these Nordic countries pegged their currencies to the ECU.

interest rate. The Norwegian Krone did not experience any realignment during our period of study. The developments of the Norwegian exchange rate and its interest rate differential are shown in figures 10-13.

Until January of 1989, the Norwegian Krone moved inside the entire band and had large variability when it reached the edges of its band. The interest rate differential was high when the krone was weakest. Thereafter, the exchange rate stabilized around the central parity and the interest rate differential decreased rapidly. In the ECU period (see figure 12), Norwegian authorities defended a narrower implicit exchange rate band than the official one. The exchange rate had a stable level 0.3% weaker than its central parity and the krone seemed unaffected by the Finnish realignment of 1991. Between the time the Swedish Krone began to flow (20 November 1992) and the time the Norwegian ECU-peg was suspended, the interest rate differential rose and the krone showed great variability.

Fig.10 NOK/BASKET index and [i(Norway) - i(basket of countries)]

1 October 1986 - 9 February 1990

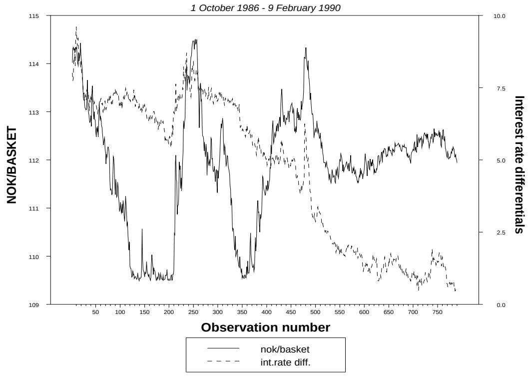


Fig.11 Annual change in NOK/BASKET, and [i(Norway) - i(basket of countries)]

1 October 1986 - 9 February 1990

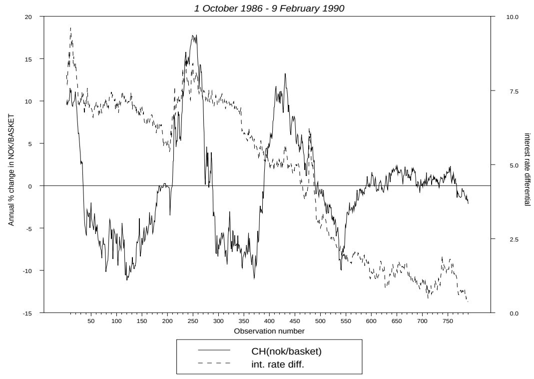


Fig.12 NOK/ECU and [i(Norway) - i(ECU)]

22 October 1990 - 7 December 1992

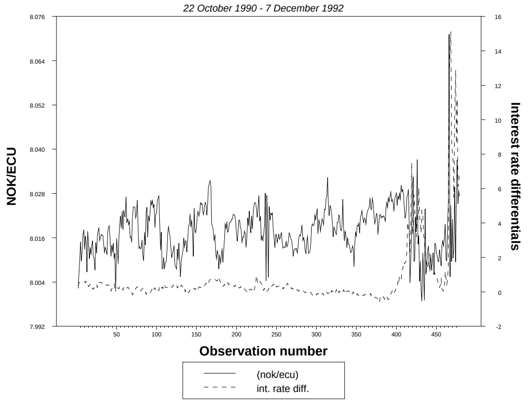
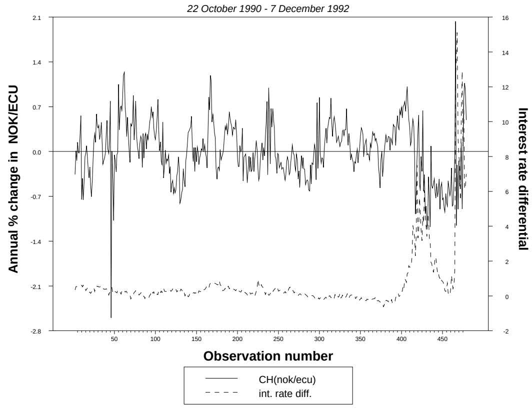


FIG.13 Annual change in NOK/ECU and [i(Norway) - i(ECU)]

22 October 1990 - 7 December 1992



The period of study for Sweden is from October 8, 1982 until May 16, 1991 when the Swedish krone was pegged to a basket of currencies and fluctuated within a bandwidth of ±2.25%. The last realignment before this period occurred on October 8, 1982, when the central parity changed from 111 to 132. On June 27, 1985 the currency band narrowed, from ±2.25% to ±1.5%. The upper and lower bounds changed to 133.98 and 130.02 from 134.97 and 129.03, respectively.[25] In this case the interest rate differential is the difference between the 3-month Swedish rate and the 3-month basket of foreign interest rates of the same the currencies included in the currency basket. Figures 14-15 show the dynamics of the Swedish Krone and its interest rate differential. The interest rate differential was relatively high (low) when the krone was strong (weak).We could now go back to table 2 where the parameter estimates for Norway and Sweden are presented. As for Britain and France, it is here also the case that state 1 is characterized by positive changes (depreciations) and relatively large volatility, in comparison to state 2 that is characterized by mostly negative changes (appreciations) and low volatility.

Fig.14 SEK/BASKET and [i(Sweden) - i(Basket)]

8 October 1982 - 17 May 1991

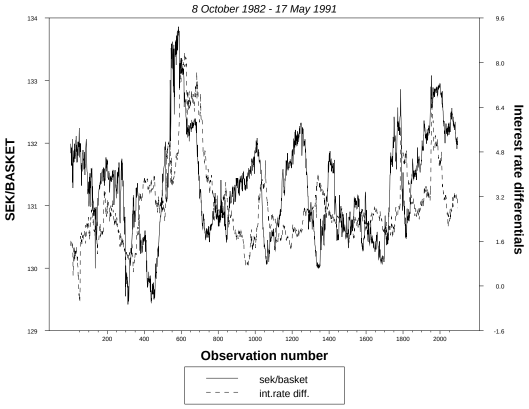


Fig.15 Change in SEK/BASKET and [i(Sweden) - i(Basket)]

8 October 1982 - 17 May 1991

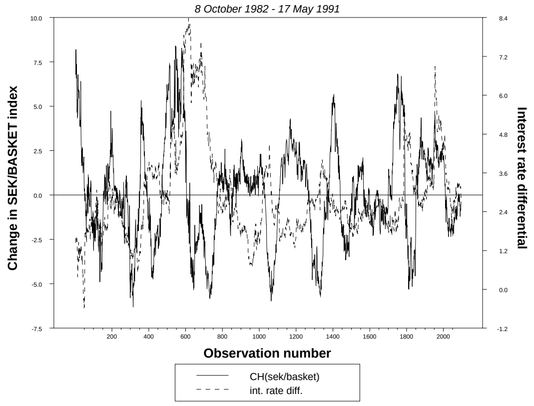


Table 2 also shows the results of estimating the effect of the interest rate differential on the transition probabilities for Norway and Sweden. During the period the Norwegian Krone was pegged to a currency basket, once the krone was in the state 1, a lower interest rate differential did

[25] From the 17 May 1991, the Swedish Krone was pegged to the ECU and fluctuated within a bandwith of 1.5%, with

not reduce the probability of the Norwegian Krone continuing in such state. α_{11} is then negative. Also, once the krone was in state 2, the lower the interest rate differential the lower the probability of continuing in state 2, thus α_{21} is positive.

In the period when the Norwegian Krone was pegged to the ECU, we find that a lower interest rate differential reduced the probability of the Norwegian Krone to continue in state 2 (with the smallest volatility and depreciation within the band), that is, α_{21} is negative. α_{11} is insignificant.

For the Swedish Krone, during its basket period, we find opposite results with regard to α_{11}, this was positive. This implies that a lower interest rate differential reduced the probability of continuing in state 1. α_{21} was found neither statistically nor numerically significant.

Figures 16-18 show the estimated expected depreciation within the band for Norway and Sweden. We here also find that the expected depreciation within the band in state 1 was smaller from than that in state 2, and that the interest rate differential lies between these two. The expected change of the NOK/ECU within its band in state 1 and state 2 were smaller than the equivalent ones obtained for the period the Norwegian Krone was pegged to a currency basket. Note particularly that the expected change of the Swedish Krone in state 1, not only was higher than the one in state 2, but they always moved in the opposite direction from each other.

Fig.16 Expected annual % change in NOK/BASKET within the band

Effect of int.rate diff. Period: 1 October 1986 - 9 February 1990

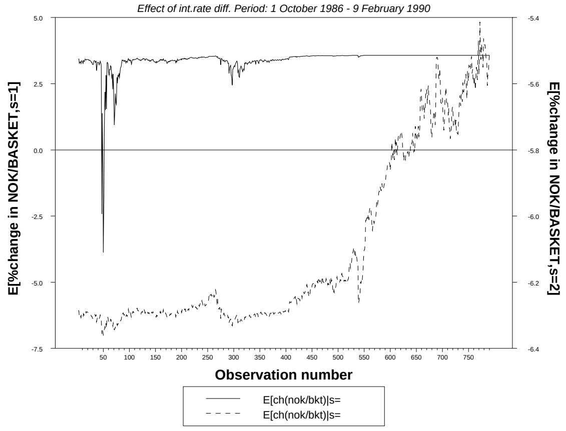
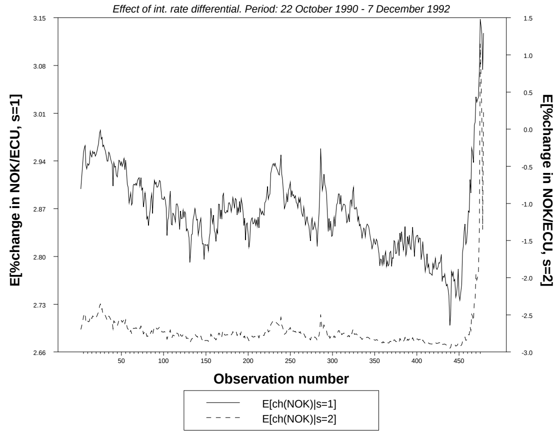


Fig.17 Expected annual % change in NOK/ECU within the band

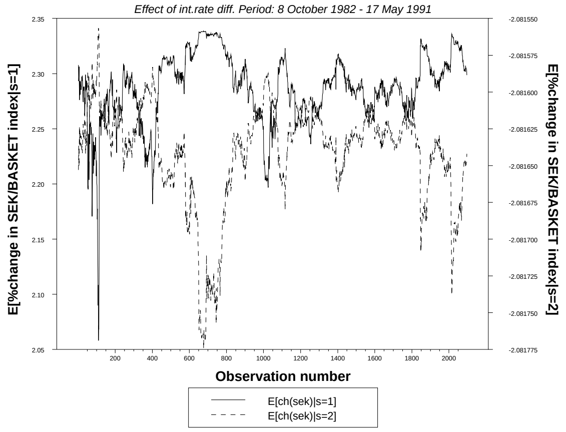
Effect of int. rate differential. Period: 22 October 1990 - 7 December 1992



central parity equal to 7.40054 and upper and lower bounds 7.5115 and 7.2895, respectively. We do not study this period because the maximum likelihood did not converge to a global maximum.

Fig.18 Expected annual % change in SEK/BASKET within the band

Effect of int.rate diff. Period: 8 October 1982 - 17 May 1991



5.3 Realignment rates for all countries

We have found for all currencies in our study, that the expected depreciation within the band was always larger in state 1 than in state 2. They only differ in size. The estimated expected realignment for each of the countries we consider here are shown in figures 19-23.[26] Note that, in almost all cases, the interest rate differential has always been of the size between the expected depreciation in states 1 and 2 yielding low (high) expected annual realignment in the state 1 (state 2). One exception is Norway, but *only* during the fall of 1992, when the interest rate differential was very large as a result of the massive speculative attacks against the Norwegian Krone. In state 1, expected realignment rates for France and Britain were always negative implying expected negative changes in the central parity: A revaluation, but large and positive in state 2. For Norway and Sweden, the expected realignment rates in state 2 were always positive but for state 1 sometimes positive and other times negative.

We compare our estimates with the ones obtained using the drift-adjustment method for France and Sweden. For Norway and Britain no similar estimates using this method have been reported in the

[26] We do not show the estimates of the expected realignment rates of the British Pound when the transition probabilities are determined by the one- and three-month implied volatility because they are similar to the one when such probabilities are modelled dependent on the interest rate differential. It can be shown upon request.

relevant literature. For the French Franc, our estimates of the realignment rates in state 2 are generally higher than the ones documented by Svensson (1993) as the upper bound of his 95% confidence interval, while the realignment estimates in state 1 are somewhat smaller than the lower bound of his 95% confidence interval. For the Swedish Krone, the estimates of the realignment rates in state 2 are also higher than the upper-bound 90% confidence interval reported by Lindberg, Söderlind and Svensson (1993). Their lower-bound 90% confidence interval estimates are closer to our estimates for state 1.[27]

Fig.19 Expected annual realignment of GBP/DEM in each state

Effect of int.rate diff. Period: 8 October 1990 - 16 September 1992

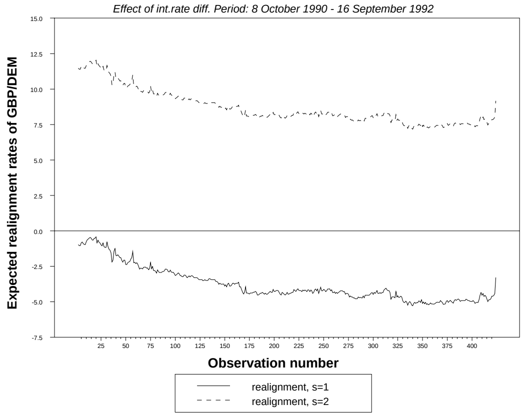


Fig.20 Expected annual realignment of FRF/DEM in each state

Effect of int.rate diff. Period: 22 July 1985 - 20 November 1992

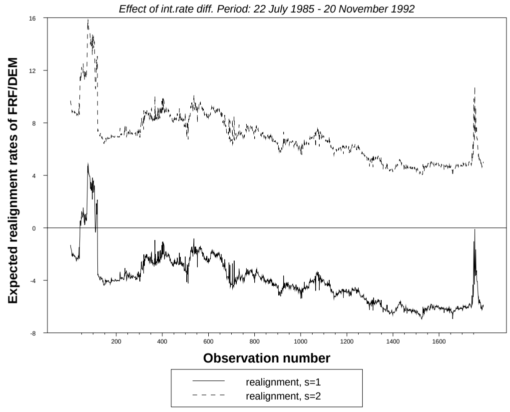


Fig.21 Expected annual realignment of NOK/BASKET in each state

Effect of int.rate diff. Period: 1 October 1986 - 9 February 1990

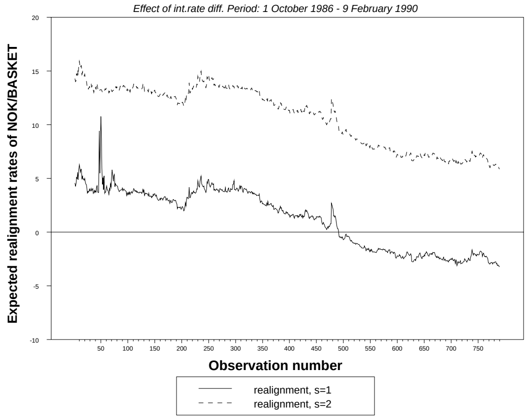
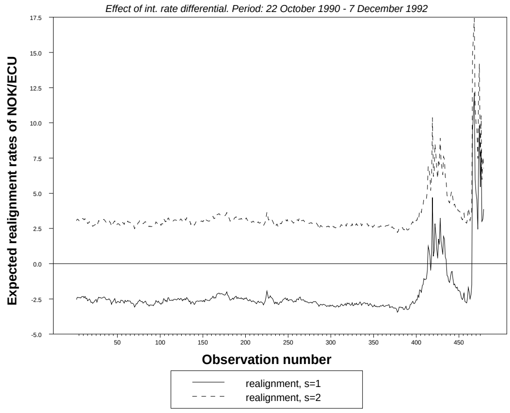


Fig.22 Expected annual realignment of NOK/ECU in each state

Effect of int. rate differential. Period: 22 October 1990 - 7 December 1992



[27] They also present estimates for the 100% confidence interval. It turns out that our estimates of the realignment rates in state 2 are lower than the upper bound of their 100% confidence interval, while our realignment estimates in state 1 are much higher than the lower bound of their 100% confidence interval.

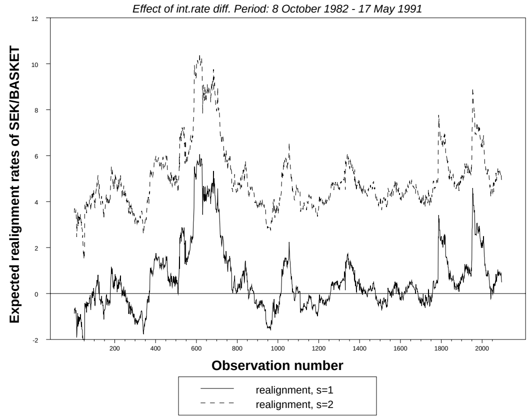


Fig.23 Expected annual realignment of SEK/BASKET in each state
Effect of int.rate diff. Period: 8 October 1982 - 17 May 1991

The estimates of the expected realignment rates done by Girardin and Marimoutou (1997) lie between our estimates for states 1 and 2. The estimates of Campa and Chang (1996) are somewhat closer to our estimates in state 1, when realignment rate expectations were low.

Let us summarise our results. *First*, the exchange rate markets we here consider were characterised by having two possible equilibria: One equilibrium (state 1) where the exchange rates had high volatility, relatively high rates of actual and expected depreciation within the band, and low expected realignment rates. Another equilibrium (state 2) with low volatility, actual and expected appreciation of the currencies, and high realignment rates. The exchange rate characteristics in state 2 were also obtained by Girardin and Marimoutou (1997). The exchange rate characteristics in *state 1* may apparently describe Bertola and Caballero (1992)'s target zone model with endogenous realignment risk with large (small) volatility when the exchange rate is near the edges (well inside its band). But here in this state 1, the expected realignment rates were low indicating that once the exchange rate was in that state, the market expected a revaluation (specially for Britain, France and Norway).[28] *Second*, our estimates of the realignment rates in state 2 are generally higher than the ones documented by Svensson (1993) and Lindberg et al. (1993) as the upper bound of their 95% (or 90%) confidence interval; while the realignment estimates in state 1 are somewhat closer to the lower bound of their 95% (or 90%) confidence interval. *Third*, the exchange rate markets of Britain, France and the Nordic countries as Norway and Sweden were also characterised as shifting from one self-fulfilling set of expectations to another, as Malz (1996) also concludes. *Fourth,* in contrast to Malz (1996), we explain what may have caused expectations and equilibria to shift. We find no evidence of sunspot equilibria. It rather was the interest rate policy of these countries that affected expectations. Only for Britain and Norway did low interest rate differentials cause the market to have higher probabilities of continuing in state 1, with low expected realignment.[29] For Britain however, when the option markets estimated high volatility of the exchange rate, it caused expectations that the pound would not continue in state 1, offsetting the effect of the interest rate differential. One should remember that the pound at the end abandoned the ERM system and was let float in the early fall of 1992. *Finally*, recall again that the countries we studied aimed to achieve low interest rates, independent of whether their exchange rates depreciated or appreciated. Our results may indicate that higher interest rate differentials would have led to even higher expected realignment rates in both states.

6. Conclusions

We have drawn attention to a possible drawback of the widely used drift-adjustment method and show that this method cannot give consistent estimates. An alternative methodology that provides consistent estimates is suggested, namely the one of Hamilton (1989). This effectively takes into account the "peso problem" that arises when estimating expected changes in the exchange rate within the band. We first assume that market participants form expectations about

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[28] Bertola and Caballero (1992) do not derive what the expected realignment rate would be.

[29] After Sweden pegged the krone to the ECU, its interest rate differentials also decreased sharply independent on whether the krone was weak or strong. This was obviously a different policy from the one followed during the basket period.The Swedish krone started to float 20 November 1992.

future changes in the exchange rate within the band, conditional on the full information set: With realignment and no-realignment possibilities and realisations. Second, the market considers that either of two equilibrium outcomes (states) for the exchange rate may occur with certain probabilities. Third, we realistically assume that changes in monetary policy and in the economic fundamentals may cause expectations to shift, and thus induce switches between possible states of the stochastic process of the exchange rate. The countries we studied were France (1985-1992), Britain (1990-1992), Sweden (1982-1991) and Norway (1986-1992). We use daily data.

We have taken care of the peso problem and shown that the exchange rate market was characterised by having multiple equilibria. Obstfeld (1994, 1996) established the possibility of obtaining multiple equilibria in the exchange rate market and that certain monetary policies can lead to self-fulfilling expectations. Moreover, our estimates of the expected realignment rates (in state 2) are always greater than the ones obtained using the drift adjustment method.

Several other important conclusions can be drawn from our estimates that are new relative to previous work. It has been argued in the relevant literature of currency and financial crises that it is problematic to obtain multiple equilibria because one cannot know how to select between one equilibrium and another. Here we find that interest rate differentials explain how specific exchange rate equilibrium was reached. More precisely, they caused the market to switch expectations. We here argue that optimal interest rate policy should (should have) take (taken) into account these possible multiplicity of equilibrium in the exchange rate market.

On the other hand, it seems that the degree of credibility of the exchange rate bands cannot be quantified perfectly from the difference between the interest rate differentials and the expected depreciation within the band. The reason is that the interest rate policies during the period of study seem to have been determined independently of the objectives of the exchange rate bands. This policy aimed both at convergence toward the German interest rates, and at the exploitation of the currency band (Svensson (1994)). With higher interest rate differentials, we would have indeed obtained higher expected realignment rates in both states. We believe that it is not just that we need to adjust the interest rate differential for the expected rate of depreciation within the band, as Svensson and Bertola (1993) and Svensson (1993) postulate.

Such interest rate policies were likely implemented at the costs of strong credible exchange rate bands, as it was for France and Sweden. We have noted that interest rate differential for the countries we consider had a decreasing trend. Possibly monetary authorities believed they had gained some degree of autonomy regarding monetary policy since they had exchange rate band regimes (Svensson (1994)). By assuming that their bands were credible, they exploited such autonomy by decreasing the interest rate differential, most likely because an expansionary economic policy was desirable. What happens if the authorities reduce the interest rate in a situation with a credible target zone? The exchange rate will immediately depreciate as the domestic capital market loses attractiveness. If the currency band is credible, there will not be expectations of devaluation (positive expected realignment rates) even after the exchange rate has weakened and after interest rates fall. Equilibrium in the capital markets will be always regained in the end. The size of the interest rate differential that the monetary authorities can achieve when exploiting their monetary autonomy will obviously depend on the width of the target zone because any smoothing in the interest rates may be achieved at the expense of a more variable exchange rate. If credibility is not there, then allowing the exchange rate to vary a lot may lead to increases in the expected rate of realignment. We here find that the interest rate differential policy in France and Sweden reduced the market's subjective probabilities of remaining in the equilibrium where expected realignment rates were low. In Britain however, high implied volatilities seemed to have offset effect that the interest rate policy in Britain had on the pound and to explain the final equilibrium outcome of the pound: Its realignment in the fall of 1992. When the option markets estimated high volatility of the exchange rate, it caused expectations that the pound will not continue in state 1 where realignment expectations were low.

One can argue that it would have been an advantage to have data on option prices of the other currencies in order to understand why France after all did not experience a realignment while Norway did not. This was so in spite of the negative and positive effects of the French and Norwegian interest rates policy on their currencies, respectively. The final conclusion is that, for the period we study, interest rate differentials did not provide the necessary information about market expectations on future changes on the exchange rate. They seemed to have been determined to achieve other objectives than credible currency bands.

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