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ASSESSING TARGET ZONE CREDIBILITY:
MEAN REVERSION AND DEVALUATION EXPECTATIONS IN THE EMS

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ABSTRACT

The paper presents estimates of devaluation expectations for

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March 1979-May 1990. The estimation method is simple and

operational, and consistently generates sensible results. The

estimates are constructed by the adjusting interest rate

differentials by subtracting estimated expected rates of

depreciation within the exchange rate band. The adjustment is

nontrivial because exchange rates within ERM bands display mean

reversion rather than random walk (unit root) behavior. The

adjustment is essential since expected rates of depreciation

within the band are usually of about the same magnitude as

interest rate differentials.

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I. Introduction

This paper presents estimates of devaluation expectations for six EMS (European Monetary System) currencies relative to the Deutsche mark, for the period March 1979-May 1990. The estimation method is simple and operational, and consistently generates sensible results. The estimates are constructed by adjusting interest rate differentials by subtracting estimated expected rates of depreciation within the exchange rate band. The adjustment is nontrivial because exchange rates within the ERM (Exchange Rate Mechanism) bands display mean reversion rather than random walk (unit root) behavior. The adjustment is essential since expected rates of depreciation within the band are usually of about the same magnitude as interest rate differentials.

The idea of extracting devaluation expectations by adjusting interest rate differentials for expected rates of depreciation within the band was first suggested by Bertola and Svensson (1990), within the context of a theoretical model of an exchange rate target zone with stochastic time-varying devaluation risk. Lindberg, Svensson and Söderlind (1991) and Rose and Svensson (1991) have since implemented the method to estimate devaluation expectations for the Swedish krona and the French franc/Deutsche mark, respectively. These papers employ a number of different methods to estimate expected rates of depreciation within the band.

This paper presents straightforward estimates of devaluation expectations relative to the Deutsche mark for the six original currencies (besides the Deutsche mark) in the Exchange Rate Mechanism of the EMS. The estimates are straightforward because the expected rates of depreciation within the band are estimated by a simple linear regression. This makes the estimation method operational and easy to implement.[1]

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[1] For alternative empirical approaches to target zone credibility see for instance Bartolini and Bodnar (1991), Bertola and Caballero (1990), Bodnar (1991), Collins (1986), Edin and Vredin (1991), Fratianni and von Hagen (1990), Giovannini (1990), Svensson (1991) and Weber (1991).

The ERM is a cooperative exchange rate regime in which the exchange rate for each participating currency is restricted to fluctuate within bands defined around bilateral central rates relative to each other participating currency. Each participating currency hence has a separate band relative to each other participating currency. In practice, the bands relative to the Deutsche mark have been the most important, since the Deutsche mark has been the strongest currency in the ERM (except very recently) and the only ERM currency never to have undergone a bilateral devaluation. Therefore, for the purpose of estimating devaluation expectations relative to the Deutsche mark we shall only consider the bilateral bands relative to the Deutsche mark.[2]

Section II presents the model of expected rates of devaluation, section III presents the data and the estimation of expected rates of depreciation within the band, and section IV reports and interprets the estimates of expected rates of devaluation. Section V concludes.

It is beyond the scope of this paper to include an independent test of the validity of the estimated expected rates of devaluation. One such test is done in Rose and Svensson (1991), with some success. Possible tests of the validity of the estimated expected rates of devaluation are briefly discussed in the concluding section V.

II. Model of Expected Rates of Devaluation

Let $\delta_t \equiv i_t - i_t^*$ denote the domestic (non-German) currency's *interest rate differential* at time t, the difference between the domestic currency interest rate i_t and a Deutsche mark (DM) interest rate i_t^*, both for deposits/bills/bonds of the same default-risk and the same maturity $\tau > 0$. Furthermore, let s_t denote the natural logarithm of the *exchange rate*, the latter measured as units of domestic currency per DM. Then we can express

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2   See for instance Ungerer, Hauvonen, Lopez-Claros and Mayer (1990) for details on the operation of the ERM.

uncovered interest parity as

(2.1) $$\delta_t = E_t[\Delta s_{t+\tau}]/\tau,$$

where E_t denotes expectations conditional upon information available at time t and $\Delta s_{t+\tau}$ $\equiv s_{t+\tau} - s_t$.[3] That is, *the interest rate differential equals the expected (average) rate of depreciation of the domestic currency relative to the DM (the rate of change of the exchange rate) during the time interval corresponding to the maturity.* Uncovered interest parity is a good approximation if the foreign exchange risk premium is small. Svensson (1990) argues that the foreign exchange risk premium is likely to be small in exchange rate target zones, even when there is devaluation risk.[4]

It is well known that uncovered interest parity has been rejected in a large number of empirical tests (see Froot and Thaler (1990)). However, the standard test of whether the forward exchange rate is an unbiased predictor of the future exchange rate is misleading for exchange rates within exchange rate bands with realignment risk. This is so since the realignment risk is just one example of the wellknown Peso problem, which undermines the standard unbiasedness test. Put differently, with realignment risk there is the problem that the sample distribution may not be representative of the underlying distribution of the error term, unless the sample includes a large number of realignments. Interestingly, for the French franc/DM exchange rate, with has experienced a few realignments, there is actually empirical support for uncovered interest parity, as noted by

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[3]   We use the approximation $\ln(1+i_t\tau) \approx i_t\tau$, etc.

[4]   Svensson (1990) shows that the foreign exchange risk premium for an imperfectly credible exchange rate band with devaluation risk has two components: one arising from exchange rate uncertainty due to exchange rate movements within the band, and the other arising from exchange rate uncertainty due to realignments of the band. The first component is likely to be very small, since conditional exchange rate variability inside the band is smaller than conditional exchange rate variability in a free float, and since foreign exchange risk premia even in a free float appear in empirical estimates to be fairly small. The second component is likely to be much larger then the first, but still of moderate size: Even with a coefficient of relative risk aversion of 8 and an expected conditional devaluation size of 10 percent, the foreign exchange risk premium is no more than 1/5 of the total interest rate differential. Hence at least 4/5 of the interest rate differential remains to be explained by something else than the foreign exchange risk premium.

Rose and Svensson (1991).

The method of estimating expected rates of devaluation in this paper will rely on the assumption of an insignificant foreign exchange risk premium and uncovered interest parity. In the concluding section V we will briefly mention how the method can be modified to incorporate a non-zero foreign exchange risk premium.

Let c_t denote (the natural logarithm of) the *central parity*. A *realignment* is a jump in the central parity. Between realignments the central parity is constant. Next, let us introduce

$$(2.2) \qquad x_t \equiv s_t - c_t,$$

the exchange rate's (log) deviation from the central parity. We shall informally refer to x_t as the *exchange rate within the band*.

It will be practical to consider *rates* of realignment rather than the absolute size of a realignment. Let us therefore rewrite the central parity as $c_t \equiv s_t - x_t$, and let us write the (average) *rate of realignment* from time t to time $t+\tau$ as $\Delta c_{t+\tau}/\tau \equiv \Delta s_{t+\tau}/\tau - \Delta x_{t+\tau}/\tau$. It follows that

$$(2.3) \qquad E_t \Delta c_{t+\tau}/\tau \equiv E_t \Delta s_{t+\tau}/\tau - E_t \Delta x_{t+\tau}/\tau.$$

That is, *the expected rate of realignment equals the expected (total) rate of depreciation minus the expected rate of depreciation within the band*.

Let us briefly extend on how the expected rate of realignment can be interpreted. At a realignment central parity jumps to a new level and remains constant there until the next realignment. Let market expectations of realignments be modeled in the following way. Let p_t^T be the *probability at time t of a realignment* during the period from time t to time $t+\tau$. During the period from time t to $t+\tau$ central parity c_t remains constant with probability $1 - p_t^T$, whereas it takes a jump of independent random size $\Delta c_{t+\tau}$ with probability p_t^T. It follows that the expected change in central parity, the *expected realignment*, can be written

$$\text{(2.4)} \qquad E_t[\Delta c_{t+\tau}] = (1-p_t^T)\cdot 0 + p_t^T \cdot E_t[\Delta c_{t+\tau}|\text{realignment}]$$
$$= p_t^T \cdot E_t[\Delta c_{t+\tau}|\text{realignment}],$$

where $E_t[\Delta c_{t+\tau}|\text{realignment}]$ denotes the *expected conditional realignment size* (conditional upon a realignment during the period from time t to $t+\tau$). (The expected conditional realignment size is positive if a devaluation is expected, negative if a revaluation is expected.) That is, *the expected realignment is the product of the probability of a realignment during the time to maturity and the expected conditional realignment size.*[5]

Define the (expected average) *frequency of realignment* during the time to maturity as $\nu_t^T \equiv p_t^T/\tau$.[6] It follows that the expected *rate* of realignment in (2.4) can be written as

$$\text{(2.5)} \qquad E_t[\Delta c_{t+\tau}]/\tau = \nu_t^T \cdot E_t[\Delta c_{t+\tau}|\text{realignment}].$$

The expected rate of realignment is the product of the frequency of realignment and the expected conditional realignment size.

Let us then go on and note that from uncovered interest parity (2.1) it follows that (2.3) can be written

$$\text{(2.6)} \qquad E_t\Delta c_{t+\tau}/\tau = \delta_t^T - E_t\Delta x_{t+\tau}/\tau .$$

That is, *the expected rate of realignment is equal to the interest rate differential minus the expected rate of depreciation within the band.* As observed by Bertola and Svensson (1990), equation (2.6) has empirical implications: In order to find an estimate of the expected rate of realignment, $E_t\Delta c_{t+\tau}/\tau$, it is sufficient to find an estimate of

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[5] We disregard the possibility of more than one realignment occuring during the period from time t to $t+\tau$. This is not restrictive since in this paper we will only consider the short period and maturity of one month. For longer maturities the possibility of two or more realignments should be taken into account (see Lindberg, Svensson and Söderlind (1991)).

[6] In the literature on stochastic processes the variable ν_t^T is usually called the (average) *intensity* (of a jump process). The variable is called the *frequency of realignment* here because that terminology is perhaps more intuitive. In any case the variable has the interpretation that the probability of a jump during a short period of duration Δt is equal to $\nu_t^T\Delta t$. The expected time to the next realignment is $1/\nu_t^T$.

$E_t \Delta x_{t+\tau} / \tau$, the expected rate of depreciation within the band, and simply subtract that estimate from the interest rate differential.

The estimation of the expected rate of depreciation within the band is made a bit complicated by the fact that the exchange rate within the band usually takes a jump at a realignment (recall that a realignment is defined as a jump in central parity). For instance, usually the exchange rate for a "weak" currency (that is, a currency that is devalued) jumps from a position near the "weak" edge of the old exchange rate band (that is, above the old central parity) to a position near or at the "strong" edge of the new exchange rate band (that is, below the new central parity). Therefore, the jump in the exchange rate is usually less than the jump in the central parity. Sometimes when the realignment is small and the new band overlaps with the old, there is no jump at all in the exchange rate.

It is complicated to estimate the expected rate of depreciation within the band *inclusive* of possible jumps inside the band at realignments, since there may be relatively few realignments and the sample distribution of realignments may not be representative. Then expectations of realignments and jumps inside the band may introduce a Peso problem in the estimation of the expected rate of depreciation within the band. For these reasons it seems safer to estimate the expected rate of depreciation within the band *conditional upon no realignment.* This practice, however, has consequences for the estimation of the expected rate of realignment that need to be clarified.

Hence, let us expand the expected change of the exchange rate within the band in two components,

$$(2.7) \qquad E_t[\Delta x_{t+\tau}] \equiv (1-p_t^T) E_t[\Delta x_{t+\tau} | \text{no realignment}] + p_t^T E_t[\Delta x_{t+\tau} | \text{realignment}]$$
$$\equiv E_t[\Delta x_{t+\tau} | \text{no realignment}]$$
$$- p_t^T \{ E_t[x_{t+\tau} | \text{no realignment}] - E_t[x_{t+\tau} | \text{realignment}] \},$$

where we recall that p_t^T is the probability of a realignment from date t up to and including date $t+\tau$. It follows from (2.7) that (2.6) can be written as

(2.8) $E_t[\Delta c_{t+\tau}]/\tau + p_t^\tau\{E_t[x_{t+\tau}|\text{realignment}] - E_t[x_{t+\tau}|\text{no realignment}]\}/\tau$

$$= \delta_t^\tau - E_t[\Delta x_{t+\tau}|\text{no realignment}]/\tau.$$

We shall use the left-hand side of (2.8) as our operational definition of the *expected rate of devaluation* (if it is positive a devaluation is expected, if it is negative a revaluation is expected). Hence, by (2.8) *the expected rate of devaluation equals the difference between the interest rate differential and the expected rate of depreciation within the band (conditional upon no realignment).*

The expected rate of devaluation as we have defined it differs from the expected rate of realignment by the second term on the left-hand side in (2.8). In order to understand this term better, let us rewrite the expected rate of devaluation as

(2.9) $\nu_t^\tau\{\ E_t[\Delta c_{t+\tau}|\text{realignment}]$

$+ E_t[x_{t+\tau}|\text{realignment}] - E_t[x_{t+\tau}|\text{no realignment}]\ \}$,

where we recall that $\nu_t^\tau \equiv p_t^\tau/\tau$ is the frequency of realignment. Hence, the expected rate of devaluation is the product of the frequency of realignment and the *expected conditional devaluation size* (conditional upon a realignment). The expected conditional devaluation size is the sum of the expected conditional realignment size and the difference between the expected exchange rate at maturity conditional upon a realignment and the expected exchange rate at maturity conditional upon no realignment.

Consider the latter difference. If the maturity τ approaches zero, the difference approaches the jump in the exchange rate within the band at a realignment. Then the expected conditional devaluation size is the expected actual jump in the (total) exchange rate at a realignment (the "true" devaluation), which differs from the jump in central parity by the jump in the exchange rate within the band. For long maturities, the difference will be small since the two expected future exchange rates within the band (conditional upon a realignment and conditional upon no realignment) will approach the unconditional mean within the band. Therefore, for sufficiently long maturities the

expected rate of devaluation will coincide with the expected rate of realignment.[7]

For sufficiently long maturities, it is also the case that the expected rate of depreciation within the band will be approximately zero, since the maximum amount of depreciation within the band is bounded by the width of the band and then divided by a long maturity. Therefore, for sufficiently long maturities the interest rate differential is an adequate measure of the expected rate of devaluation (and also of the expected rate of realignment since the two then coincide), and there is no need to adjust the interest rate differential. However, for short maturities, the expected rate of depreciation within the band may be sizable, as we shall see.

In summary, we shall estimate the expected rate of devaluation as defined in (2.9), remembering that it differs from the expected rate of realignment in that it takes into account the possibility that the exchange rate within the band may jump at realignments.

III. Estimates of Expected Rates of Depreciation within the Band

Data

The data used is part of a database created by Andrew Rose from BIS data. The database is used and described by Flood, Rose and Mathieson (1990). Daily data for the seven initial ERM currencies are included: the Belgian/Luxembourg franc (BF), the Danish krone (DK), the Deutsche mark (DM), the French franc (FF), the Italian lira (IL), the Irish pound (IP) and the Netherlands guilder (NG). The period covered is March 13, 1979, through May 16, 1990.[8] The spot exchange rates are recorded at the daily "official fixing"; interest rates are annualized bid rates for 1 month Euro-market bills at around

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[7] This is true also when proper account is taken of the possibility that several realignments can occur within long maturities.

[8] Data and programs are available from the author upon receipt of a formatted 3.5-inch high-density diskette.

10am Swiss time.

Figures 1a-f show time-series plots of the log of the BF/DM,...,NG/DM exchange rates and their bands. The exchange rates are expressed in percentage deviation of the log exchange rate from the initial log central parity. (The scale is the same for all exchange rates except the IL/DM rate.) The realignment dates and central parities are given in *Table 1.* The band-width is ±2.25 percent for all currencies except the Italian lire which had a ±6 percent band before January 8, 1990, and a ±2.25 percent from then on. Table 1 also shows the number of days (excluding weekends) in each subsample between realignments (including the observations within τ before each realignment).

Figures 2a-f show the corresponding log exchange rates within the band. (The scale is the same for all exchange rates except the IL/DM rate.) *Figures 4a-f* show the interest rate differentials between the BF,...,NG interest rates and the DM interest rate. (The scale is the same for all interest rate differentials.)

In section II we mentioned that the exchange rate within the band usually jumps at a realignment. As examples we can take the realignments of the FF/DM exchange rate in October 1981 and June 1982 (see Figure 2c). Then the realignments was larger than the devaluation, in our terminology. We also mentioned that there are cases when the old and the new exchange rate overlap at a realignment and the exchange rate does not jump at all. Then there is a realignment but no devaluation, in our terminology. As examples we can take the realignments of the IL/DM exchange rate in September 1979 and January 1987 (see Figure 1d).

Estimation

We wish to estimate the expected rate of depreciation within the band, $E_t[\Delta x_{t+\tau}| \text{no realignment}]/\tau \equiv (E_t[x_{t+\tau} - x_t|\text{no realignment}]/\tau$, conditional upon information available at time t, where τ is 1/12 year (which corresponds to about 22 daily observations), and conditional upon no realignment between date t and date $t+\tau$. (From

now on, "expected depreciation within the band" should be understood to be conditional upon no realignment unless explicitly stated otherwise.) In the Bertola-Svensson model the single determinant of the expected future rate of depreciation within the band is the current exchange rate band within the band, x_t. Although in principle the relation between the expected rate of depreciation within the band is nonlinear, Bertola and Svensson suggest that a linear approximation may be acceptable for typical parameters. Lindberg, Svensson and Söderlind (1991) and Rose and Svensson (1991) consider a number of different estimation methods, functional forms, and explanatory variables.[9] Their results combined indicate that a simple linear regression of realized rates of depreciation within the band on the current exchange rate consistently generates sensible results; whereas fancier techniques sometimes generate clearly unreasonable results. Consequently we shall use the simple linear regression here.

The expected rates of depreciation are estimated by linear regression of the equation

$$(3.1) \qquad 12(x_{t+22} - x_t) = \Sigma_j \beta_{0j} d_j + \beta_1 x_t + \epsilon_{t+22}.$$

This regression is run separately for each of the six cross DM exchange rates: BF/DM,...,NG/DM. The variable d_j is a dummy for "regime j", that is, each period between realignments. (For instance, for the BF/DM exchange rate we see in Table 1 that there are 6 realignments and hence 7 regimes.) Hence, for each exchange rate the intercepts are allowed to vary across regimes. For reasons detailed below, the slopes are restricted to be identical across regimes.

Estimating the expected future exchange rate depreciation within the band is of course equivalent to estimating the expected future exchange rate within the band. That is, estimation of (3.1) is equivalent to estimation of

$$(3.2) \qquad x_{t+22} = \Sigma_j \gamma_{0j} d_j + \gamma_1 x_t + \eta_{t+22},$$

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[9] The different cases examined include as explanatory variables the exchange rate within the band, its square and its cube; lagged exchange rates within the band; other ERM cross exchange rates; interest rate differentials. Also GARCH regressions, locally weighted regressions, and recursive regressions have been used.

where the coefficients and error terms of (3.1) and (3.2) are related by $\gamma_{0j} \equiv \beta_{0j}/12$, $\gamma_1 \equiv \beta_1/12 + 1$, and $\eta_{t+22} \equiv \epsilon_{t+22}/12$. Equation (3.2) highlights the mean-reversion in the data. *Table 2* shows the result of OLS estimation of (3.2). Newey–West standard errors allowing for both serial correlation and heteroscedasticity are computed, since the data are overlapping and in addition heteroscedasticity is likely.

Table 2 shows the regression results for the 6 exchange rates, with standard errors within parentheses. For instance, in column (6) we see that the NG/DM exchange rate has 2 realignments (79:09:24 and 83:03:31) and 3 regimes. Regime 1 (79:03:13-79:09:23) has intercept .52; regime 2 (79:09:24-83:03:20) has intercept -.13; and regime 3 (83:03:21-90:5:16) has intercept .00. The slope, restricted to be the same across regimes, is .73. The number of observations varies across the exchange rates. It is lower with more realignments, since the estimation is conditional upon no realignment and therefore 22 observations before each realignment are excluded (in order not to include the jump in the exchange rate within the band that usually occurs at a realignment).[10]

The slopes vary between .73 and .90. They are estimated precisely, with standard errors between .04 and .07. They appear significantly less than unity, indicating mean-reversion in the exchange rate within the band. However, it is known that if the true slope is unity, there is a downward bias in the estimate of the coefficient (Fuller (1976)) and the usual t-distribution does not apply. The "t-values" for the coefficient being less than unity is between -3.80 and -5.71 for all exchange rates, except IL/DM for which it is -2.77. The critical level for a standard Dickey-Fuller test on a 5 percent significance level is -2.86 for this sample size (Fuller (1976, Table 8.5.2)). Therefore a unit root can be rejected (and mean-reversion be asserted) at 5 percent significance level for all exchange rates except the IL/DM exchange rate (for which the marginal significance level

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[10] The number of observations is also less than the number of days in Table 1 because some observations are missing.

nevertheless is less than 10 percent).[11]

Table 3 shows the result of OLS estimation of (3.1). Table 3 can of course be constructed from Table 2; the standard errors in Table 3 are 12 times the standard errors in Table 2, etc. We see that the intercepts for the expected rates of depreciation within the band vary between -6.67 (regime 10 for IL/DM) and 13.89 (regime 4 for BF/DM) percent per year. Some of the intercepts for the short regimes are fairly imprecisely estimated. The slopes of the expected rates of depreciation within the band vary between -1.16 and -3.29 per year, with standard errors of between .42 and .86 per year.[12]

Figures 3a-f give a time-series plot of the resulting estimates of the expected rates of depreciation within the band. (The scale is the same for all exchange rates.) We see that the expected rates of depreciation within the band are sizable, usually between ±5 percent per year, although occasionally they are as large as 10 percent per year or more. The expected rate of depreciation within the band of the NG/DM exchange rate is smaller in magnitude than those of the other exchange rates, particularly after the first few years of the EMS.

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[11] Inclusion of lags and the square and cube of the exchange rate within the band might reduce standard errors and increase the magnitude of the t-statistics somewhat, increasing the possibility that a unit root is rejected also for the IL/DM exchange rate. Serially correlated error terms because of overlapping data does not invalidate the Dickey-Fuller test as long as the standard errors are consistently estimated (see Phillips (1987)). However, intercepts that are allowed to differ across regimes motivate variants of the Dickey-Fuller test that are likely to have critical values somewhat larger in magnitude than the standard test (see Perron (1989)). The margins to the critical t-value seem large enough that a unit root will still be soundly rejected at a 5 percent significance level, except possibly for the IL/DM exchange rate.

[12] Equations (3.1) and (3.2) have also been estimated without the restriction that the slopes are the same across regimes (the detailed results are not reported here). For FF/DM and NG/DM the hypothesis that the slopes are the same across regimes cannot be rejected, so for those two exchange rates the restriction to identical slopes across regimes is not binding. For the other exchange rates the hypotheses of identical slopes across regimes are rejected. Typically the slopes for some of the short regimes are outliers. In a couple of instances for short regimes the slope in equation (3.2) is above unity (indicating mean dispersion), although not significantly so. As discussed in Rose and Svensson (1991), imposing restrictions across regimes may alleviate small-sample problems arising with short regimes.

The hypothesis that incercepts for each exchange rate are identical across regimes is rejected, and there is no reason not to allow different intercepts for each regime.

IV. Estimates of Expected Rates of Devaluation

In order to estimate the expected rates of devaluation the interest rate differentials in *Figures 4a-f* should be adjusted for the estimated expected rates of depreciation within the band in *Figures 3a-f* , by equation (2.8). The resulting time-series of estimated expected rates of devaluation are displayed in *Figures 5a-f*. (The scale in Figures 3-5 is the same for all exchange rates. For the FF/DM during the last days before the realignment on March 21, 1983, the interest rate differential in Figure 4c and the expected rate of devaluation in Figure 5c extend beyond the top edge of the graph to about 80 percent per year.)

The NG/DM exchange rate has the smallest and least variable expected rate of devaluation. The expected rate of devaluation for the BF/DM exchange rate is also rather small and stable after 1984.

The average expected rates of devaluation are smaller after 1984 for all exchange rates, but not by much for some of the exchange rates. After 1984 expected rates of devaluation of 5 percent per year have been quite common, and sometimes they have reached 10 percent per year. There has also been a fair amount of fluctuation in the expected rates of devaluation (for instance for DK/DM and FF/DM). The expected rates of devaluation have usually been higher before realignments, and much smaller after (sometimes even negative, indicating an expected revaluation).

Is it really necessary to adjust the interest rate differentials for the expected rates of depreciation within the band, or could we do almost as well with just the interest rate differentials as estimates of expected rates of devaluation? If the exchange rates within the band had unit roots and followed a random walk within the band, the expected rates of depreciation within the band would be zero and no adjustment of the interest rate differentials would be warranted. Since the exchange rates within the band indeed do

display clear mean reversion, expected rates of depreciation within the band are generally nonzero. Nevertheless, they could still be of such small magnitude that the adjustment does not matter much. However, the expected rates of depreciation within the band are usually of the same magnitude as the interest rate differentials (often around 5 percent per year, as we have seen), so the adjustment is indeed essential, except possibly for the very large interest rate differentials sometimes observed immediately before realignments.

Specifically, consider the DK/DM exchange rate during 1989. The interest rate differential in Figure 4b was around 2.5 percent per year for most of the year. The expected rate of depreciation within the band in Figure 3b was around -2.5 percent per year. Hence, the expected rate of devaluation in Figure 5b was around 5 percent per year, double the interest rate differential, during most of 1989. (If the expected rate of depreciation within the band had instead been around $+2.5$ percent per year, the expected rate of devaluation would have been around zero.) Clearly the adjustment of the interest rate differential is necessary here for a precise estimation of devaluation expectations.

Let us recall how an expected rate of devaluation of 5 percent per year should be interpreted. By expression (2.9) the expected rate of devaluation can be interpreted as the expected conditional devaluation size (conditional upon a realignment) times the frequency of realignment. Suppose the expected conditional devaluation size is 2.5 percent. (In Figure 1b we see that the realignments after 1982 have been of about that size.) Then the corresponding frequency of realignment is as high as 2 per year. Put differently, the expected time to a realignment (the reciprocal of the frequency) is as short as 6 months. The probability of a realignment within a month is about 17 percent [(2 per year)·(1/12 year)]. If instead the expected conditional devaluation size is 5 percent, the expected frequency of realignments is 1 per year, the expected time to a realignment is 1 year, and the probability of a realignment within one month is about 8 percent.

Let me also comment on the results for the IL/DM exchange rate after the time of the

realignment of January 8, 1990. The central parity was increased by 3.75 percent. At the same time the bandwidth was reduced from ±6 percent to ±2.25 percent, as we can see in Figures 1d and 2d. As a consequence the upper edge of the band remained constant whereas the lower edge was increased by 7.5 percent. The exchange rate did not jump at the realignment, but the exchange rate within the band jumped from the upper part of the old band to the center of the new band.

We see in Figure 5d that the expected rate of devaluation took an upward jump after the realignment. This is a bit odd since usually the expected rate of devaluation drops at an increase in the central parity. The upward jump in the expected rate of devaluation is not due to any jump in the interest rate differential but due solely to a downward jump in the estimated expected rate of depreciation within the band, as we can see in Figures 3d and 4d. The downward jump in the expected rate of depreciation within the band is in turn due to the large negative intercept (-6.67 percent per year) estimated for regime 90:01:08-90:05:16 (Table 3, column (4)). This intercept is an outlier among the other intercepts. Even though the intercept is fairly precisely estimated, with a standard deviation of .88, I believe the estimate is misleading and biased downwards because of a small-sample problem.

The reason why a large negative intercept is precisely estimated is apparent from Figure 2d. There we see that the exchange rate within the band appreciated rapidly and very steadily after the realignment in January 1990 up to the end of the sample in May 1990, which naturally results in such an estimate of the intercept. However, the rapid and steady appreciation within the band is not representative and cannot be sustained, since then the exchange rate within the band would shortly end up outside the band. Clearly, an extension of the sample period to include later observations would by necessity result in a less negative estimate. For this reason the estimate of the intercept for this regime is biased downwards and misleading.[13]

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[13] As discussed in Rose and Svensson (1991), this small-sample problem can arise when

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V. Conclusions

In summary, I argue that the "naive" measure of devaluation expectations for a currency with an exchange rate band, the interest rate differential, can be considerably improved upon by adjusting the interest rate differential for the expected rate of depreciation within the band. The reason such adjustment is essential is that exchange rates within ERM bands display clear mean reversion, causing expected rates of depreciation within the band to be of about the same magnitude as the interest rate differentials. The expected rates of depreciation within the band have been estimated with a very simple and operational method, which consistently delivers sensible results.

The expected rates of depreciation within the band has been found to be sizable for the short maturity of one month that we have examined. We have noted that for sufficiently long maturities the expected rates of depreciation within the band must be approximately zero, though, since the maximum amount of depreciation within the band is bounded by the width of the band and then divided by a long maturity. Therefore, for sufficiently long maturities the interest rate differential itself is an adequate measure of the expected rate of devaluation (and of the expected rate of realignment, since these coincide for sufficiently long maturities), and no adjustment of the interest rate differential is necessary. This reasoning is confirmed by the empirical results of Lindberg, Svensson and Söderlind (1991). They estimate the expected rates of depreciation within the band for the Swedish krona for maturities between 1 and 12 months. The expected rate of depreciation within the band for 12 month maturity is rarely above 1 percent per year in magnitude, whereas the expected rate of depreciation within the band for 6 month

the length of the regime is sufficiently short compared to the expected time for the exchange rate within the band to hit one of the edges of the band when starting at the center. This small-sample problem can hence arise also with a high frequency of data and many observations.

maturity and shorter is sometimes above 4 percent per year. A tentative conclusion from the Lindberg, Svensson and Söderlind (1991) study is that for the narrow Swedish band (±1.5 percent) it is necessary to adjust the interest rate differential for the expected rate of depreciation within the band for maturities below one year, whereas it is probably not necessary for maturities above one year.[14]

Several extensions of the method to estimate expected rates of devaluation, and several potentially fruitful uses of the estimates are obvious. It would clearly be very interesting, although it is beyond the scope of this paper, to analyze and compare the estimated expected rates of devaluation for the EMS currencies with other information about devaluation expectations. It would also be very interesting to correlate the estimated expected rates of devaluation with potential fundamental determinants of realignments, like inflation differentials, real exchange rates, reserve levels, unemployment, etc.

The estimates of the expected rates of devaluation given here are point estimates. As demonstrated in Lindberg, Svensson and Söderlind (1991) a confidence interval can be constructed for the expected rates of depreciation within the band, given the estimated covariance matrix for the intercepts and slopes of the expected rate of depreciation within the band.[15] This results in a confidence interval for the expected rates of devaluation that can be conveniently plotted as a complement to Figures 5a-f.

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[14] The maximum magnitude of the expected rate of depreciation within the band depends on both the maturity and the width of the band. For the standard EMS exchange rate band of ±2.25 percent the maximum magnitude of the rate of depreciation within on year is 4.5 percent per year if the exchange rate drifts from one edge to the other in one year, and 2.25 percent per year if the exchange rate is expected to drift to the middle of the band. For the wide EMS bands of ±6 percent, the corresponding maximum magnitudes are 12 and 6 percent per year, respectively. Clearly, the expected rate of depreciation within the band within on year can be seizable, and the safe way is of course to estimate the expected rate of depreciation rather than to assume that it is negligible.

[15] In addition to the standard errors reported in Table 3, the covariance estimates between the intercept and slope estimates are needed.

The expected rates of devaluation have been estimated under the maintained hypothesis of uncovered interest parity and a negligible foreign exchange risk premium. Although I believe there are sound arguments why the foreign exchange risk premium can be neglected in narrow exchange rate bands, it is in principle possible to compute the expected rates of devaluation with nonzero foreign exchange risk premia. Given an estimate of the foreign exchange risk premium, the interest rate differential is then simply adjusted by *both* the foreign exchange risk premium and the expected rate of depreciation within the band. For instance, suppose that the foreign exchange risk premium was not negligible during 1989 for the DK/DM exchange rate discussed above, and suppose that it has, one way or another, been estimated to be as high as +1 percent per year. Then the expected rate of devaluation for the DK/DM exchange rate during 1989 was not around 5 percent per year but around 4 percent per year. With an expected conditional devaluation size of 2.5 percent, the frequency of realignment was 1.6 per year, the expected time to a realignment was 7.5 months, and the probability of a realignment within one month was about 13 percent.

It is beyond the scope of this paper to independently test and evaluate the validity of the reported estimates of the expected rates of devaluation. Such tests can be done in a number ways. One way is to compare the estimates with other information about devaluation expectations, for instance rumors reported in newspapers, surveys of expectations, and anecdotal evidence. Another way is to test whether the estimated expected rates of devaluation can predict actual devaluations and realignments. Under the maintained hypothesis of rational expectations by market agents, such a test can be seen as a test of the overall model of expected rates of devaluation. Under the maintained hypothesis that the model of expected rates of devaluation is true, the test can be seen as a test of how good market agents were in predicting actual devaluations and realignments. Rose and Svensson (1991) conduct a test the predictive power of the expected rate of

devaluation for the FF/DM exchange rate. They find that the estimated expected rate of devaluation indeed has some predictive power.

Although the method of extracting expected rates of devaluation that is used here is independent of the validity of the theoretical Bertola-Svensson (1991) model (or any other target zone model), the estimated expected rates of devaluation can of course be used to test that model (and other models of devaluation in exchange rate target zones). Rose and Svensson (1991) report some results along this line, for instance plots of the inferred exchange rate function and unit-root tests of the expected rate of devaluation. The results lend some empirical support for the Bertola-Svensson model. A more systematic study of the Bertola-Svensson model can be done with the techniques of Flood, Rose and Mathieson (1990).

Table 1. Realignment Dates and Bilateral Central DM Rates in the EMS

	BF/DM	DK/DM	FF/DM	IL/DM	IP/DM	NG/DM	No. days
79:03:13	15.7164	2.82237	2.30950	457.314	0.263932	1.08370	139
79:09:24	16.0307	2.96348	2.35568	466.460	0.269210	1.10537	49
79:11:30	16.0307	3.11165	2.35568	466.460	0.269210	1.10537	341
81:03:23	16.0307	3.11165	2.35568	496.232	0.269210	1.10537	140
81:10:05	16.9125	3.28279	2.56212	539.722	0.284018	1.10537	100
82:02:22	18.4837	3.38433	2.56212	539.272	0.284018	1.10537	80
82:06:14	19.2693	3.52817	2.83396	578.574	0.296090	1.10537	200
83:03:21	20.0285	3.63141	3.06648	626.043	0.323703	1.12673	610
85:07:22	20.0285	3.63141	3.06648	679.325	0.323703	1.12673	185
86:04:07	20.4252	3.70332	3.25617	699.706	0.333416	1.12673	85
86:08:04	20.4252	3.70332	3.25617	699.706	0.362405	1.12673	115
87:01:12	20.6255	3.81443	3.35386	720.699	0.373281	1.12673	780
90:01:08	20.6255	3.81443	3.35386	748.217	0.373281	1.12673	92

Source: Ungerer, Hauvonen, Lopez-Claros and Mayer (1990, Table 4). The last column gives the number of days (excluding weekends) to the next realignment. The last date of sample is 90:05:16.

Table 2. Expected Future Exchange Rate within the Band, (3.2)

	(1) BF/DM	(2) DK/DM	(3) FF/DM	(4) IL/DM	(5) IP/DM	(6) NG/DM
Intercepts						
79:03:13	.63 (.16)	.75 (.27)	.31 (.07)	-.21 (.22)	.27 (.15)	.52 (.12)
79:09:24	.28 (.12)	.84 (.14)	-.02 (.12)	.35 (.15)	.13 (.11)	-.13 (.07)
79:11:30		.06 (.11)				
81:03:23				.31 (.24)		
81:10:05	.39 (.08)	.23 (.13)	.46 (.21)	.58 (.26)	.34 (.21)	
82:02:22	1.16 (.43)	.48 (.29)				
82:06:14	.49 (.14)	.28 (.19)	.24 (.11)	.33 (.27)	.40 (.19)	
83:03:21	.33 (.07)	.03 (.07)	-.01 (.05)	.09 (.17)	.06 (.08)	.00 (.02)
85:07:22				.16 (.12)		
86:04:07	.48 (.11)	.54 (.13)	.33 (.17)	.02 (.09)	.47 (.34)	
86:08:04					.56 (.13)	
87:01:12	.29 (.07)	.17 (.08)	.14 (.07)	.28 (.12)	.04 (.05)	
90:01:08 -90:05:16				-.56 (.07)		
Slope	.76 (.04)	.80 (.04)	.83 (.04)	.90 (.04)	.86 (.04)	.73 (.07)
Diagnostics						
N	2420	2457	2426	2431	2461	2618
R-squared	.69	.77	.77	.87	.74	.68
σ	.43	.55	.52	.74	.54	.35

OLS on (3.2) with Newey-West standard errors within parentheses (22 lags). Regressand is x_{t+22} (%) (22 daily observations correspond to one month), regressor is x_t (%), where $x = \ln(BF/DM),...,$ $\ln(NG/DM)$. A vertical bar for a realignment date indicates that the corresponding currency was not realigned and that the estimate straight above applies.

Table 3. Expected Exchange Rate Depreciation within the Band, (3.1)

Intercepts	(1) BF/DM	(2) DK/DM	(3) FF/DM	(4) IL/DM	(5) IP/DM	(6) NG/DM
79:03:13	7.57 (1.87)	8.96 (3.29)	3.72 (.88)	-2.54 (2.58)	3.24 (1.76)	6.20 (1.42)
79:09:24	3.36 (1.41)	10.09 (1.70)	-.18 (1.45)	4.26 (1.81)	1.57 (1.38)	-1.63 (.81)
79:11:30		.75 (1.32)				
81:03:23				3.72 (2.88)		
81:10:05	4.74 (.94)	2.70 (1.54)	5.54 (2.51)	7.02 (3.07)	4.11 (2.49)	
82:02:22	13.89 (5.18)	5.74 (3.52)				
82:06:14	5.84 (1.65)	3.39 (2.23)	2.83 (1.37)	4.00 (3.24)	4.77 (2.27)	
83:03:21	3.90 (.84)	.33 (.86)	-.07 (.55)	1.12 (1.98)	.70 (.93)	.02 (.18)
85:07:22				1.92 (1.50)		
86:04:07	5.80 (1.30)	6.43 (1.60)	3.95 (2.06)	.28 (1.06)	5.62 (4.14)	
86:08:04					6.74 (1.52)	
87:01:12	3.51 (.79)	2.01 (1.01)	1.63 (.88)	3.34 (1.49)	.47 (.55)	
90:01:08 -90:05:16				-6.67 (.88)		
Slope	-2.86 (.50)	-2.34 (.49)	-1.99 (.49)	-1.16 (.46)	-1.64 (.42)	-3.29 (.86)
Diagnostics						
N	2420	2457	2426	2431	2461	2618
R-squared	.24	.19	.15	.08	.13	.17
σ	5.2	6.6	6.2	8.9	6.4	4.2

OLS on (3.1) with Newey-West standard errors within parentheses (22 lags). Regressand is $(x_{t+22}-x_t)/\tau$ (%/yr), $\tau = 1/12$ year (22 daily observations), regressor is x_t (%), where $x = \ln(\text{BF/DM}),..., \ln(\text{NG/DM})$. A vertical bar for a realignment date indicates that the corresponding currency was not realigned and that the estimate straight above applies.

References

Bartolini, Leonardo, and Gordon M. Bodnar, "Target Zones and Forward Rates in a Model with Repeated Realignments," Working Paper (unpublished, International Monetary Fund and University of Rochester, 1991).

Bertola, Giuseppe, and Ricardo J. Caballero, "Target Zones and Realignments," Discussion Paper No. 398 (unpublished, Centre for Economic Policy Research, 1990).

——, and Lars E. O. Svensson, "Stochastic Devaluation Risk and the Empirical Fit of Target-Zone Models", Seminar Paper No. 481 (unpublished, Institute for International Economic Studies, 1990).

Bodnar, Gordon M., "Target Zones and Euro-Rates: A Model of Eurocurrency Interest Rate Differentials in the European Monetary System," Working Paper (unpublished, University of Rochester, 1991).

Collins, Susan M., "The Expected Timing of Devaluation: A Model of Realignment in the European Monetary System," Working Paper (unpublished, Harvard University, 1986).

Edin, Per-Anders, and Anders Vredin, "Devaluation Risk: Evidence from the Nordic Countries," Working Paper (unpublished, Trade Union Institute for Economic Research, Stockholm, and Uppsala University, 1991).

Flood, Robert P., Andrew K. Rose and Donald J. Mathieson "An Empirical Exploration of Exchange Rate Target-Zones", Working Paper No. 3543 (unpublished, National Bureau of Economic Research, 1990). Carnegie-Rochester Series on Public Policy, forthcoming.

Fratianni, Michele, and Juergen von Hagen, "Asymmetries and Realignments in the EMS," in Paul de Grauwe and Lucas Papademos, eds., The EMS in the 1990s, (London: Longwood, 1990).

Froot, Kenneth A., and Richard H. Thaler, "Anomalies: Foreign Exchange," <u>Journal of Economic Perspectives</u> 4-3, 179-192.

Fuller, Wayne A., <u>Introduction to Statistical Time Series</u>, (New York: Wiley, 1976).

Giovannini, Alberto, "European Monetary Reform: Progress and Prospects," <u>Brookings Papers on Economic Activity</u>, (2: 1990), pp. 217-291.

Lindberg, Hans, Lars E. O. Svensson and Paul Söderlind, "Devaluation Expectations: The Swedish Krona 1982-1991," Working Paper (unpublished, Institute for International Economic Studies, 1991).

Perron, Pierre, "The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis," <u>Econometrica</u>, Vol. 57 (1989), pp. 1361-1401.

Phillips, P. C. B., "Time Series Regression with a Unit Root," <u>Econometrica</u>, Vol. 55 (1987), pp. 277-301.

Rose, Andrew K., and Lars E. O. Svensson, "Expected and Predicted Realignments: The FF/DM Exchange Rate during the EMS," Seminar Paper No. 485 (unpublished, Institute for International Economic Studies, 1991).

Svensson, Lars E. O., "The Foreign Exchange Risk Premium in a Target zone with Devaluation Risk", Seminar Paper No. 475 (unpublished, Institute for International Economic Studies, 1990).

——, "The Simplest Test of Target Zone Credibility," <u>IMF Staff Papers</u>, Vol. 38 (1991), forthcoming.

Ungerer, Horst, Jouko J. Hauvonen, Augusto Lopez-Claros, and Thomas Mayer, "The European Monetary System: Developments and Perspectives," Occasional Paper No. 73 (International Monetary Fund, 1990).

Weber, Axel A., "Reputation and Credibility in the European Monetary System," <u>Economic Policy</u>, Vol. 12 (1991), pp. 57-102.

Figure 1a. BF/DM log exchange rate
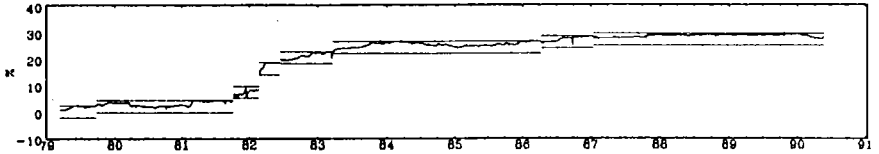
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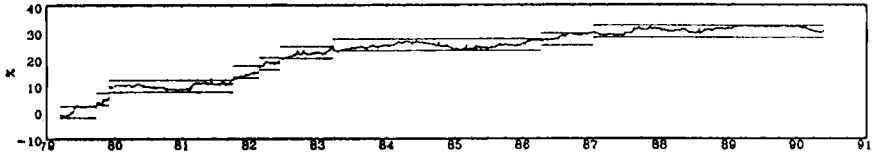
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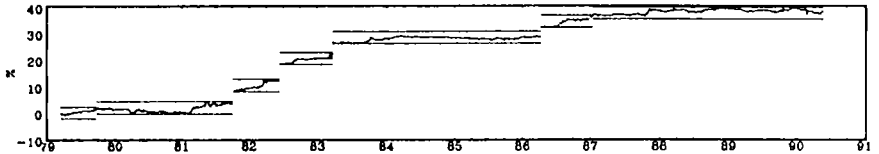
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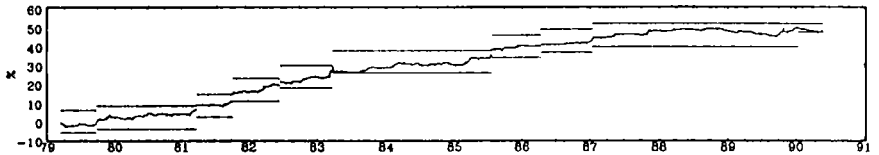
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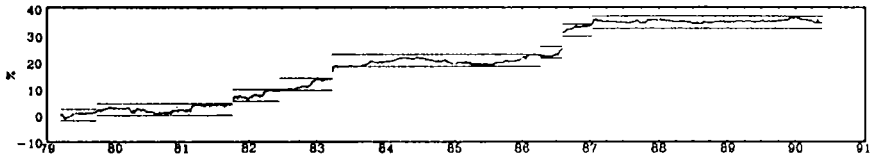
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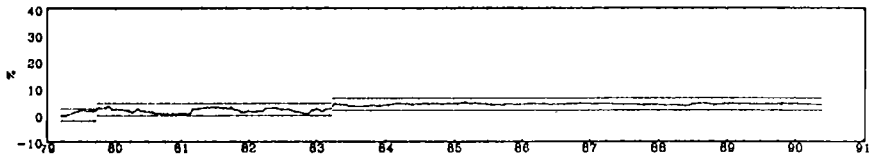
Figure 2a. BF/DM log exchange rate within band
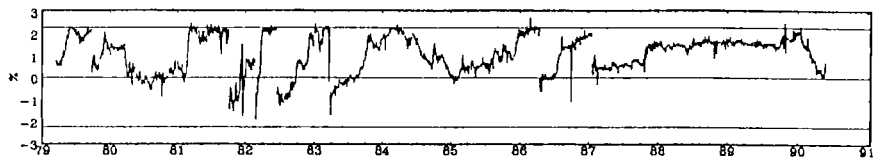
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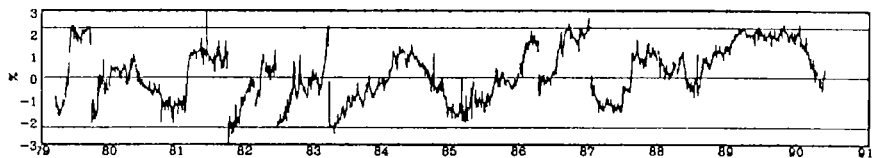
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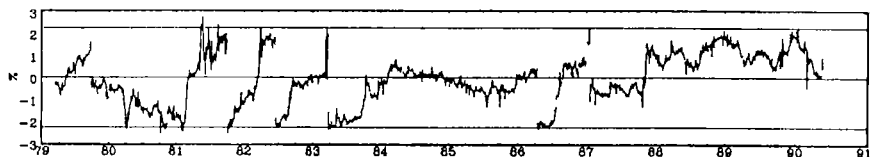
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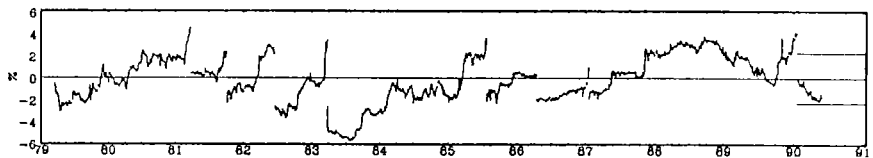
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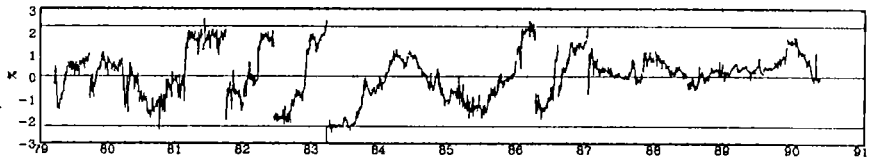
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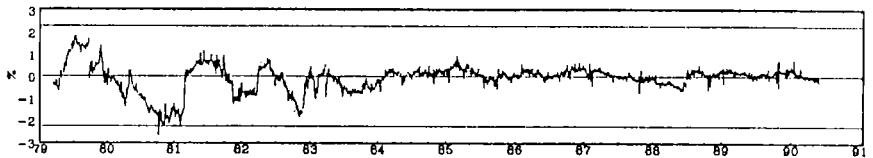
Figure 3a. BF/DM expected rate of depreciation within band
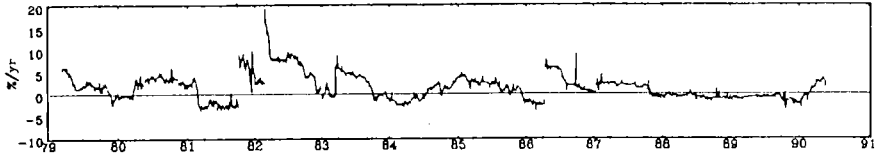
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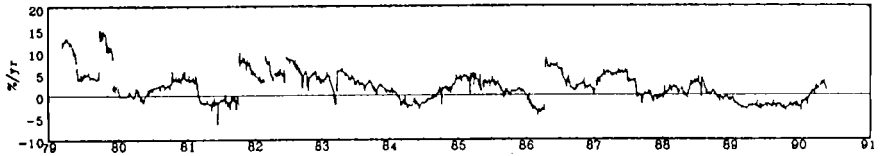
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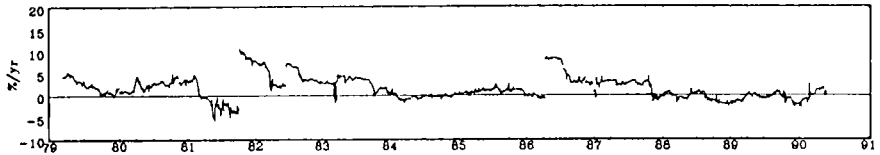
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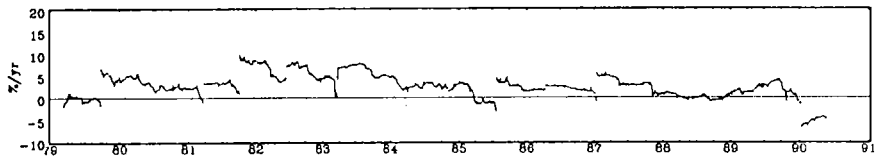
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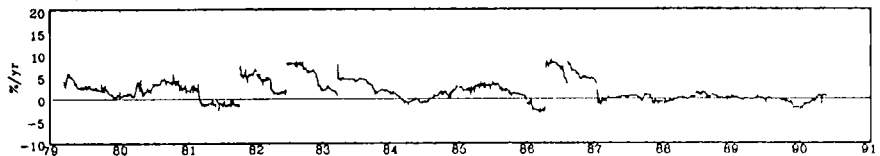
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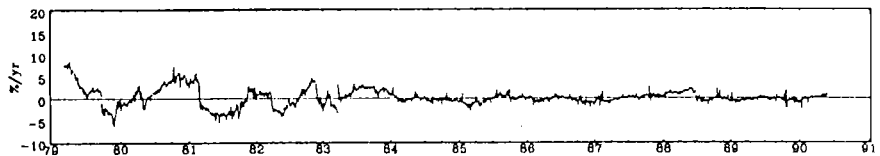
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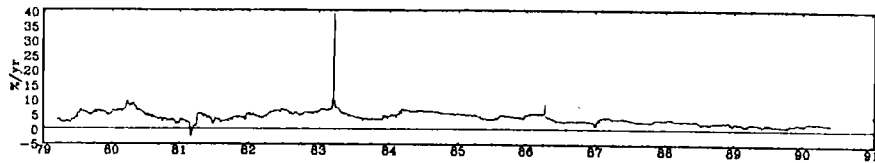
Figure 4b. DK/DM interest rate differential

Figure 4c. FF/DM interest rate differential
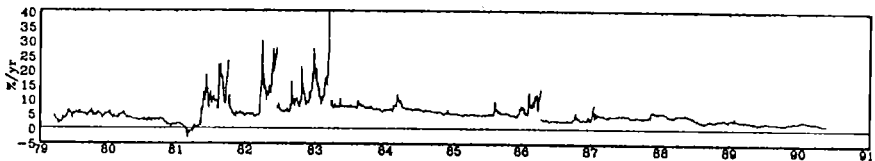
Figure 4d. IL/DM interest rate differential

Figure 4e. IP/DM interest rate differential
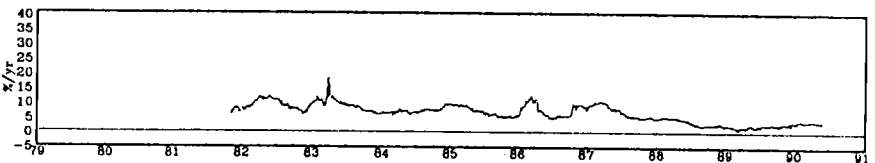
Figure 4f. NG/DM interest rate differential
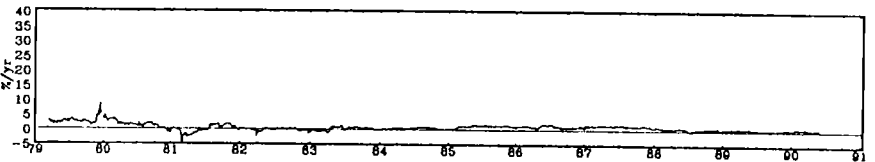
Figure 5a. BF/DM expected rate of devaluation
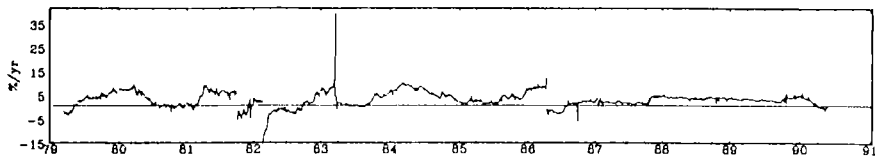
Figure 5b. DK/DM expected rate of devaluation

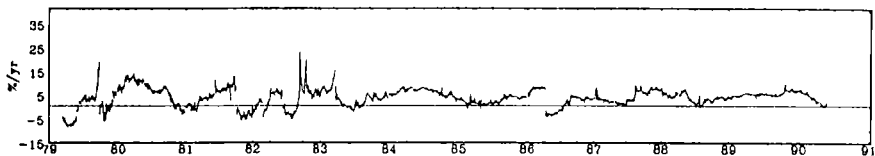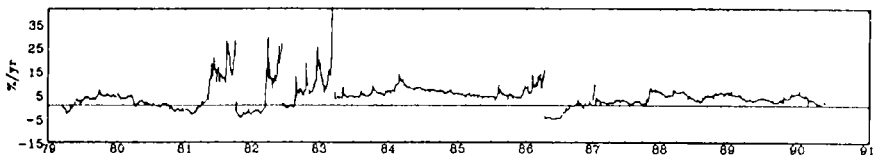Figure 5c. FF/DM expected rate of devaluation

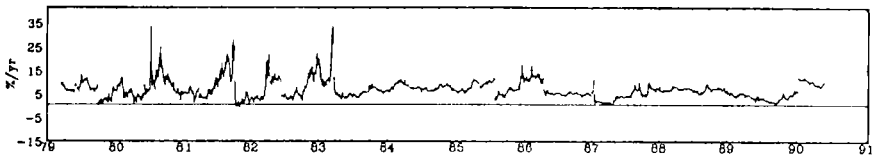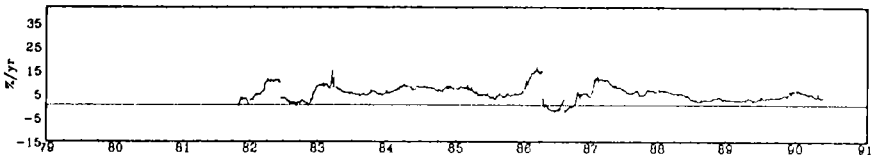Figure 5d. IL/DM expected rate of devaluation

Figure 5e. IP/DM expected rate of devaluation

Figure 5f. NG/DM expected rate of devaluation