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Zhaohui Chen

Alberto Giovannini

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ABSTRACT

This paper develops a simple econometric procedure for estimating expected exchange rate under target zones. We employ the linear projection methodology to make predictions without relying on any prior structural or distributional assumptions, and at the same time demonstrate that such a methodology has to be modified in an important way to account for the presence of the fluctuation band. Our empirical results show that the band effect is nontrivial for narrow target zones such as the Bretton Woods system. We also develop a method to estimate the shapes of the unconditional distributions of exchange rates under target zones. The empirical results show that the unconditional distributions of exchange rates can take several different shapes, which may correspond to possibly widely different monetary and exchange-rate intervention policies. We also show how to use the projection equations and the information about the band to test the credibility of the exchange rate regimes.

Zhaohui Chen
Graduate School of Business
622 Uris Hall
Columbia University
New York, NY 10027

Alberto Giovannini
Graduate School of Business
622 Uris Hall
Columbia University
New York, NY 10027
and NBER

1 Introduction

Movements of asset prices are often subject to band restrictions. In the case of exchange rates, these bands characterize every system of fixed exchange rates—from the international gold standard onwards. The upper and lower limits of fluctuation of currencies' exchange rates are in many instances announced publicly: for example, under the Bretton Woods regime the price of dollars in terms of member currencies was restricted within a band of 1 percent on either side of central parities; under the European Monetary System (EMS) bilateral exchange rates of most currencies are allowed to fluctuate within bands of 2.25 percent on either side of central parities.

The theoretical implications of target zones were not studied until recently. See, for example, Krugman (1988), Bertola and Caballero (1989), Bertola and Svensson (1990), Svensson (1991a), and Lindberg and Söderlind (1991). These studies find, among other things, the following consequences of a target zone: (1) The exchange rate distribution is bounded on both the upper and lower sides. (2) The unconditional distribution depends on the type of monetary intervention policy involved and the structural relations assumed. (3) The conditional distribution is heteroskedastic. (4) The interest rate differential as a measure of expected realignment is imprecise.

Following the theoretical literature, a number of empirical papers have appeared, aiming at estimating the unconditional distributions of exchange rates and testing the credibility of target zones. Among these, see in particular Flood, Rose and Mathieson (1990), Giovannini (1990), Lindberg, Svensson and Söderlind (1991), Rose and Svensson (1991) and Svensson (1991b,c). Typically, they compare interest-rate differentials, which are used as proxies of expected exchange-rate changes, with information about the exchange-rate bands. Such comparisons lead to propositions about the credibility of the bands.

Two challenging problems remain in the empirical studies of exchange rates under the target zones. The first is the presence of the band restriction on the exchange rates. Since rational agents should include the announced band as part of their information set, it is important for the econometrician to explicitly take that into account. The second has to do with the difficulty in estimating the exchange rate distribution. Since the distribution varies with the intervention policies assumed, and since the theoretical models have closed form solutions for only a few simplified policy rules, it is difficult to estimate a distribution corresponding to the true underlying policy and model structure.

In what follows we present a method for estimating expected exchange rates within target zone bands and a method for estimating the unconditional distribution of exchange rates which are not conditional on any fundamental model of exchange rates. The spirit of our test derives from the projection-equation methods to estimate expectations, as discussed, for example, by Abel and Mishkin (1983). The advantage of this methodology is its generality: projection equations are often alternatives in tests of structural models. We show, however, that in the case of target zones the projection-equation methodology of estimating expectations has to be modified in an important way, to account for the presence of target zones.

The general test procedure followed in this paper is like that of Rose and Svensson (1991), Svensson (1991c) and Lindberg, Svensson and Söderlind (1991). Unlike these authors, however, we explicitly account for the distributional implications of target zones. We show that failing to do so leads to estimation bias and develop a new econometric procedure that is unbiased and asymptotically efficient. Our procedure does not hinge on special assumption on the distribution of the projection error, but can allow for a large family of distributions which can approximate those implied by the theoretical models. To illustrate our empirical methodology, we apply it two datasets taken from different exchange-rate regimes, including the Bretton Woods regime and European Monetary System.

The rest of the paper is organized as follows. Section 2 develops a method of estimating expected exchange rates under target zones and applies the method to testing the credibility of exchange rate regimes. Section 3 presents a method to estimate the unconditional distributions and applies it to the data. Finally, section 3 contains a few concluding remarks.

2 Estimating Expected Exchange Rates within Band and Testing the Credibility Exchange Rate Regimes

2.1 The Estimation

Following Svensson (1991a), we decompose the log exchange rate (s_t) into the summation of the log central parity (c_t) and the log percentage deviation from the central parity (x_t), the latter is restricted by the fluctuation band ($-L \leq x_t \leq L$). We call it the exchange rate within band. Our task in this section is to estimate the expected exchange rate within band.

Conventional estimation methods are developed for random variables that are unbounded and, preferably, normally distributed. To deal with the bounded exchange rates with unknown distribution, we first transform the random variable into an unbounded one, and then employ estimation methods that do not rely on distributional assumptions.

We now transform the expected exchange rate within band, x_t, into a new variable y_t^*:

$$y_t^* \equiv \ln\left(\frac{L + x_t}{L - x_t}\right), \quad -L \leq x_t \leq L. \tag{1}$$

We adopt the above transformation on both technical and conceptual grounds. Technically, the range of the transformed variable y_t^* is unconstrained, we can, in principle, use conventional techniques to estimate the parameters. Conceptually, as we mentioned before, we need to take the band restriction into account since it is an essential part of the agents' information set. Our definition of y_t^* turns out to be a measure of exchange rate inside the band that takes into account the presence of both bounds. To see this, consider the terms $L + x_t$ and $L - x_t$. The former is the distance between the exchange rate inside the band and the lower limit of the band, and the latter is the distance between the exchange rate inside the band and the upper limit of the band. The ratio of the two terms is therefore a measure of the position of the exchange rate relative to the upper and lower limits of the band. Therefore the band information is naturally embedded in our transformed variable y_t^* (the log of the ratio).

Following the projection methodology, we propose the following linear projection equation for y_t^*:

$$y_t^* = z_t'\beta + u_t, \tag{2}$$

where z_t is the vector of information variables, β is a vector of parameters to be estimated, and u_t is contemporaneously independent of z_t'.

In estimating expected exchange rates within bands the projection horizon is usually longer than the sampling intervals of the data. To make full use of the sample information we follow the strategy developed in Hansen and Hodrick (1980), Cumby, Huzinga and Obstfeld (1983), and Hansen (1982) to obtain consistent estimates of β and its covariance matrix.[1] Following Svensson (1991c) we also use the Newey-West (1985) modification to account for the conditional heteroskedasticity.

The projection equation gives the estimate of the expectation of y_t^* as $z_t'\hat{\beta}$. To estimate the expected values for x_t, consider the reverse transformation:

$$x_t = \frac{\exp\left(\frac{y_t^*-\gamma}{\delta}\right) - 1}{\exp\left(\frac{y_t^*-\gamma}{\delta}\right) + 1} L.$$

Since $\hat{\beta}$ is asymptotically normal and efficient (See Hansen (1982)), and its covariance matrix ($\hat{V}_\beta$) can be calculated using the Newey-West (1982) procedure, it follows that y_t^* is asymptotically normal with mean $z_t\hat{\beta}$ and variance $z_t'\hat{V}_\beta z_t + e'e/T$, where e is the vector of residual terms and T is the sample size. We can then obtain the asymptotic density function for x_t using the change-of-variables procedure:

$$f(x_t) = \frac{2L}{L^2 - x^2}\phi\left(\frac{\ln\frac{L+x_t}{L-x_t} - z_t\hat{\beta}}{\sqrt{z_t'\hat{V}_\beta z_t + e'e/T}}\right),$$

where $\phi(\cdot)$ is the standard normal density functiion. The expected value of x_t is given by

$$\hat{x}_t = \int_{-L}^{L} x_t f(x_t) dx_t.$$

[1] The usual GLS and maximum likelihood estimators are inconsistent in the case of autocorrelated errors, if the independent variables are not econometrically exogenous (See Cumby and Huizinga, 1990). In the case of exchange rate models, most information variables are predetermined rather than exogenous.

The 95% confidence intervals can then be numerically calculated for each $\hat{x}_t$. Due to conditional heteroskedasticity, the confidence interval is asymmetric. So its upper and lower bounds need to be computed separately. Specifically, the upper bound at time t, B_t^U, can be computed numerically as the solution to the following nonlinear equation:

$$\int_{\hat{x}_t}^{B_t^U} f(x_t)dx_t = 47.5\%. \tag{3}$$

Similarly, the lower bound B_t^L can be obtained by solving

$$\int_{B_t^L}^{\hat{x}_t} f(x_t)dx_t = 47.5\%. \tag{4}$$

By construction $\hat{x}_t$ and its confidence interval can only fall between $-L$ and L.

The advantage of the above method is its simplicity and generality. It does not assume any structural relations between the exchange rate and the fundamentals,[2] rather it relies on the projection equation to extract information useful in predicting exchange rates. It does not impose restrictions on the distribution of the exchange rate. The band restriction, however, is explicitly imposed in a natural way.

2.2 Comparison with Existing Estimation Methods

One way to estimate the expected exchange rates within target zones is to use a fully specified model and numerically simulate the probability densities and compare the simulated moments with the empirical moments. This is known as the simulated method of moments (see Lindberg and Söderlind (1991)). The method is tied to the particular model structure. It gives accurate estimates of the model parameters if the model is the true description of the mechanism generating the data. If, however, the model is not a good approximation to the true exchange rate mechanism, either because of the difficulty in selecting proper fundamental variables or because of the oversimplified assumptions about the intervention policy, then the estimated exchange rates will be imprecise. In the latter case, our unconstrained method can often give improved estimation. Another commonly used procedure applies the OLS directly

[2] This is desirable due to the poor empirical performance of nearly all structural models for exchange rates.

to the data within the band. The method is completely unconstrained: it is not only flexible in the choice of fundamentals and the distribution, but also imposes no band restrictions on the exchange rates. The motivation for this method is that the OLS is robust to the distributional assumptions, so it should be applicable to distributions of any shapes and forms, including the bounded distributions. However, this method is problematic for the following reasons: the OLS requires the error term to be identically distributed and uncorrelated with the regressor. But when the dependent variable is subject to the band restriction, these conditions no longer hold. To see this, let the OLS regression equation be

$$x_t = z_t'\beta + e_t,$$

where by the assumption of the OLS, e_t is an independently and identically distributed random variable with mean zero, and is uncorrelated with z_t'. But the target zone restriction requires that

$$-L \leq x_t \leq L,$$

which implies

$$-L - z_t'\beta \leq e_t \leq L - z_t'\beta.$$

As we can see, the error term is regulated by the upper bound $(L - z_t'\beta)$ and the lower bound $(-L - z_t'\beta)$, so its distribution depends on the value of the independent variable at time t, i.e., it is not identically distributed, and it is correlated with the regressor. Also the zero mean assumption does not hold in general. The OLS estimator is therefore biased.

The economic interpretation of these biases is simple: since the band restriction is part of the information set for the rational agents, the agents can exploit the information to predict future monetary interventions. For example, when the current exchange rate is too close to the upper limit, it can only be expected to move downward, and the agents know how much room (the lower limit) there is for the downward movement, if the target zone is credible. Therefore the band restrictions has to be imposed in the empirical estimation. Ignoring them introduces a correlation between information and surprises which is not exploited by agents if they use simple

OLS projections, and therefore implies a deviation from the rational expectations hypothesis.

2.3 An Empirical Illustration

We now apply the econometric methodology developed above to data from the European Monetary System and the Bretton Woods regime. The data are compiled as follows. For the Bretton Woods period, the end-of-month spot exchange rates are from the International Financial Statistics, the three month forward exchange margin (a proxy used to construct the interest rate differential) is obtained from Grubel (1966). For the EMS period, the monthly exchange rates are the last daily quote of each month from the data set compiled by Andrew Rose.[3] The three-month interest rates data are from the international database currently maintained at the Federal Reserve Board. The money supply data for both the Bretton Woods and the EMS regimes are from the IFS tape. To focus on the target zone problem, we have adjusted the values of a few large observations so that they lie inside the band.

While in the EMS fluctuation bands are 2.25 percent on either side of the central parity, under Bretton Woods they were only 1 percent on either side of the *dollar* parity.[4] Hence the width of the Bretton Woods bands we study here is less than half the width of the EMS bands.

2.3.1 Projection Equations

We use various information variables to estimate the projection equations. Specifically, we use current y_t^*, its higher order terms, interest rate differential (we use forward exchange margin is used as a proxy of interest rate differential for the Bretton Woods period), money supplies (for countries with monthly data available), and regime dummies corresponding to different central parities. The point estimation results are reported in Table 1 through 6.

[3]We thank Lars Svensson for having made available the EMS data set originally developed by Andy Rose. That data set is described in Flood, Rose and Mathieson (1990).

[4]The implication is that bilateral fluctuation bands for non-dollar exchange rates were 4 percent wide.

To compare our method with the conventional method, we also report the results of the conventional projection equation which ignores the band restrictions. Such unrestricted model regresses x_{t+3} on x_t and its higher order terms, and other information variables used in the constrained model.

Figures 1 through 6 are the estimated 95% confidence intervals for expected exchange rates within band (with 47.5% confidence region on either side of the estimates). The solid lines are the results our restricted model (with band restriction imposed via the transformation procedure), while the dotted lines are results of the convectional linear projection of x_t. As we can see, in the former case the estimated values and confidence intervals are all within the band, but in the latter case, we find many periods when the estimated values and confidence intervals lie outside the band, which is clearly inconsistent with the presence of the band. The problem is more serious during the Bretton Woods regime, when the band is narrower (1 %). Also, when the band restriction is imposed, the confidence intervals are mostly asymmetric, which is a direct consequence of special form of the conditional density function under the target zones.

It is interesting to note that, under the band restriction, even when the projection error is large (e.g. the Belgian franc under the EMS), the restricted confidence interval tends to fill the whole target zone but is bounded by the latter. This implies that even when the information set is noisy the information about the band is still exploited.

Svensson (1991c) found mean reversion in the exchange rate within the band and show that the interest rate differential needs to be adjusted for the expected rate of devaluation within the band to yield the correct expected devaluation. This is also confirmed in our empirical results: the adjustment on the interest rate differential is sizable in most cases. The coefficient for the current y_t^* is, like the case of unrestricted models, usually far less than 1, even though y_t^* it is by definition unrestricted has a larger range of fluctuations in the data. This implies the fluctuations within a given target zone are transitory, mean reversion processes. This implies that the central bank allows temporary fluctuations within the band while deferring long-run adjustment to later realignment of central parity.

2.3.2 Testing the Credibility of Exchange Rate Regimes

Rose and Svensson (1991) and Svensson (1991c) formulate a method to test the credibility of exchange rate regimes. The essence of the test is to compare the estimated expected exchange rate devaluation with the announced official target, and see if they are significantly different. The expected exchange rate devaluation is shown to be the interest rate differential adjusted for the expected depreciation within band, i.e.,

$$\begin{aligned} & E_t \Delta c_t + p_t[E_t(x_{t+1}|\text{realignment}) - E_t(x_{t+1}|\text{no realignment})] \\ & = i_t - i_t^* - E_t(\Delta x_t|\text{no realignment}), \end{aligned} \tag{5}$$

where i_t and i_t^* are the domestic and foreign interests respectively. The left-hand side of (5) can be interpreted as the expected rate of devaluation: it is the combination of the expected change in the central parity and the expected change in the deviation from the central parity. See Rose and Svensson (1991) for more discussions.

A test of credibility of the target zone is a test that the left-hand side of equation (5) is equal to zero. It is constructed as follows: First, estimate $E_t(\Delta x_t|\text{no realignment})$ and compute its confidence interval. Then subtract the confidence interval from the interest rate differential $i - i^*$. At any time t, we conclude that the band is credible if zero (which corresponds to the central parity) is contained in the resulting confidence interval.

Figures 7 to 12 contain the results of the credibility tests. They report the estimated 95% confidence intervals for the expected devaluation three month ahead. Again, we report results of both the restricted model (solid lines) and unrestricted model (dotted lines). Figures 7 and 8 show the case of the pound sterling and the Deutsche mark under the Bretton Woods system. The confidence intervals given by the unconstrained model are much wider than those implied by the constrained model. As a result, there are many periods when credibility is clearly rejected by the restricted model but not by the unconstrained model. This has to do with the erroneous estimates of confidence intervals for the expected future exchange rates (see figures 1 and 2). For the EMS period (figures 9 to 12), the difference of confidence intervals are evident, but less striking than the case of the Bretton Woods period, suggesting that the band restrictions are less severe when the band is wider (2.25% under the EMS). Also, under the EMS, frequent rejections of credibility occur for the Belgian franc (figure 9), the Danish krona (figure 10), and the French franc (figure 11), and the rejections tend to occur at roughly the same time, suggesting that most credibility problems are a result of common shocks faced by these countries. The case of Dutch guilder is shown in figure 12. As we know, the guilder was kept well inside the target zone, and the fluctuations were very small except for the beginning part of the EMS period. Not surprisingly, we find very few rejections of credibility for the guilder.

3 Estimating the Unconditional Distributions

3.1 The Methodology

In this section we discuss a way to estimate the unconditional distribution of exchange rates under the target zones. Theoretical target zone models (e.g., Krugman (1991) and Lindberg and Söderlind (1991)) are constructed on the basis of the standard asset price model for the exchange rate:

$$s(t) = f(t) + \alpha dE[s(t)]/dt, \tag{6}$$

which states that the current exchange rate depends on its fundamental value $f(t)$ and the expected future exchange rate. The central bank intervenes by altering such fundamentals as the money supply in accordance with the target zone policy. Krugman postulates an infinitesimal intervention policy which occurs only at the limits of the target zone[5] and shows that the asymptotic (unconditional) distribution of the exchange rate is U-shaped (bimodal). See Flood, Rose and Mathieson (1990) for more discussions. Lindberg and Söderlind consider the case of intra-marginal intervention with the degree of intervention being proportional to the deviation of money supply from its targeted level.[6] They conclude that the asymptotic distribution of the exchange rate is bell-shaped. The bell-shape is consistent with the notion of

[5] The policy leads to a regulated Brownian motion specification for $f(t)$.

[6] This specification leads to a regulated Ornstein-Uhlenbeck process for $f(t)$.

mean reversion due to the nature of the assumed intervention policy. In both cases the distributions are bounded (truncated) by the targeted exchange rate band.

The target zone models have closed form solutions only for a few simplified specifications of intervention policies such as those mentioned above. The models themselves usually do not address the question of what the economic fundamentals should be included in determining $f(t)$. It is conceivable that other specifications of the fundamentals and of the intervention policies will yield different forms of distributions.

The above discussions suggest that in formulating a general estimation procedure, one should explicitly take into account the band restriction, but at the same time should be flexible on the selection of the fundamental variables and on the assumption about the distributional forms. In this spirit, Flood, Rose and Mathieson (1990) plot the data frequency charts for various currencies. The disadvantage of that eye-balling method is that it is not a formal estimation. Here we propose a way to parameterize and estimate the density curves under target zone restrictions.

The underlying density function is not known. However, there is a rich tradition in probability studies to mimic different shapes of density curves using a limited number of parameters. A classical example is the Pierson family of distributions, which can mimic most known distributions. In our particular problem, we require a mimicking system that captures different shapes of density curves for data with upper and lower bounds. Johnson (1949) and Johnson and Kotz (1970) develop a parameterization system (known as the S_B system) for the bounded data. They use the standard normal density function as a basic building block, together with a transformation function with only four parameters, two for the shaping function, and two for the lower and upper bounds, to describe a rich variety of distributions. The same methodology is followed in the Box-Cox transformation procedure. Following this methodology, we propose the following transformation

$$y_t \equiv \gamma + \delta \ln \left(\frac{L + x_t}{L - x_t} \right), \quad -L \leq x_t \leq L, \tag{7}$$

where L is the half-width of the symmetric band.[7] The transformed variable y_t is assumed to be $N(0,1)$. As such, the distribution of x_t given L is determined uniquely by the two transformation parameters γ and δ. With different combinations of γ and δ, one can numerically simulate almost all relevant density curves for the random variable x_t with lower and upper bounds. The density curves can take the documented U-shape and bell shape, as well as other shapes that are not documented in previous literature. When $\gamma = 0$ the density curve is symmetric. The normal distribution corresponds to the case $\delta \to \infty$.

Maximum likelihood is a natural way to estimate the density curve without imposing prior structural restrictions. Let $\phi(y)$ be the density function for the standard normal distribution, then by the change-of-variables rule the density function for x_t is

$$f(x) = J\phi(\gamma + \delta \ln \frac{L+x}{L-x}). \tag{8}$$

The Jacobian J is given by

$$\delta \frac{2L}{L^2 - x^2}.$$

The log likelihood function is

$$l = \sum_T \ln J_t + \sum_T \ln \phi(\gamma + \delta \ln \frac{L+x_t}{L-x_t}) \tag{9}$$

Maximizing the likelihood function l we can obtain estimates of γ and δ. The density curve can be numerically generated for the estimated parameters. We can then examine what kind of intervention policy is more likely to be consistent with the exchange rate data, as we will demonstrate in the empirical section.

3.2 Empirical Results

Table 7 reports maximum-likelihood estimates of the parameters γ and δ which characterize the shape of the unconditional distribution of x. As we argued in section 4, a value of γ close to zero indicates that the estimated unconditional distribution of x is approximately symmetric. A value of δ close to zero implies a U-shaped unconditional distribution, while when δ gets large the distribution approximates a bell-shape.

[7] The proçedure can be extended easily to asymmetric bands.

For the Bretton Woods sample,[8] the unconditional distribution of x for the pound sterling is symmetric (γ insignificantly different from zero), and is between the bimodal and the bell shape, as shown in figure 9. Figure 10 shows the case of the Deutsche mark during the Bretton Woods period. The distribution is an asymmetric U, with most of the probability mass concentrated by the lower edge of the fluctuation band (stronger DM).

Figures 11 to 14 report the plots of the estimated unconditional distribution for x during the EMS for the Belgian franc, Danish krona, French franc and Dutch guilder, respectively. In the case of the EMS the U-shaped distribution is prevalent, while the bell shape is observed, interestingly, only in the case of the guilder.

As we know, the U-shaped distribution is a prediction of the Krugman (1990) model, in which the monetary intervention occurs on the edges of the band, while the bell-shaped distribution (e.g., the case of the guilder) is consistent with the type of intra-marginal intervention policy described by Lindberg and Söderlind (1991). The asymmetry in most of the distributions implies that the central bank may be actually defending an implicit upper or lower bound. The distribution of the pound is an intermediate case between the bell shape and the U shape, which may imply a monetary policy that lies in between the marginal and intra-marginal interventions.

Recall that the transformed variable y differs from our previously defined y^* only by the parameters γ and δ, which further change the mean and variance of the density curve. The normal assumption is not a strong restriction to the original variable x, but is a convenient tool to simulate the underlying distribution. In the conditional projection estimations, we did not impose the normal distribution assumption, however, with our estimated $\hat{\beta}$, y^* is asymptotically normal.

4 Concluding Remarks

This paper has developed techniques to estimate the exchange rate distributions and the expected changes in exchange rates when the latter are constrained within a given band. The techniques have the advantage of not relying on a structural model, and

[8] We used the daily sample from the Rose dataset.

not imposing any particular shape to the unconditional distribution of the exchange rate, while at the same time explicitly exploiting the information contained by the presence of fluctuation limits.

Our empirical results show that the presence of the band can indeed affect the estimates of the expected future exchange rates and the credibility tests. The effect is large when the band is tight. It is therefore important to take the band restrictions into account whenever the band restriction is likely to be binding.

The empirical results also show that the unconditional distributions of exchange rates can take several different shapes, which may correspond to possibly widely different monetary and exchange-rate intervention policies. The possibility of widely different models of fundamental determinants of exchange rates within fluctuation bands underscores the use of atheoretical projection equations like those developed in this paper.

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TABLE 1

Estimation of Expected Future Exchange Rate within Band:

BP/US$ under the Bretton Woods System

Projection Equation: $y^*_{t+3} = \sum_{i=1}^{2} \alpha_i d_i + \sum_{j=1}^{4} \beta_j z_{j,t} + u_t$.

Variable	Definition	Coefficient*	Std Error**
d_1	Regime dummy 55:07-67:10	0.0389	0.1208
d_2	Regime dummy 67:11-71:05	0.5732	0.4273
z_1	y^*_t	0.4609	0.1135
z_2	Forward exchange margin	-0.4369	0.7763
z_3	y^{*2}_t	-0.0794	0.1801
z_4	y^{*3}_t	-0.0095	0.0141

	Diagnostics		
	Number of observations	170	
	Standard Error	1.204	
	R-squared	0.128	
	$F(6, 164)$	4.032	
	Number of autocovariances	2	
	Autocorrelation of errors:		
	One period	0.351	
	Last period	0.123	

*The Coefficients are estimated using OLS.

**The standard errors of coefficients are the GMM estimates adjusted for heteroskedasticity using the Newey-West method.

TABLE 2

Estimation of Expected Future Exchange Rate within Band:

DM/US$ under the Bretton Woods System

Projection Equation: $y^*_{t+3} = \sum_{i=1}^{3} \alpha_i d_i + \sum_{j=1}^{5} \beta_j z_{j,t} + u_t$.

Variable	Definition	Coefficient*	Std Error**
d_1	Regime dummy 55:07-61:02	-3.1024	1.0631
d_2	Regime dummy 61:03-69:09	-2.1362	0.8148
d_3	Regime dummy 69:10-71:05	-3.0586	0.8641
z_1	y^*_t	0.6043	0.1221
z_2	Forward exchange margin	-0.3347	0.4375
z_3	Relative money supply	-1.9303	0.7836
z_4	y^{*2}_t	0.0765	0.1116
z_5	y^{*3}_t	-0.0245	0.0184

Diagnostics	
Number of observations	170
Standard Error	0.889
R-squared	0.381
$F(8, 162)$	26.695
Number of autocovariances	2
Autocorrelation of errors:	
One period	0.357
Last period	0.127

*The Coefficients are estimated using OLS.

**The standard errors of coefficients are the GMM estimates adjusted for heteroskedasticity using the Newey-West method.

TABLE 3

Estimation of Expected Future Exchange Rate within Band:

BF/DM under the EMS

Projection Equation: $y^{*}_{t+3} = \sum_{i=1}^{8} \alpha_i d_i + \sum_{j=1}^{4} \beta_j z_{j,t} + u_t$.

Variable	Definition	Coefficient*	Std Error**
d_1	Regime dummy 79:04-79:08	0.8942	0.6819
d_2	Regime dummy 79:09-81:09	0.7995	0.4562
d_3	Regime dummy 81:10-82:01	3.1896	1.5007
d_4	Regime dummy 82:02-82:05	1.4922	1.7202
d_5	Regime dummy 82:06-83:02	1.7218	1.0455
d_6	Regime dummy 83:03-86:03	1.2145	0.5388
d_7	Regime dummy 86:04-86:12	-0.2546	0.7503
d_8	Regime dummy 87:01-90:04	0.6412	0.3842
z_1	$y*_t$	0.6587	0.4965
z_2	$i - i^*$	0.0226	0.0383
z_3	y_t^{*2}	-0.1169	0.2473
z_4	y_t^{*3}	0.0026	0.0254

Diagnostics	
Number of observations	130
Standard Error	1.867
R-squared	0.094
$F(12, 118)$	8.589
Number of autocovariances	2
Autocorrelation of errors:	
One period	0.351
Last period	0.123

*The Coefficients are estimated using OLS.

**The standard errors of coefficients are the GMM estimates adjusted for heteroskedasticity using the Newey-West method.

TABLE 4

Estimation of Expected Future Exchange Rate within Band:

DK/DM under the EMS

Projection Equation: $y^{*}_{t+3} = \sum_{i=1}^{9} \alpha_i d_i + \sum_{j=1}^{5} \beta_j z_{j,t} + u_t$.

Variable	Definition	Coefficient*	Std Error**
d_1	Regime dummy 79:04-79:08	1.7287	2.1743
d_2	Regime dummy 79:09-79:10	1.8242	1.8376
d_3	Regime dummy 79:11-81:09	0.1006	1.8292
d_4	Regime dummy 81:10-82:01	0.0035	1.5009
d_5	Regime dummy 82:02-82:05	-0.4193	1.5957
d_6	Regime dummy 82:06-83:02	0.2743	1.6487
d_7	Regime dummy 83:03-86:03	0.5394	1.1185
d_8	Regime dummy 86:04-86:12	2.1835	1.1412
d_9	Regime dummy 87:01-90:04	1.8676	0.8238
z_1	y^{*}_{t}	0.2372	0.1256
z_2	$i - i^{*}$	-0.3441	0.0924
z_3	Relative money supply	-1.5949	1.5583
z_4	y^{*2}_{t}	0.0006	0.0198
z_5	y^{*3}_{t}	-0.0047	0.0045

	Diagnostics	
	Number of observations	130
	Standard Error	1.463
	R-squared	0.418
	$F(14, 116)$	6.503
	Number of autocovariances	2
	Autocorrelation of errors:	
	One period	0.343
	Last period	0.117

*The Coefficients are estimated using OLS.

**The standard errors of coefficients are the GMM estimates adjusted for heteroskedasticity using the Newey-West method.

TABLE 5

Estimation of Expected Future Exchange Rate within Band:

FF/DM under the EMS

Projection Equation: $y^*_{t+3} = \sum_{i=1}^{7} \alpha_i d_i + \sum_{j=1}^{4} \beta_j z_{j,t} + u_t$.

Variable	Definition	Coefficient*	Std Error**
d_1	Regime dummy 79:04-79:08	1.2585	0.4132
d_2	Regime dummy 79:09-81:09	0.3772	0.5297
d_3	Regime dummy 81:10-82:05	2.0667	0.7838
d_4	Regime dummy 82:06-83:02	1.7153	0.9060
d_5	Regime dummy 83:03-86:03	1.4008	0.4066
d_6	Regime dummy 86:04-86:12	1.1571	0.3852
d_7	Regime dummy 87:01-90:04	1.4008	0.2960
z_1	y_t^*	0.3129	0.1402
z_2	$i - i^*$	-0.2670	0.0624
z_3	y_t^{*2}	0.0758	0.0523
z_4	y_t^{*3}	0.0111	0.0066

Diagnostics	
Number of observations	130
Standard Error	1.337
R-squared	0.421
$F(11, 119)$	8.367
Number of autocovariances	2
Autocorrelation of errors:	
One period	0.368
Last period	0.136

*The Coefficients are estimated using OLS.

**The standard errors of coefficients are the GMM estimates adjusted for heteroskedasticity using the Newey-West method.

TABLE 6

Estimation of Expected Future Exchange Rate within Band:

NG/DM under the EMS

Projection Equation: $y^*_{t+3} = \sum_{i=1}^{3} \alpha_i d_i + \sum_{j=1}^{5} \beta_j z_{j,t} + u_t$.

Variable	Definition	Coefficient*	Std Error**
d_1	Regime dummy 79:04-79:08	-2.5379	2.0686
d_2	Regime dummy 79:09-83:02	-3.7415	1.9555
d_3	Regime dummy 83:03-90:04	-3.0848	1.8025
z_1	y^*_t	0.4111	0.3005
z_2	$i - i^*$	-0.2434	0.0783
z_3	Relative money supply	-2.6767	1.4893
z_4	y^{*2}_t	0.0805	0.1852
z_5	y^{*3}_t	0.0075	0.0223

Diagnostics	
Number of observations	130
Standard Error	0.776
R-squared	0.291
$F(8, 122)$	7.130
Number of autocovariances	2
Autocorrelation of errors:	
One period	0.399
Last period	0.159

*The Coefficients are estimated using OLS.

**The standard errors of coefficients are the GMM estimates adjusted for heteroskedasticity using the Newey-West method.

TABLE 7

Point Estimation of Parameters for the Unconditional Distributions

Exchange Rate	Regime	γ	δ
BP/US$	Bretton Woods	0.009504 (0.07603)	0.794694 (0.042723)
DM/US$	Bretton Woods	0.502989 (0.080694)	0.633059 (0.034034)
BF/DM	EMS	-0.85691 (0.022309)	0.585428 (0.007898)
DK/DM	EMS	-0.154889 (0.0191)	0.530343 (0.00712)
FF/DM	EMS	0.103102 (0.019176)	0.572672 (0.007745)
NG/DM	EMS	0.180468 (0.019062)	1.335625 (0.017858)

Note: Standard errors are reported in parentheses.

Figure 1.—95% confidence intervals for expected future exchange rates within band: 3-month BP/US$ under the Bretton Woods System

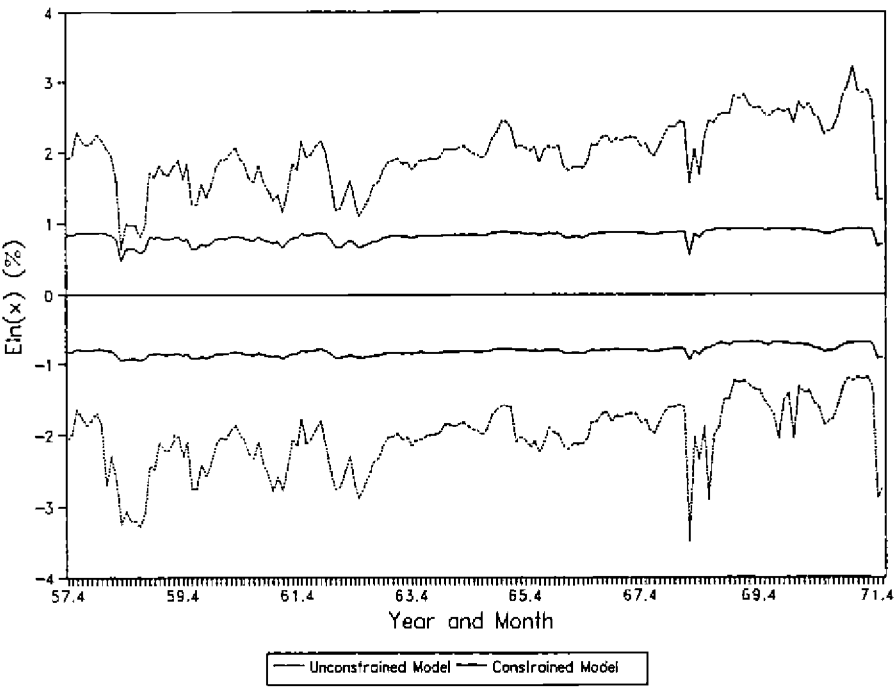

Figure 2.—95% confidence intervals for expected future exchange rates within band: 3-month DM/US$ under the Bretton Woods System

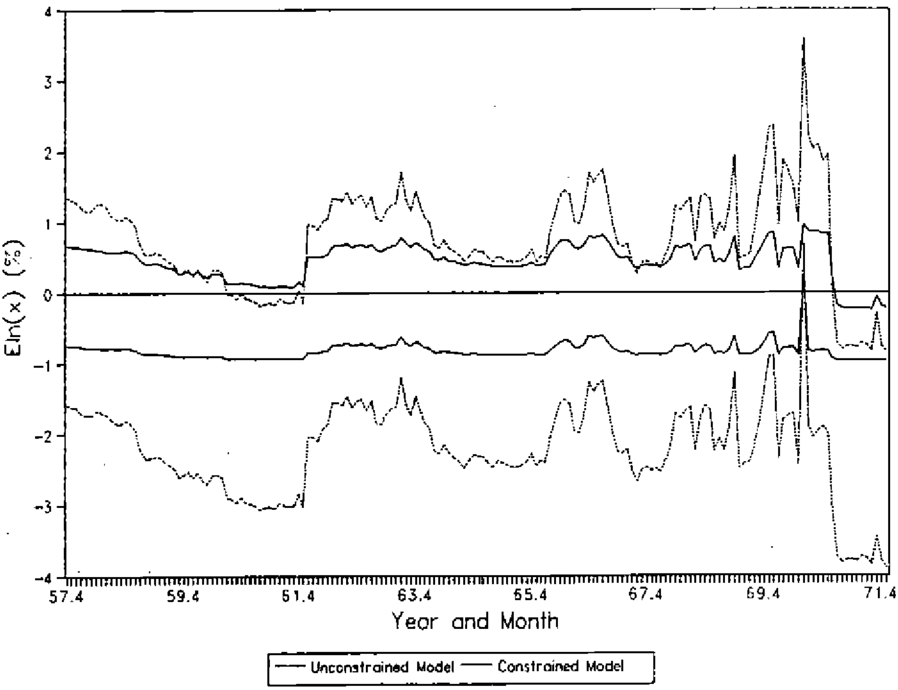

Figure 3.—95% confidence intervals for expected future exchange rates within band: 3-month BF/DM under the EMS

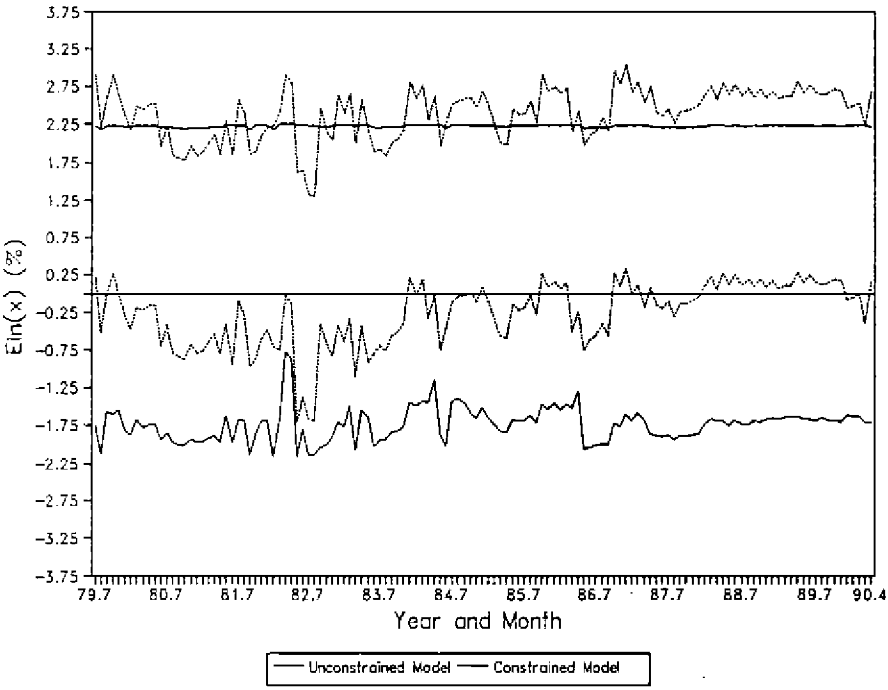

Figure 4.—95% confidence intervals for expected future exchange rates within band: 3-month DK/DM under the EMS

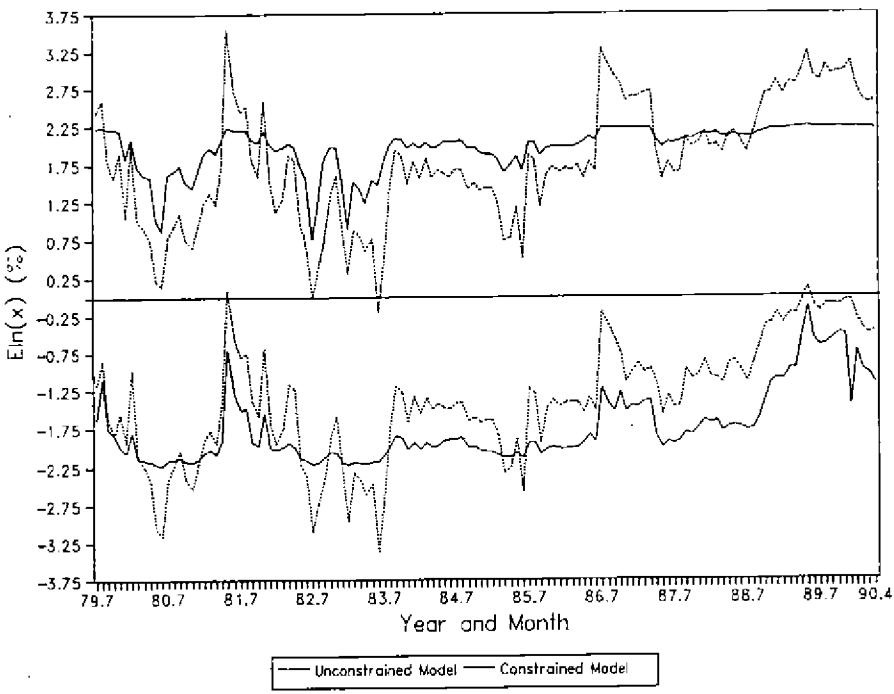

Figure 5.—95% confidence intervals for expected future exchange rates within band: 3-month FF/DM under the EMS

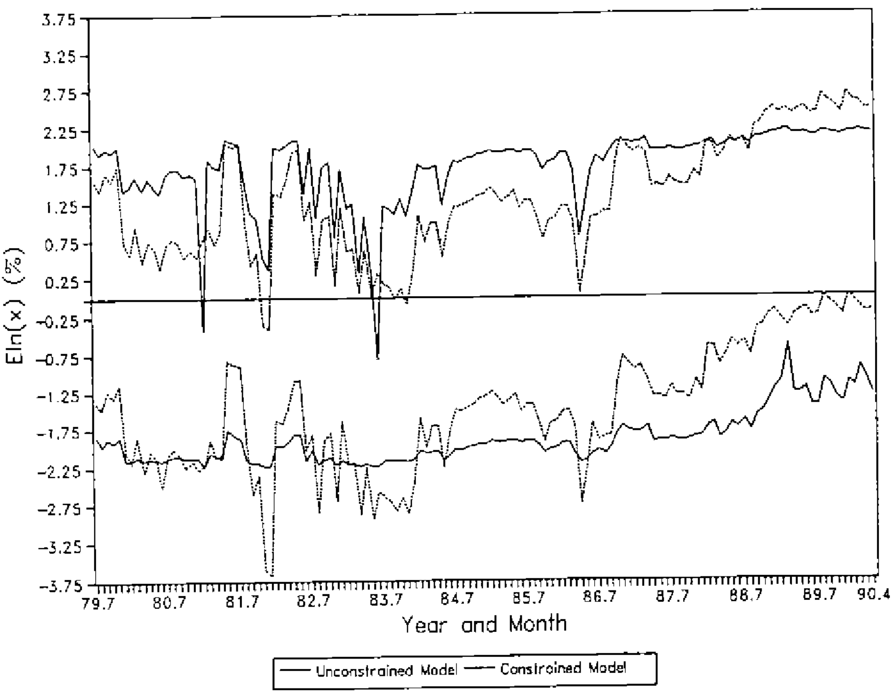

Figure 6.—95% confidence intervals for expected future exchange rates within band: 3-month NG/DM under the EMS

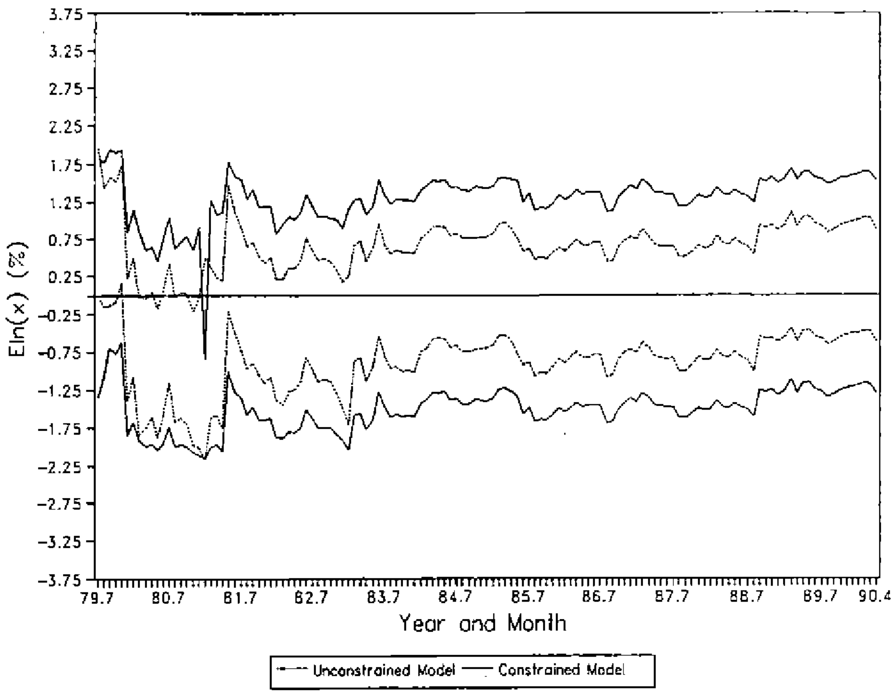

Figure 7.—95% confidence interval for the 3-month expected devaluation: BP/US$ under the Bretton Woods Regime

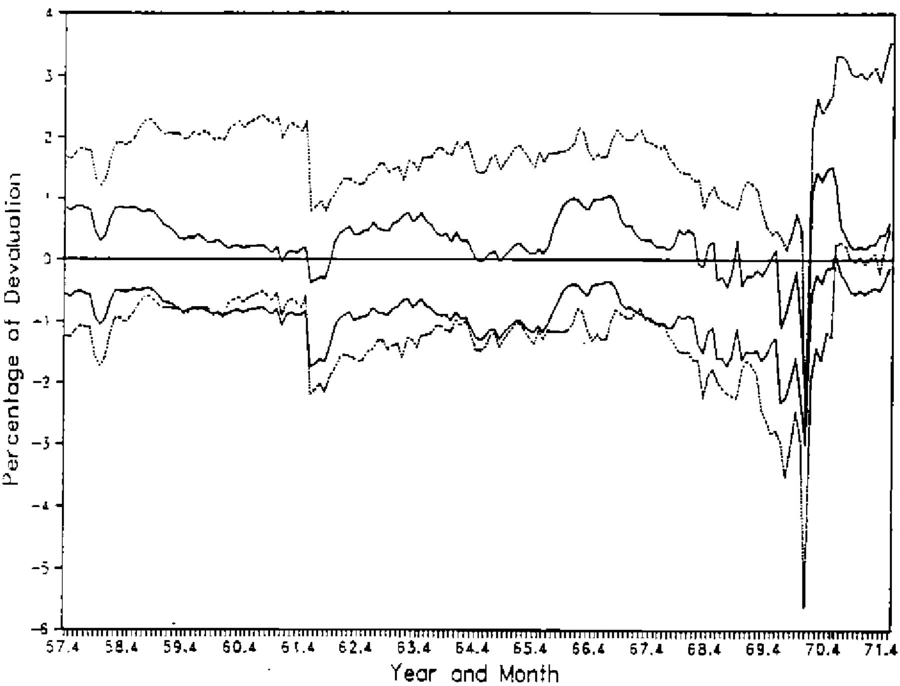

Figure 8.—95% confidence interval for the 3-month expected devaluation: DM/US$ under the Bretton Woods Regime

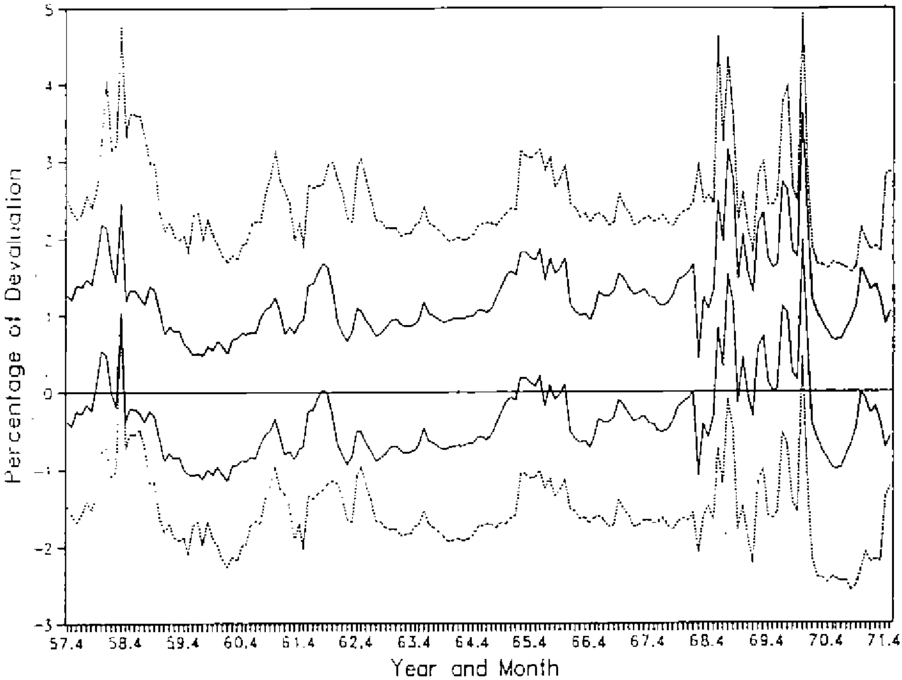

Figure 9.—95% confidence interval for the 3-month expected devaluation: BF/DM under the EMS

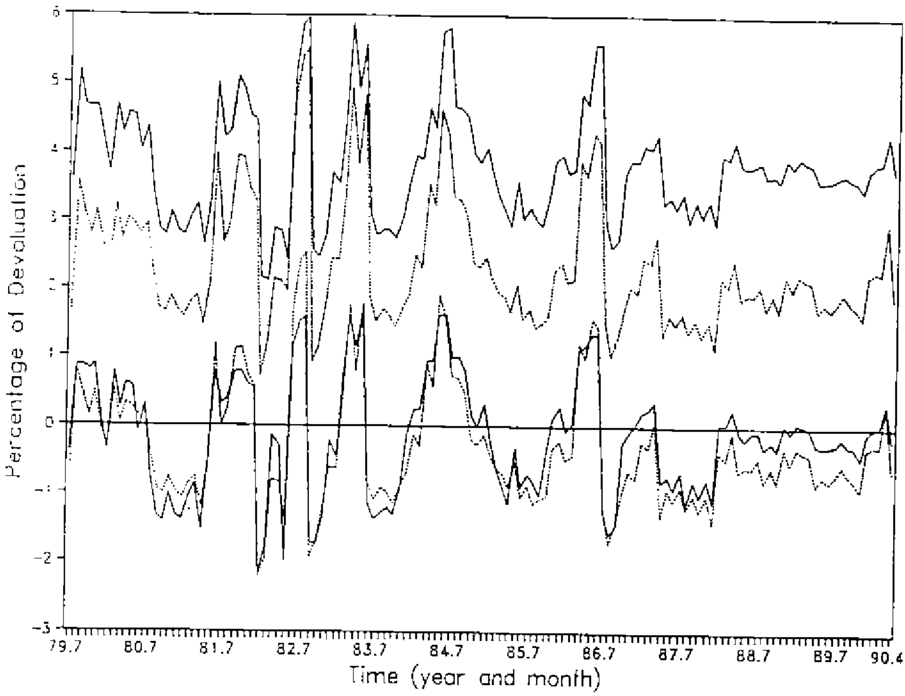

Figure 10.—95% confidence interval for the 3-month expected devaluation: DK/DM under the EMS

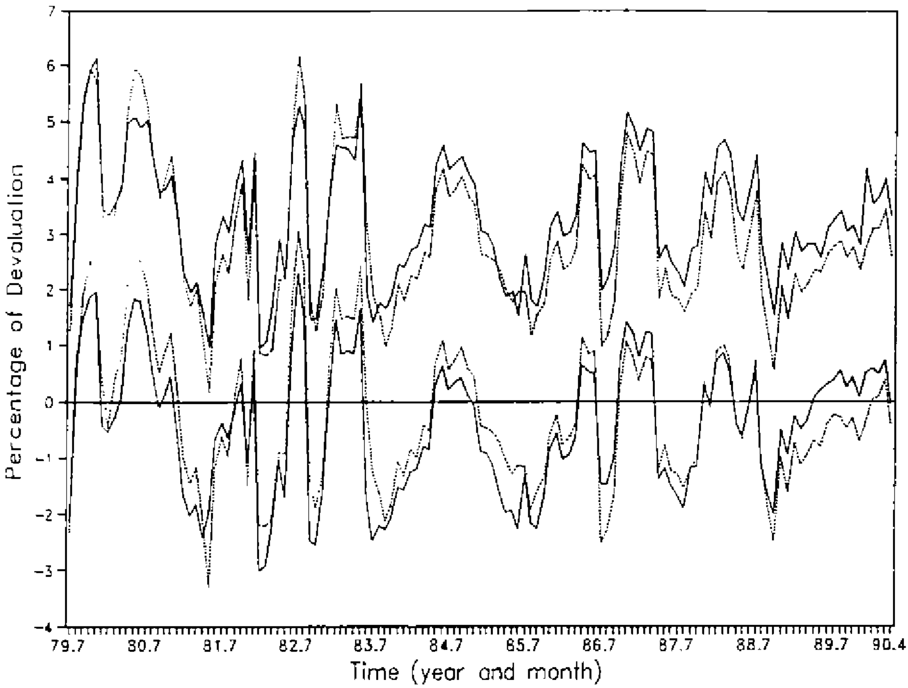

Figure 11.—95% confidence interval for the 3-month expected devaluation: FF/DM under the EMS

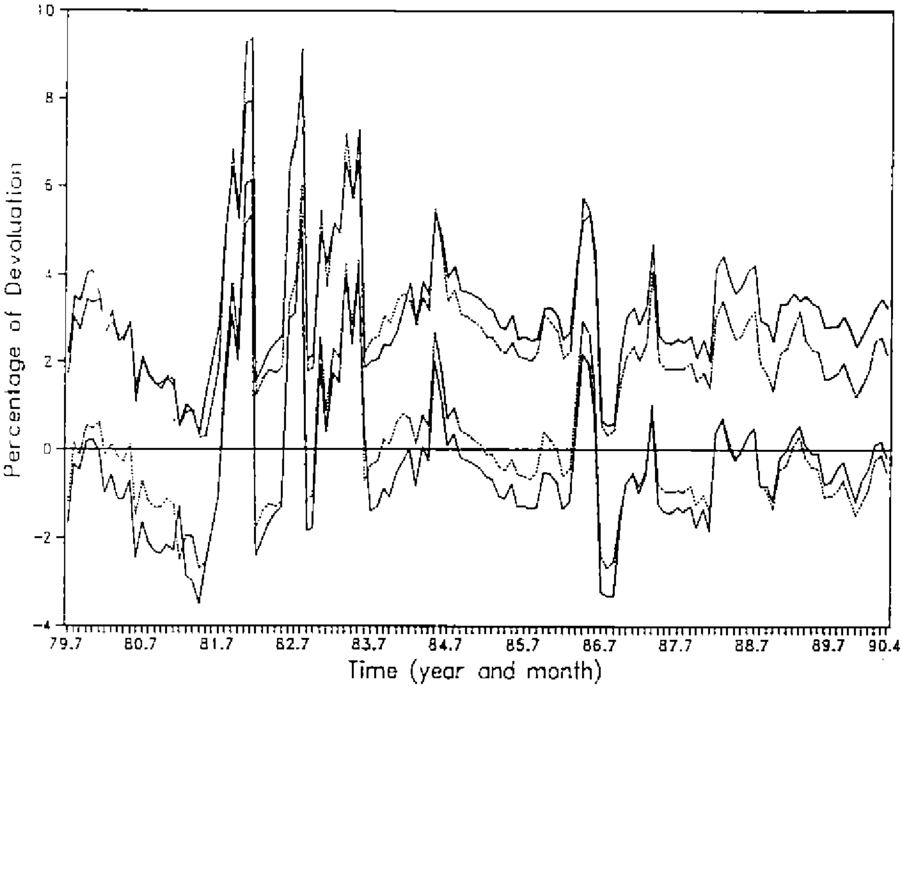

Figure 12.—95% confidence interval for the 3-month expected devaluation: NG/DM under the EMS

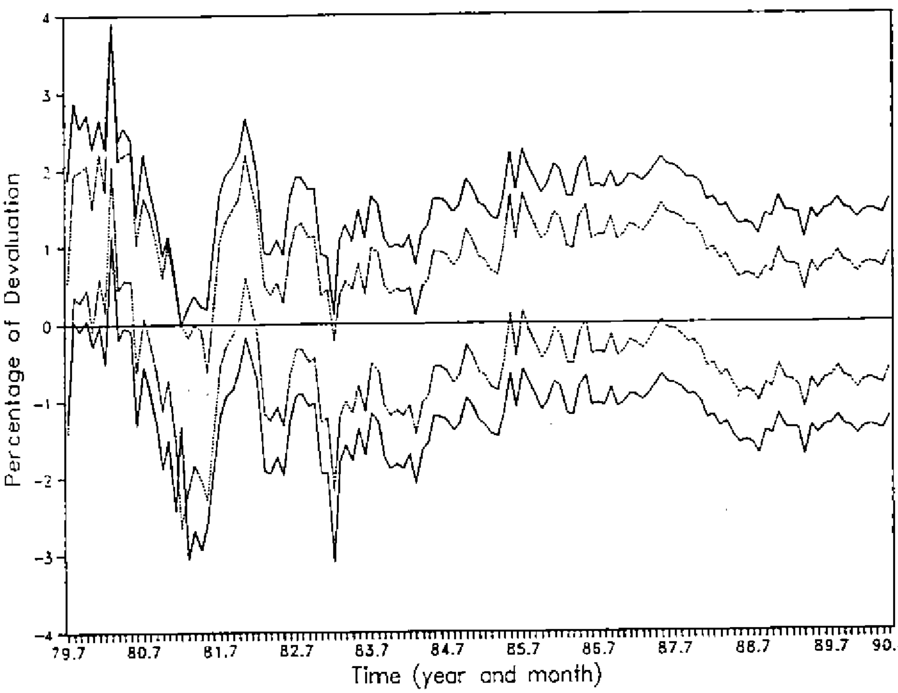

Figure 13.—Estimated unconditional density curve for BP/US$ under the Bretton Woods regime

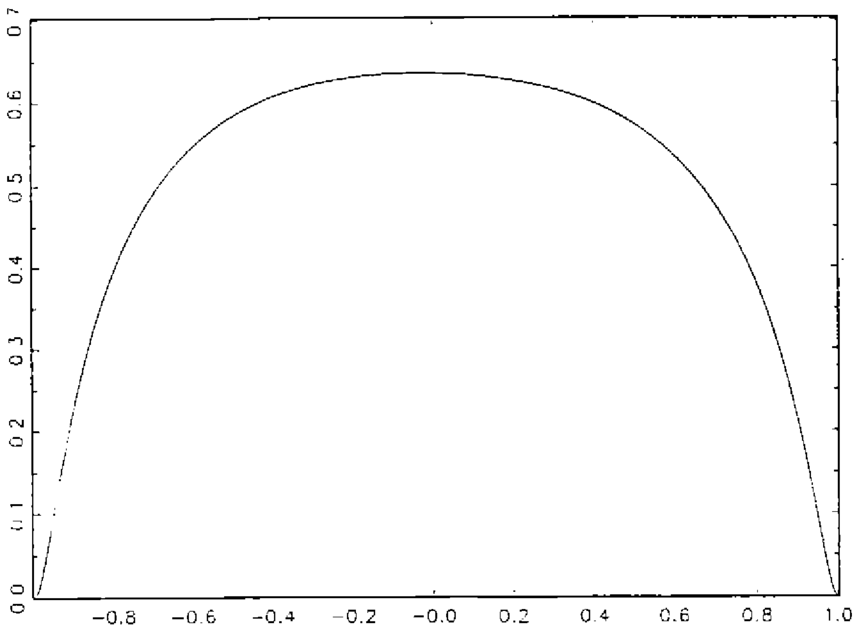

Figure 14.—Estimated unconditional density curve for DM/US$ under the Bretton Woods regime

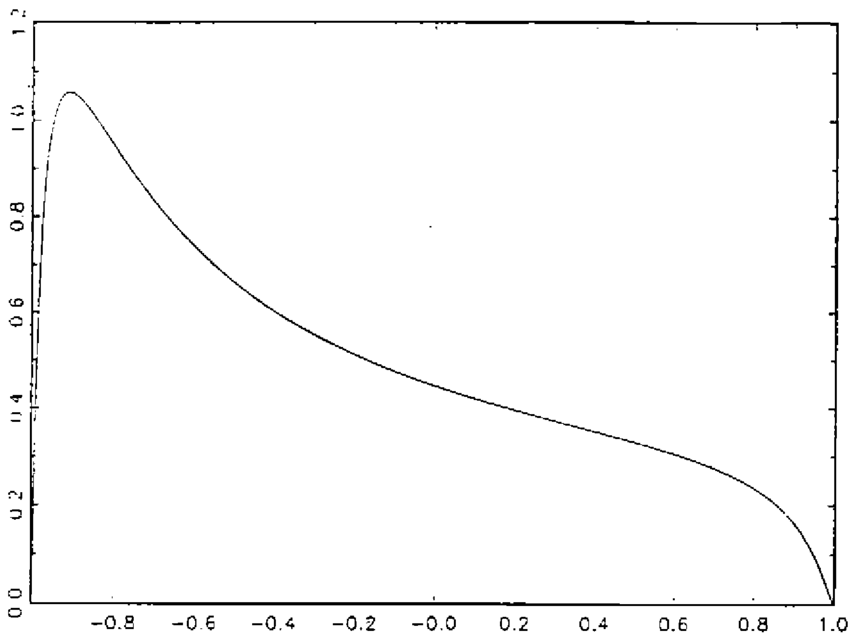

Figure 15.—Estimated unconditional density curve for BF/DM under the EMS

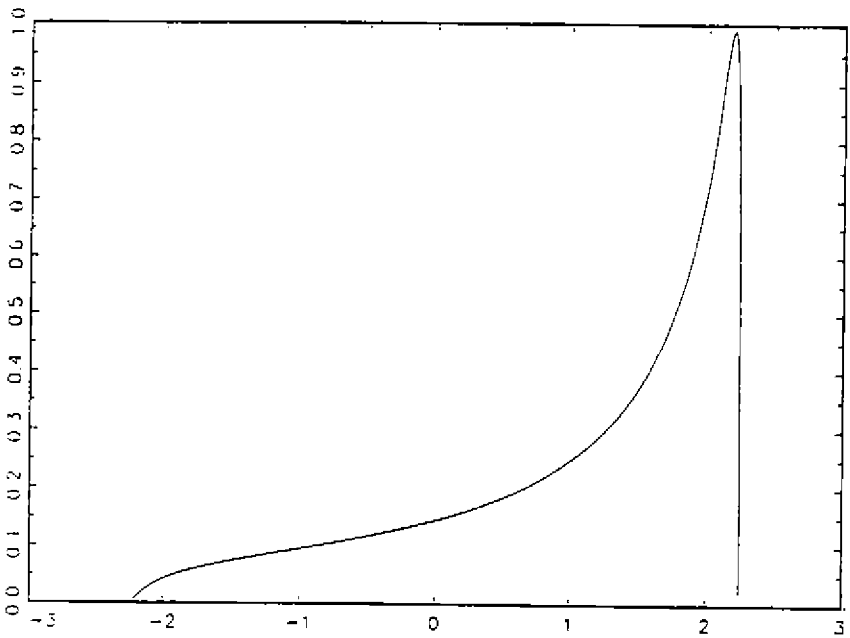

Figure 16.—Estimated unconditional density curve for DK/DM under the EMS

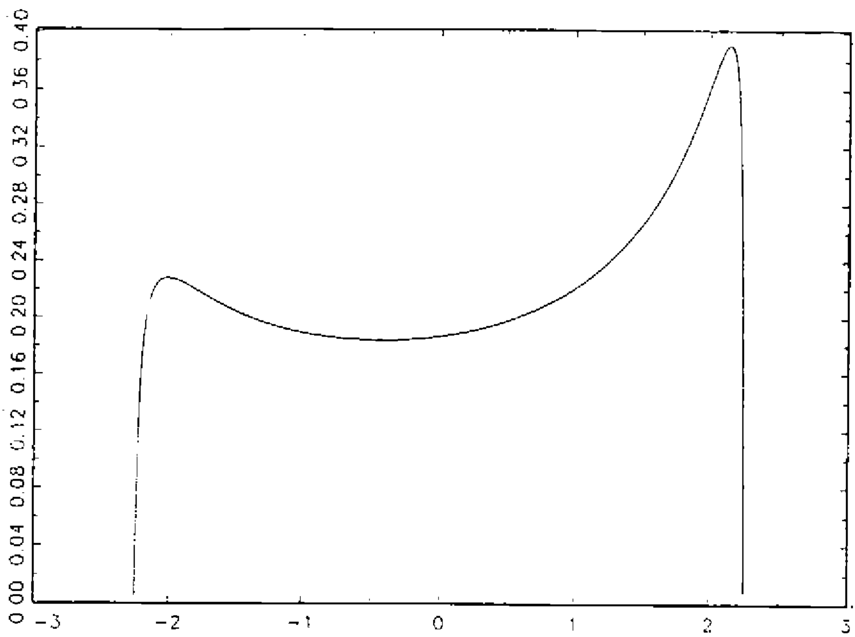

Figure 17.—Estimated unconditional density curve for FF/DM under the EMS

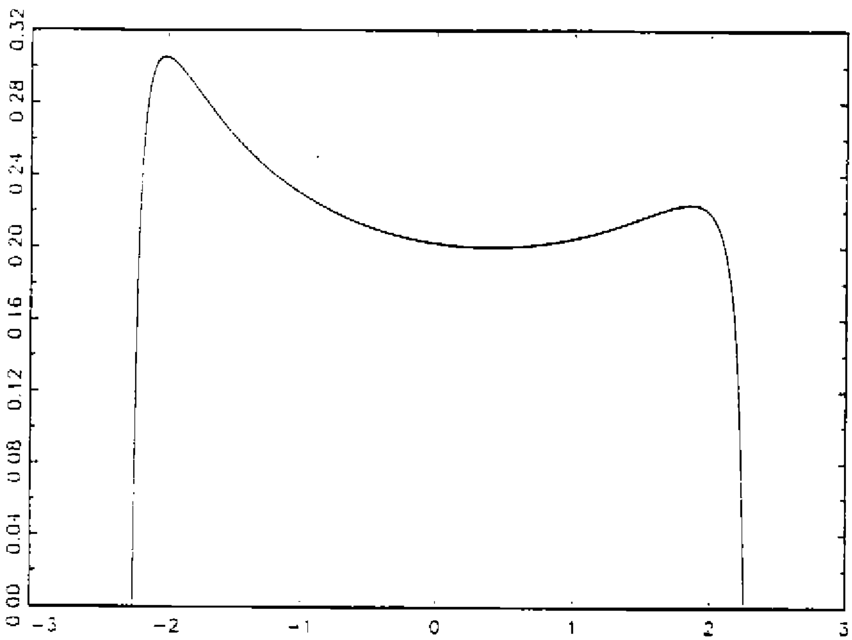

Figure 18.--Estimated unconditional density curve for NG/DM under the EMS