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Exchange Rate Dynamics and Intervention Rules

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Summary

One justification for the use of exchange market intervention by central banks is that goods prices adjust more slowly than asset prices; as a result, monetary shocks can produce exchange rate appreciations or depreciations that lead to divergences of real currency values from their long-run equilibrium levels. The present paper considers two questions: (1) whether exchange market intervention that is sterilized--that is, intervention that does not involve a change in the money supply--can be effective, and (2) if effective, whether it is desirable to use intervention for this purpose. The results of estimating a small macroeconomic model for Germany suggest that there may be some statistically significant effect of sterilized intervention, but that its magnitude is small. In addition, the results suggest that intervention aimed at resisting real exchange rate movements may induce cyclical fluctuations in the economy and may imply that the economy adjusts to random shocks more slowly than in the absence of intervention.

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I. Introduction

The period of generalized floating of exchange rates, which began in early 1973, has been associated with wider fluctuations of both nominal and, especially, real exchange rates than early advocates of exchange rate flexibility had anticipated. 1/ There is considerable debate concerning the causes of these fluctations, and the extent to which they have exerted unfavorable effects. One possible cause for concern is the existence of short-term price fluctuations that are not predictable: increased uncertainty about relative prices may have unfavorable effects on economic activity. 2/ A different question is whether exchange rate levels are appropriate; that is, whether they are consistent with some notion of underlying equilibrium. Williamson (1983) has argued strongly that the real exchange rates of the largest industrial countries have been significantly and persistently out of line with what he calls "fundamental equilibrium", and he advocates that policies be directed at narrowing these misalignments. One of the sources of misalignments may be government policies themselves: for instance, a policy of monetary restraint often causes real exchange rate appreciation during the transition period while domestic prices adjust. 3/ Though Williamson favors subordinating monetary policy, to a greater or lesser extent, to exchange rate objectives, another instrument that has often been put forward as a possible means of limiting misalignments is sterilized intervention. 4/ However, the effectiveness of this policy is generally thought to be quite limited, as Williamson himself notes. A recent study by a working group set up at the Versailles summit also concludes that the effect of sterilized intervention on the exchange rate is likely, at best, to be very modest. 5/ Nevertheless, if the authorities are unwilling to adjust monetary policy in order to achieve their exchange rate objectives, those who wish to make a case for greater exchange rate management must address the question of the effectiveness of sterilized intervention and, more generally, of the extent to which the behavior of the economy differs depending on whether such intervention takes place.

The present paper considers the effect of sterilized intervention in a model where it is assumed that changes in monetary policy can produce misalignments, and in the context of imperfect substitutability between domestic and foreign bonds, which implies that the changes in asset supplies brought about by sterilized intervention have some effect on the equilibrium value of the exchange rate. In contrast to much of the

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1/ For a survey of that experience, see Shafer and Loopesko (1983).

2/ A recent study by the IMF (1984) reviews the evidence concerning exchange rate variability and international trade and concludes that there is little evidence of adverse effects.

3/ Williamson (1983), p. 54.

4/ Williamson (1983), pp. 70-71.

5/ Report of the Working Group on Exchange Market Intervention, 1983.

theoretical work on sterilized intervention, this policy is here viewed not as a one-time exchange market operation, but rather as a rule that the authorities consistently follow in an attempt to limit exchange rate movements. We further assume that the objective is not to resist short-run fluctuations but rather to limit misalignments, in Williamson's sense. Furthermore, we do not discuss the possible costs of either volatility or misalignment of exchange rates; rather we take as given the contention that intervention policy is directed at limiting misalignments, and then study what this state of affairs would imply for the dynamic behavior of the economy.

The now-familiar overshooting model [see Dornbusch (1976)] implies that financial shocks, such as a shift in asset preferences or a change in monetary policy, will produce an initial change in the exchange rate that is larger than the amount necessary for achieving long-run equilibrium. Overshooting occurs in this model because, for a host of well-known reasons, prices in goods and labor markets are more sluggish than those in financial markets. As a result, initially a money supply shock has the following effects: the nominal exchange rate overshoots its long-run equilibrium level while the price level changes very little, and this implies a deviation of the real exchange rate from its long-run equilibrium level. If the speed of adjustment of prices is very slow, the real exchange rate misalignment may persist for a considerable period.

The Dornbusch model cannot be applied in its original form to the questions addressed in this paper since it does not provide a role for intervention unless the latter leads to a change in the money supply; that is, sterilized intervention has no effect in his model. In order to examine the effects of intervention it is necessary to work with a generalization of Dornbusch's model in which assets denominated in domestic and foreign currencies are not perfect substitutes, so that the uncovered interest parity relationship is modified by a risk premium that depends on the relative supplies of the assets. The model is usually called the portfolio balance model, and there are a number of articles applying it to observed exchange rate movements. 1/ It is important to note at the outset that the empirical evidence is mixed concerning the existence of significant effects of sterilized intervention on the exchange rate. It has not been conclusively proved that sterilized intervention is useless as a policy instrument, however, and the model for Germany reported below provides an element of support for the hypothesis that intervention can influence the value of the exchange rate. 2/

1/ For an early survey, see Isard (1978). See also Branson and Halttunen (1979), Branson, Halttunen and Masson (1977), Martin and Masson (1979), Frankel (1982), Hooper and Morton (1982), Obstfeld (1983), and Blundell-Wignall (1984).

2/ From this point on we use "intervention" as a short-hand for "sterilized intervention."

In the portfolio balance model, intervention has a role because it alters the mix of domestic and foreign currency assets held by private investors. In effect, the central bank that does the intervening swaps a bond in domestic currency for one in foreign currency. As long as the two are not perfect substitutes in investors' portfolios, the swap alters the exchange rate that equilibrates private demand for assets with the supply outside of the central bank's portfolio.

In the Dornbusch model, overshooting occurs because goods prices adjust more slowly than asset prices. The portfolio balance model provides an additional reason for overshooting, namely the slow accumulation of assets, in particular claims on foreigners acquired as the counterpart of current account surpluses. The dynamics of exchange rate adjustment due to this channel were developed in articles by Kouri (1976) and Branson (1976), and a synthesis of the two types of overshooting models is attempted in Henderson (1981) and Frenkel and Rodriguez (1982). The Henderson article explicitly considers the effect of intervention in a general overshooting model; however, intervention is treated as a once-and-for all asset swap--in particular, a purchase of foreign money with home money--rather than as an ongoing dynamic process that can be described as a feedback rule relating the change in foreign exchange reserves to other endogenous variables. It is the latter that is the concern of this paper: we analyze the effect on the dynamics of the economy of an intervention rule describing the behavior of a central bank that attempts to limit movements of the real exchange rate away from the authorities' notional long-run equilibrium level, but that is subject to a "reserves constraint." The reserves constraint requires that reserves lost by the central bank through sales of foreign exchange must eventually be replenished.

There is another rationale for intervention, namely to stabilize "disorderly markets." This role is extremely short term in focus and involves the central bank giving "tone" and "breadth" to the market. On occasion there may be few active traders, leading to erratic swings in the exchange rate as the random arrival of new orders meets little demand on the other side of the market. Intervention may dampen these swings and decrease the magnitude of bid/ask spreads. We will not be concerned with this aspect of intervention. Our focus is longer term, on the effect of official intervention aimed at limiting deviations of the exchange rate from its long-run equilibrium level, defined as the one which is consistent with an (assumed known) level of international competitiveness. 1/

1/ In practice, of course, the problem of determining the sustainable level of a country's real exchange rate is a formidable one. For a detailed discussion, see Artus and Knight (1984). Another recent paper, Boughton (1984), develops a model in which speculators do not have a firm notion of long-run equilibrium exchange rates. Instead, they are assumed to readjust their assessments of what constitutes equilibrium with observed exchange rate movements.

We proceed by first attempting to analyze a theoretical model that is the simplest possible generalization of that in Dornbusch (1976); a risk premium variable and an intervention rule of the type discussed above are included. Subsequently, a more complicated version of that model with an endogenous current account is estimated for Germany. The estimation results suggest that the period since floating is consistent with the hypothesis that the Bundesbank intervenes in such a way as to resist movements of the real exchange rate away from some normal level of international competitiveness, and that intervention has a small, but statistically significant effect on the value of the deutsche mark. We then proceed to simulate the model's behavior in the face of a monetary shock in order to gauge its economic significance, and to examine its effect on the dynamic behavior of the economy.

II. The Dynamics of Intervention

The literature on foreign exchange market intervention is now voluminous. A long series of articles has considered Friedman's (1953) contention that stabilizing intervention should also be profitable to central banks. A recent contribution is Taylor (1982). On the question of whether sterilized intervention has any effect at all, a task force of representatives of the seven major industrial countries (Report of the Working Group on Exchange Market Intervention, 1983, cited above, and various background studies) has provided new empirical evidence, as well as a discussion of the rationale for intervention. Two recent papers have also surveyed the empirical literature on the effectiveness of sterilized intervention [see Genberg (1981) and Solomon (1983)]; that is, whether such intervention constitutes an additional instrument that is capable of moving the exchange rate in the direction desired by the authorities, separate from overall monetary policy. Both studies found that existing empirical evidence indicates at most a very limited degree of effectiveness for sterilized intervention. Genberg also raises the issue of a possibly destabilizing role for sterilized intervention, if it is combined with a target for holdings of international reserves. 1/ This point is not amplified upon by Genberg, beyond referring to similarities between this case and the case of non-sterilized intervention with a preannounced path for a monetary target, treated in an earlier paper [Genberg and Roth (1979)]. The idea behind each case is that if there are other targets that force intervention to be reversed at some point in the future, then its effects on the exchange rate will also be reversed, at a possibly inconvenient time.

It is convenient to illustrate the effect of intervention in a model that is as close as possible to that in Dornbusch (1976), in particular his model with sticky prices and output that is driven by aggregate demand.

1/ See Genberg (1981), p. 458.

Using his notation, the model in the Appendix to his paper can be written:

$$-\lambda R + \phi y = m - p \tag{1}$$

$$R = R^* + x \tag{2}$$

$$y = u + \delta(e-p) + \gamma y - \sigma R \tag{3}$$

$$\dot{p} = \Pi(y-\bar{y}) \tag{4}$$

The variables R, y, m, p, and e are the domestic short-term interest rate, output, money supply, prices, and the nominal exchange rate, (defined as the domestic currency price of foreign currency) respectively; R^* refers to foreign interest rates, and $\bar{y}$ to potential output. Greek letters refer to parameters; they are all positive. Lower case letters refer to natural logarithms of variables. The model assumes a world without trend inflation and with constant potential real output and money supply; expected inflation does not appear in equations (3) and (4) as would otherwise be appropriate. The foreign price level is normalized at unity, so it does not appear explicitly in the model. Expectations of the change in the exchange rate, x, are formed rationally; they are given by:

$$x = \theta(\bar{e}-e) \tag{5}$$

where $\bar{e}$ is the exogenous long-run equilibrium rate. Rational expectations make θ a known function of the other parameters in the model.

We proceed by first making minor extensions to this model to render expectations of domestic price inflation explicit and to take into account intervention by the authorities in the foreign exchange market. Instead of (2), which states that uncovered interest parity holds, we introduce a risk premium, assumed to depend on the private stock of net claims on foreigners, K - F, where K is total net claims (assumed to be denominated in foreign currency) and F is the net claims of the central bank, i.e., foreign exchange reserves:

$$R = R^* + x - \psi(K-F) \tag{2'}$$

Such a specification could result from a portfolio balance relationship where domestic and foreign interest-bearing assets are not perfect substitutes in private-sector portfolios: in order to be induced to hold a greater proportion of foreign assets, domestic residents require a higher expected return on those foreign assets; alternatively, the foreign portfolio preferences could be reflected in the risk premium term. In either case, this term should be scaled by portfolio size, but for simplicity it is specified here as being linear in K-F. We will not make explicit the theory underlying such an equation, but take it as given. 1/ In addition, we introduce an equation explaining the endogenous intervention behavior of the authorities, where s below is defined to be the real exchange rate ($s=e+p^*-p$):

$$\dot{F} = \beta(\bar{s}-s) + \mu(\bar{F}-F) \tag{6}$$

Central banks are assumed to resist movements away from the long-run equilibrium real exchange rate $\bar{s}$; in addition, they try to prevent reserves from deviating too far above or below some target level, $\bar{F}$. For the time being, we keep exogenous the current account, and hence also net foreign assets, K.

As for expectations formation, we retain for the moment Dornbusch's specification for the expected exchange rate, but write it in terms of the expected real exchange rate:

$$\dot{s}^e = \theta(\bar{s}-s) \tag{5'}$$

An equivalent specification written in terms of nominal exchange rates is

$$x = \dot{p}^e - (\dot{p}^*)^e + \theta(\bar{s}-e-p^*+p)$$

A monotonic adjustment to equilibrium in response to a shock occurs in the Dornbusch model because the dynamics are such that, excluding expectations, the model can be reduced to a single differential equation of the first order. Such is no longer the case, however, if we have an equation like (6) for intervention. However, it seems reasonable to start with the assumption that expectations are formed according to a

1/ A mean-variance model with a similar property is described in Dornbusch (1983). The adjustments necessary to go from a model framed in terms of assets denominated in different currencies to a model using balance of payments data are discussed in the appendix to Hooper et al. (1983).

simple rule and in a manner that would have been rational in the absence of intervention. This is also the procedure followed in Henderson (1980), which he terms "long-run perfect foresight."

Actual inflation is assumed here to equal expected inflation plus a function of the output gap. Thus:

$$\dot{p} = \Pi(y-\bar{y}) + \dot{p}^e \qquad (4')$$

Furthermore, expected inflation enters the output equation as well, through the ex ante real rate of interest:

$$y = u + \delta(e+p^*-p) + \gamma y - \sigma(R-\dot{p}^e) \qquad (3')$$

For the time being, we assume that expectations of inflation are exogenous with respect to the endogenous variables of the model. For instance, inflation expectations could be based on the rate of growth of the money supply, as in Buiter and Miller (1982). 1/ Thus inflation expectations do not affect the dynamics of the model here.

The model of equations (1), (2') through (5'), and (6) can be reduced to a pair of differential equations in p and F. Equations (1), (2') and (3') express R, y and the real exchange rate s in terms of p, F, and exogenous variables. First note that equations (2') and (5') can be solved for s:

$$s = \bar{s} + [R^*-(\dot{p}^*)^e-(R-\dot{p}^e)]/\theta - (\psi/\theta)(K-F) \qquad (7)$$

The real exchange rate may differ from its equilibrium level either because real interest rates differ at home and abroad or because private net claims on foreigners are non-zero. The LM and IS curves, equations (1) and (3') respectively, can be solved jointly to express R and y as functions of of m and $\dot{p}^e$ (the demand shift variable u is ignored from now on):

$$R = \frac{1}{\Delta}\,[(1-\gamma)p-(1-\gamma)m+\theta\delta s+\theta\sigma\dot{p}^e] \qquad (8)$$

1/ In the empirical work reported in Section III below, we generalize the model in a number of ways. In particular, it is assumed that both exchange rate and inflation expectations are formed rationally, conditional on the same information set.

$$y = \frac{1}{\Delta}\,[-\sigma p+\sigma m+\lambda\delta s+\lambda\sigma \dot{p}^{e}] \qquad (9)$$

where $\Delta = \phi\sigma + \lambda(1-\gamma) > 0$.

Equations (7), (8), and (9) can be solved together to express s, R, and y as quasi-reduced-form functions of p and F and exogenous variables. If we take what results and substitute it into (4') and (6), the dynamics of the model can be summarized by the following pair of differential equations (exogenous variables are omitted):

$$\begin{bmatrix} \dot{p} \\ \dot{F} \end{bmatrix} = \begin{bmatrix} -\Pi(\delta+\sigma\theta)/\Gamma & \Pi\psi\lambda\delta/\Gamma \\ \beta(1-\gamma)/\Gamma & -\beta\psi\Delta/\Gamma-\mu \end{bmatrix} \begin{bmatrix} p \\ F \end{bmatrix} \qquad (10)$$

where $\Gamma = \Delta\theta + \delta\phi > 0$.

The sign pattern of the elements of the adjustment matrix is as follows:

$$\begin{bmatrix} - & + \\ + & - \end{bmatrix}$$

The trace is obviously negative, and it can also be shown that the determinant is positive. Therefore the Routh-Hurwicz conditions for stability are satisfied, and the model is stable whatever the value of the intervention parameter β. Furthermore, it can be shown that the two roots must be real as the discriminant is always positive, whatever the parameter values.

Given its assumptions, this simple generalization of the Dornbusch model thus implies that the authorities can help to guide the exchange rate toward its long run equilibrium value without inducing short-run fluctuations in that rate. Though the above model makes the simplifying assumption that both the authorities and the private sector have a correct assessment of the long-run equilibrium, it also assumes that private investors either do not anticipate the intervention behavior of the authorities or, if they do, do not consider that it has any effect. We proceed to modify this feature by considering a model with intervention and fully rational expectations regarding the exchange rate.

If expectations correctly take account of intervention, the expected path of the exchange rate in response to a shock may no longer involve a monotonic movement toward its equilibrium value after an initial jump, unlike in the Dornbusch model. The reason is that now the order of the system is increased by one. Instead of equation (5') we would have $x = \dot{e}$, and equation (2') would constitute a differential equation describing the rate of change of the exchange rate:

$$\dot{e} = R - R^* + \psi(K-F) \tag{11}$$

Using equations (8) and (9) to substitute out for R and y, we can therefore write the model as a system of three first-order differential equations (ignoring the exogenous variables):

$$\begin{bmatrix} \dot{e} \\ \dot{p} \\ \dot{F} \end{bmatrix} = \begin{bmatrix} \phi\delta/\Delta & [(1-\gamma)-\phi\delta]/\Delta & -\psi \\ \Pi\lambda\delta/\Delta & -\Pi(\sigma+\lambda\delta)/\Delta & 0 \\ -\beta & \beta & -\mu \end{bmatrix} \begin{bmatrix} e \\ p \\ f \end{bmatrix} \tag{12}$$

The characteristic equation can be written as follows:

$$D^3 + [\mu+B]\ D^2 + [\mu B - C - \beta\psi]\ D - [\beta\psi\Pi\sigma/\Delta+\mu C] = 0 \tag{13}$$

where

$$B = [\Pi(\sigma+\lambda\delta)-\phi\delta]/\Delta$$

$$C = \Pi\delta/\Delta > 0.$$

The signs of the coefficients of (13) above depend on the sign of B, which in turn depends on a number of parameters in the IS, LM, and Phillips curves. Let us label the coefficients of the characteristic equation as follows:

$$D^3 + a_1 D^2 + a_2 D + a_3 = 0$$

Now, $-a_3$ is the product of the characteristic roots; since $\Delta > 0$ it is clear that $a_3 < 0$. Hence there are either three roots with positive real parts or one positive and two negative ones; in the latter case the model has the saddle-point property. In any case, it is clear that one root must be real. Coefficients a_1 and a_2 are ambiguous as to sign. If B is positive, then $a_1 > 0$ but a_2 is ambiguous as to sign; if B is negative, a_1 is ambiguous but a_2 is negative. Under either case, however, there is only one change of sign in the coefficients of the characteristic equation, which implies, by Descartes' rule of signs, that there must be only one positive real root. It can also be shown that the other roots, if they are complex, must have negative real parts. Hence the model has the saddle-point property: there is one unstable root, associated with the rationally expected exchange rate; the other roots are stable.

We can isolate the effect of intervention, in particular of larger values of β, using the root locus method. 1/ If we let

$$g(D) = D^3 + (\mu+B)\, D^2 + (\mu B-C)\, D - \mu C$$

$$h(D) = D + \Pi\sigma/\Delta$$

and $K = -\beta\psi$, then (13) can be rewritten as:

$$F(D) = g(D) + Kh(D) = 0 \tag{14}$$

We start by considering the case where there is no systematic intervention, i.e., $\beta = 0$. In this case the characteristic equation can be factored to give:

$$(D+\mu)(D^2+BD-C) = 0.$$

Since C is positive, it is clear that the roots to the quadratic must be real, since the discriminant $B^2 + 4C$ will be positive whatever the sign of B.

We can differentiate equation (14) to evaluate the effect of a nonzero value of β on the characteristic roots. It can be shown that, starting from a situation of no systematic intervention, increasing β will tend to increase the value of the positive (unstable) root. The root is in some sense a discount factor to be applied to future information; therefore, intervention can be interpreted as making the distant future less important when forming expectations. The effect of intervention on the negative (stable) roots can go in either direction. Consider one of those characteristic roots, say Z. If $|Z|$ is either greater or

1/ See Krall (1970).

less than both μ and $\Pi\sigma/\Delta$, so that $Z + \mu$ and $Z + \Pi\sigma/\Delta$ have the same sign, then increasing β will make Z more negative, that is, speed up the adjustment to past shocks. This is necessarily the case when $\mu = \Pi\sigma/\Delta$. On the other hand, if $|Z|$ is included in an interval bounded by μ and $\Pi\sigma/\Delta$, so that $Z + \mu$ and $Z + \Pi\sigma/\Delta$ have opposite signs, then increasing β will have the opposite effect: it will tend to slow down adjustment speed.

Turning now to the other limiting case, we can use the negative root locus to discover what happens when intervention resists exchange rate movements very strongly. 1/ As $\beta \to \infty$, and hence $K \to -\infty$, arbitrarily good estimates of two of the roots will be given by:

$$D = -(\mu+B-\Pi\sigma/\Delta)/2+(\beta\psi)^{1/2} \qquad (15)$$

and $$D = -(\mu+B-\Pi\sigma/\Delta)/2-(\beta\psi)^{1/2} \qquad (16)$$

The root described by (15) obviously becomes unbounded in a positive direction as $\beta \to \infty$ while the root given by (16) is increasingly negative as $\beta \to \infty$. Thus, in the limit, intervention does not lead to cyclical behavior in this model. We leave open the possibility that there is an intermediate range for β where cyclical behavior may result.

This analysis suggests that in a Dornbusch model modified to include a risk premium an intervention rule to stabilize the real exchange rate (a) is likely to help moderate overshooting, and (b) is unlikely in itself to induce any subsequent cyclical patterns. These results seem favorable to the case for intervention. However, it should be borne in mind that the model analyzed so far has been unrealistically simplified, especially in two respects: inflation expectations are exogenous, and, though intervention has been endogenized, the current balance has not, despite the two variables appearing symmetrically in the exchange rate equation. Now the dynamics of the current balance, and especially its perverse short-run response to exchange rate changes, are a key factor in the economy's dynamic behavior when subject to shocks. 2/ To account properly for the J-curve, as well as for dynamics resulting from sticky prices, we are forced to move to a fourth order system or higher, and this takes us beyond the bounds of analytical tractability. We therefore turn to a more complex, and empirically-based macro-model, which we analyze numerically.

1/ Krall (1970), p. 66.

2/ For a recent contribution to the literature, see Levin (1983).

III. Intervention in a Modified Dornbusch Model for Germany

Examination of recent data suggests that, while the German Bundesbank may not explicitly have attempted to stabilize the real exchange rate of the deutsche mark, ex post Bundesbank intervention was consistent with the reaction function analyzed in Section II. For example, after substantial real appreciation of the deutsche mark in 1978, the Bundesbank began more actively to purchase U.S. dollars on the foreign exchange markets. Conversely, in late 1980 and early 1981, sharp nominal and real depreciation of the deutsche mark led to persistent official sales of dollars. Empirical evidence presented below also suggests that the risk premium variable seems to be important in the case of Germany, so that intervention may have been effective in influencing the exchange rate. The intervention function and portfolio balance equation for the exchange rate are estimated simultaneously with a small set of equations representing a macroeconomic model of the German economy. The model is estimated subject to rational expectations for the exchange rate and for the price level.

1. The estimated model

For purposes of estimation, we have specified a discrete-time system analogous to the Dornbusch model. As discussed in Wickens (1984), unless lags are arbitrarily introduced into the price equation, the model in this form may not produce overshooting, where the Dornbusch model, written in continuous time, would. The reason for this is that in discrete time the price level can in fact jump, for instance at the point of a monetary shock, even if it does not immediately attain its equilibrium level. Whether or not overshooting occurs in Wickens' model depends on the amount the price level jumps: if it increases by enough that real balances fall in response to a positive monetary shock (i.e., the interest rate rises), then the exchange rate undershoots—admittedly not a very plausible case. In our model the price equation, discussed below, allows for jumps because it depends contemporaneously on the exchange rate as well as on the expected value of the price level in the following period, and these expectations are formed rationally. 1/ As we shall see below, however, whether the exchange rate overshoots or not depends on more than just the behavior of real balances in a model where output is endogenous and where there is a J-curve phenomenon in the determination of the current balance, as is the case in our model.

Table 1 contains a list of the equations of our generalization of the Dornbusch model, written in discrete time. This model has been estimated using the full information maximum likelihood method on a sample of

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1/ Thus our discussion of the effect of intervention does not impose an extreme dichotomy between rational exchange rate expectations and adaptive inflation expectations. The present authors must plead guilty to having committed this misdemeanor in previous work, however.

Table 1. Modified Dornbusch Model and FIML Estimates, 1973 Q3 to 1982 Q2

		Structural parameters	FIML estimate	t-ratio	Imposed coefficients	
C1	$e = \hat{e}(+1)+(R^*-R)/4-\psi(a_o k-b_o f-c_o t)/4$	ψ	0.0521	2.40	a_0	1.23
C2	$\Delta f = \beta_1(p-p^*-e)+\mu(\bar{f}-f_{-1})$	β_1	0.2512	2.00	b_0	2.23
C3	$\Delta p = \Pi\Delta p_{-1}+(1-\Pi)[\eta\Delta p_{+1}+(1-\eta)(\Delta e+\Delta p^*)]$	μ	0.2532	3.87	η	0.30
	$+ \xi(y_{-1}-c_1 t)$	Π	0.8056	16.93	c_0	0.02052
C4	$y = c_1 t+\sigma(R-4\Delta\hat{p}_{+1})+\delta(e+p^*-p)$	ξ	0.0631	0.72	c_1	0.00604
C5	$\Delta m = \beta_3(\phi y+\lambda R-m_{-1}+p_{-1})+\Delta p$	σ	-0.3554	12.84	β_6	0.1623
C6	$\Delta R = \beta_4(R^*-R_{-1})+\beta_5(m_{-1}-c_o t)$	δ	0.0462	4.41	β_7	0.3071
C7	$\Delta k = -\beta_6 Q+\beta_7 y^*-\beta_8 y+\Delta p+c_1$	β_3	-0.3582	7.59	β_8	0.4316
C8	$Q = \beta_9 Q_{-1}-\beta_{10}Q_{-2}-\beta_{11}(p-e-p^*)$	ϕ	1.6555	32.04	β_9	0.8660
	$+\beta_{12}(p-e-p^*)_{-1}$	λ	-0.2045	2.17	β_{10}	0.1430
C9	$\hat{e}(+1)$ = fn (exogenous variables)	β_4	0.1853	4.29	β_{11}	1.5960
C10	$\hat{p}(+1)$ = fn (exogenous variables)	β_5	0.0832	1.01	β_{12}	1.8780

Fit statistics of estimated model

Root mean square error statistics

Equation 1	0.0179
2	0.0475
3	0.0111
4	0.0092
5	0.0197
6	0.0050
7	0.0243
8	0.1016
9	0.0334
10	0.0096

Full model fit statistics

1. Carter-Nagar System R^2 statistic of overidentified model 0.9993

2. Test of overidentifying restrictions: log-likelihood ratio equals 668.0 versus a critical value of the chi-quare at the 1 percent level of 164.7

data for Germany for the period 1973, third quarter to 1982, second quarter. In what follows, Φ is the first difference operator, with $\Phi x = x - x_{-1}$, and $\hat{x}(+1)$ indicates the expectation formed at t for the value of x in period t+1. We use $\Phi\hat{x}(+1)$ as a shorthand for $\hat{x}(+1) - x$.

Equation (C1) is the interest parity condition augmented by a risk premium; the expected (log) change in the exchange rate was multiplied by four to convert to annual rates for comparability with interest rates, and then both sides of the equation were divided by four. The exchange rate is a trade-weighted effective rate; the foreign interest rate is a weighted average of short-term rates prevailing in other industrial countries. The risk premium on foreign currency assets $\upsilon(a_0k - b_0f - c_0t)$ is assumed to be proportional to net foreign assets (the current account, cumulated from a benchmark figure, minus foreign exchange reserves) minus a time trend which proxies the growth in wealth, where, as before, lower case letters denote variables in natural logarithms. The coefficients a_0 and b_0 are constants used in the log-linearization of net foreign assets through a Taylor series expansion about sample means. Coefficient c_0 is also imposed; it was estimated as the trend growth in money over the sample period, roughly 8 percent at an annual rate.

The intervention function (C2) is specified such that movements away from the equilibrium level of the real exchange rate are resisted, but that intervention is constrained by the level of foreign exchange reserves. Excessive declines or increases in reserves are symptomatic of exchange rate pressure and may lead to destabilizing expectations. Moreover, at zero reserves intervention would cease to be possible while, from the point of view of the society as a whole, very high levels of reserves may be associated with large foregone earnings on alternative investments. It is assumed that there is some target reserve level $\bar{f}$. Since in the sample reserves exhibited little trend, $\bar{f}$ is taken to be a constant which is estimated jointly with the other parameters.

The price equation (C3) combines elements of price stickiness and forward-looking expectations. Variable p is a value-added deflator, the largest component of which is composed of wages. We suppose that average wages contain an element of inertia, for instance, because of emulation and overlapping contracts, and also that they anticipate future developments of the price of the consumption basket, consisting of domestic and foreign goods. We therefore model the value-added deflator in the following way:

$$\Phi p = \ell \Phi p_{-1} + (1-\ell)\, \Phi \hat{pc}_{+1} + \beta(y-\bar{y})_{-1} \qquad (17)$$

We assume that expectations of pc are formed rationally. The consumption deflator pc can be written as follows:

$$pc = \eta p + (1-\eta)\, (e+p^*)_{-1} \qquad (18)$$

on the assumption that there is a one-quarter lag between the production of foreign goods and their consumption domestically. Combining (17) and (18) yields equation (C3). It is clear that the price level in this formulation is not predetermined (unless $\Pi=1$) as it is affected by contemporaneous movements in the exchange rate as well as anticipation of future movements in p itself. There is an element of sluggishness to price movements which is greater, the greater is the value of the Π parameter.

The standard lagged adjustment formulation for the demand for real money balances is given in equation (C5), while the domestic short-term interest rate is explained by a policy reaction function in equation (C6). The latter assumes that interest rates are adjusted both to resist movements in the differential with rates prevailing abroad and to limit deviations from monetary targets, here proxied by a uniform trend over the sample period. Monetary settings may be adjusted to external factors so as to avoid potential pressures on the exchange rate brought on by large interest differentials vis-à-vis other countries; if so, monetary aggregate targets may not be hit exactly. It should be noted that in this form the model relaxes the assumption made by Dornbusch that interest rates move instantaneously to equate money demand with exogenous money supply. Here interest rates respond to other factors, including external ones, and some monetary accommodation on the part of the authorities will tend to limit the degree of overshooting, as has been discussed by Papell (1983). Such behavior seems to characterize the historical period more accurately than strict monetary targeting. The simulations performed below will however replace this reaction function by the Dornbusch assumption that interest rates are set solely to achieve monetary targets, based on the equilibrium demand for money function. This is discussed more fully below.

Equations (C7) and (C8) represent the determination of the cumulated current balance. The coefficients of these equations are imposed on the small macro model, being derived through partial simulations of a much larger model of the German economy. 1/ The variable Q is a synthetic competitiveness variable which is a function of current and lagged values of the real exchange rate; its second order lag structure incorporates the J-curve effect implicit in the larger model. The rest of the model is estimated subject to the prior restrictions imposed on the trade submodel. Given the highly aggregated nature of the cumulated current balance, the coefficients, necessarily, had to be derived (in the manner described) from the considerably more disaggregated model.

1/ The current account equation is derived by simulation of the OECD INTERLINK model. See OECD (1984). Variables for domestic income, foreign income and the real exchange rate were successively shocked, holding other variables constant.

In treating next period's expected exchange rate $\dot{e}(+1)$ and price level $\dot{p}(+1)$, the assumption is made that expectations are unbiased so that next period's realized values can be taken as measures of the expectations, subject to white-noise errors. We proceed to estimate the model using what Wickens (1982) calls the "errors in variables method." Two additional unrestricted reduced form equations are included in the model, where next period's exchange rate and price level, respectively, are set equal to functions of the exogenous variables. These equations appear in Table 1 as equations C9 and C10. Wickens shows that using a subset of the exogenous variables, rather than the full set, also gives consistent estimates of the model's parameters. Because of collinearity problems, we restricted the subset of exogenous variables to lagged values of domestic prices, current and lagged values of foreign prices, a lagged value of the competitiveness index, the lagged exchange rate, and a time trend.

As is evident from the above description, the model is parameterized in quite a parsimonious manner. The aim was to keep the model as small as possible, and to keep it linear without sacrificing too much realism or explanatory power. Some experimentation was necessary concerning the lagging of variables--for instance, output is lagged in the price equation--and the form of reaction functions. Rather than including unrestricted time trends, trends were fitted to the money supply and to real output over the sample: the estimated slope coefficients, c_0 and c_1, respectively, were imposed in the estimation of the full model. It proved impossible to estimate sensible parameters for the price equation when all were unrestricted. We therefore imposed a value for η, .3. This parameter measures the purely domestic cost influences on consumer prices; while somewhat implausibly low, it gave a higher likelihood for the full model than values of η closer to unity.

Table 1 presents estimates of the model's parameters obtained by full information maximum likelihood. 1/ The estimates have the expected signs, and most are significantly different from zero on the basis of asymptotic t-ratios. The estimate of υ in equation C1 tends to support the hypothesis that there is a risk premium that is related to net foreign asset stocks. The intervention equation, C2, seems to correspond to Bundesbank behavior over the sample period; a more general equation (not reported) also included the change in the nominal exchange rate as an explanatory variable, consistent with the hypothesis that the authorities attempt to smooth short-run fluctuations. Such behavior does not show up in our

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1/ Using the RESIMUL program developed by C.R. Wymer. Estimates of the parameters for expectations of the exchange rate and of the price level are not reported, nor are intercept coefficients, which are included in all equations. The statistic that is referred to as the "t-ratio" is in fact asymptotically normally distributed.

sample of quarterly data, however, as the parameter estimate was insignificantly different from zero. 1/ The estimated price equation, C3, implies considerable inertia, as ℓ is closer to unity than to zero; it is, however, significantly different from both polar cases and does include a forward-looking element. The effect of excess demand is positive, as expected, but not statistically significant; such was also the case when current, rather than lagged excess demand was included. The output equation, C4, was originally estimated to allow lagged adjustment. However, the speed of adjustment parameter was insignificantly different from unity and the equation was simplified to its current form. It implies a strong negative real interest rate effect on economic activity and a significant positive effect of the real exchange rate, both operating within the current quarter. The money demand estimates are conventional, though the interest elasticity of M3 estimated here is considerably below that reported for Germany in Blundell-Wignall et al. (1984). Finally, the interest rate reaction function embodies the effects of foreign rates and of domestic money targets, but the parameter capturing the latter is not well determined.

Of primary interest to us is the possible effect of intervention on the exchange rate. The risk premium parameter, υ, is of the correct sign and is significantly different from zero at the 1 percent level. It suggests that a 1 percent change in the cumulated current account will lead to a 0.05 percent change in the spot exchange rate, other things being given. Evaluated at the mean level of reserves for 1983, this would imply that a once-and-for-all DM 1 billion purchase of foreign currency assets by the Bundesbank would lead to an immediate depreciation of roughly .08 percent in the deutsche mark's effective exchange rate. As a standard of comparison, two previous studies imply that sterilized intervention of a similar size would cause a depreciation of .07 percent in the case of Branson, Haltunnen and Masson (1977) and .003 percent in the case of Obstfeld (1983). 2/ The smallness of this coefficient seems, on the face of it, to be consistent with the negligible effect found by many previous studies. 3/ That the risk premium parameter is very small does not necessarily imply that the impact of intervention will be small when

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1/ Artus (1976) reports estimates of a similar equation over a shorter sample period of monthly data (April 1973-July 1975) where both the deviation of the deutsche mark from its purchasing power parity level and the rate of change of the nominal exchange rate have significant coefficients.

2/ These two studies model the bilateral dollar/deutsche mark rate, and not the effective rate as is the case here. The effect quoted above for Obstfeld was obtained by scaling the number quoted in Tryon (1983) by the reserve money stock for 1983; it includes other model feedbacks and is not directly comparable to our parameter υ, however.

3/ See Tryon (1983) for a survey of previous small empirical models of exchange market intervention.

the model is solved under rational expectations. It should be stressed that in principle agents solve for the entire future path of the economy under rational expectations, so that the effects today of anticipated future intervention may be quite large. It is hard to judge on the basis of this one parameter estimate what will be the influence of an intervention rule, as opposed to the effect of a one-time intervention.

In order to examine its effect, we simulate the model with and without official intervention in the market for foreign exchange, on the assumption that market participants know the structure of the model and the future values of the exogenous variables. In the absence of uncertainty about parameters and about exogenous variables, our simulations thus involve calculating perfect foresight solutions to the model. We do so using the algorithm of Blanchard and Kahn (1980). 1/

In the Dornbusch overshooting model the monetary authorities are assumed strictly to target the money supply, and interest rates adjust to equate money demand with the exogenous supply. The historical data do not reflect interest rates determined in this way; in practice the authorities have also attempted to achieve other objectives and the money supply has to some extent been endogenous, with interest rate fluctuations being limited by central bank accommodation. It is for this reason that it proved necessary to estimate the interest rate as a policy reaction function with the money supply adjusting partially to demand.

For the purposes of subsequent policy analysis, however, the interest rate reaction function is suppressed and the estimated money demand equation, in its equilibrium form, is inverted to determine the interest rate. In other words, lags are eliminated from the demand for money equation, and the long-run demand for money function used. While this may seem to be an arbitrary procedure, the justification for it is that if money were strictly controlled, it is doubtful that interest rates would exhibit the dynamic behavior implied by the inverted money demand in response to a monetary shock with other variables constant, namely, a sharp jump and a gradual subsequent decline. Laidler (1982) has argued that estimated lags in "money demand equations" do not reflect lags in adjustment of demand so much as the stickiness of prices--captured elsewhere in our model.

1/ The exchange rate and the price level are the only truly "forward looking" variables; however, the other state variables X are not predetermined in the sense of Buiter (1982) because they can jump in response to news available at t. We avoided this problem by creating a vector of new state variables X1 composed of the lagged values of the variables X. The X1 are predetermined, and the model can then be written in the Blanchard-Kahn notation, with initial conditions imposed on X1 at time 0 and transversality conditions imposed on e and p such that they do not exhibit explosive behavior.

The dynamic properties of the model can conveniently be examined by calculating its eigenvalues (or characteristic roots), since the model is linear. A conventional model in difference equation form will be stable provided all roots have modulus less than unity; a perfect foresight model will be stable provided there are only as many eigenvalues with modulus greater than unity as there are non-predetermined variables, in this case two (the exchange rate and the price level), as transversality conditions are imposed on these variables to prevent them from exhibiting explosive behavior. Complex roots are evidence that some variables will respond in cyclical fashion when the model is subjected to shocks. The eigenvalues of the model with the modifications described above, both with and without the estimated reaction function for intervention, are presented in Table 2. As expected, there are two unstable roots corresponding to the rationally-expected exchange rate and domestic price level. Intervention increases the size of one of these roots, as was the case for the theoretical model developed in Section II above. The other roots have modulus less than unity, but there are complex roots, indicating cyclical behavior. We will see below that a monetary shock does in fact induce quite long and pronounced cycles. Interestingly enough, intervention adds a pair of complex roots, suggesting that it may itself be the source of cyclical fluctuations in response to shocks.

Table 2. Eigenvalues of the Estimated Model With the Long-Run Money Demand Function Renormalized on the Interest Rate

Without Intervention		With Intervention	
Eigenvalue	Modulus	Eigenvalue	Modulus
14.018	14.018	14.018	14.018
1.194	1.194	1.211	1.211
.984 ± .056i	.986	.963 ± .059i	.965
.838	.838	.910	.910
.747	.747	.689 ± .013i	.689
.670	.670	.221	.221
.221	.221		

The result of simulating the model when subjected to a domestic money supply shock 1/ are presented in Table 3. The nominal exchange rate does not overshoot its equilibrium value, either with or without intervention. In contrast to Wickens (1984) this is not the result of real balances falling in response to a positive shock to nominal balances; rather it is due to some rise in the domestic price level and a substantial rise in output, combined with a large income elasticity of money demand (see Table 1). The subsequent behavior of these variables is not that of monotonic adjustment toward their equilibrium levels: there are strong cycles and the exchange rate appreciates for a time before depreciating once again. The price level moves fairly steadily upward, but exceeds its equilibrium level after three years; in consequence, the real exchange rate, which had depreciated by over 8 percent initially, has appreciated relative to baseline by almost that amount after five years. The cumulated current account balance is strongly cyclical, as expected given the J-curve. It moves perversely at first, the depreciation leading to a lower net foreign asset position.

The effect of intervention is small, especially over the initial few periods. Even though the Bundesbank intervenes by an amount exceeding 2 percent of its reserves in the initial quarter (over $1 billion), the effect on e is only .05 percent. Differences widen as the simulation progresses, and after 20 quarters the exchange rate in both nominal and real terms is almost 2 percent higher (and hence closer to its equilibrium) than in the absence of intervention. Note that at this point reserves are some 7 percent higher than in the baseline, and that other variables--the price level, the nominal interest rate, and the cumulated current account--are farther from their equilibrium values than in the absence of intervention. It is also the case that the amplitude of the cyclical swings in the cumulated current account is larger for the simulation where the central bank intervenes.

The qualitative response of the model to the monetary shock will in fact depend on the values taken on by the parameters. Overshooting is more likely the less output and prices respond in the first instance, and the less sensitive is money demand to their movements. Conversely, the more interest elastic is money demand the less interest rates must move to equate money demand and money supply, and hence the less period-to-period movement in the exchange rate there will be. The presence or absence of cycles will also depend on the configuration of parameter values.

1/ Of perhaps greater interest is the effect of a foreign monetary shock, because in this case the open market operation and the intervention operation are performed by different monetary authorities. Since our model does not contain equations for foreign income and money demand, we cannot perform this experiment, the results for which should however be qualitatively similar to the one we have performed but reversed in sign.

Table 3. Simulated Effects of a Sustained 10 Percent Increase in the German Money Supply

(Percentage deviations from baseline)

Variable	Time Period (quarter)									
	0	1	2	3	4	7	11	15	19	∞
					Without Intervention					
e	9.87	8.27	6.87	5.68	4.68	2.69	1.81	2.22	3.39	10.00
f	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
p	1.42	2.69	3.81	4.81	5.69	7.76	9.56	10.71	11.45	10.00
e+p*-p	8.45	5.58	3.06	0.87	-1.01	-5.07	-7.75	-8.49	-8.06	0.00
y	4.41	3.76	3.18	2.66	2.21	1.14	0.23	-0.34	-0.70	0.00
R	-6.25	-5.34	-4.55	-3.85	-3.23	-1.73	-0.30	0.72	1.46	0.00
k	-2.68	-3.80	-3.48	-2.33	-0.83	3.27	5.15	3.52	0.06	0.00
					With Intervention					
e	9.82	8.28	6.99	5.92	5.05	3.46	3.05	3.84	5.25	10.00
f	-2.11	-2.98	-3.02	-2.52	-1.70	1.44	4.92	6.68	6.99	0.00
p	1.41	2.68	3.83	4.86	5.79	8.07	10.14	11.41	12.09	10.00
e+p*-p	8.41	5.60	3.16	1.06	-0.29	-4.61	-7.09	-7.57	-6.84	0.00
y	4.42	3.77	3.18	2.66	2.18	1.04	-0.00	-0.01	-0.01	0.00
R	-6.24	-5.28	-4.41	-3.61	-2.89	-1.08	0.63	1.69	2.26	0.00
k	-2.67	-3.80	-3.50	-2.35	-0.83	3.49	6.02	5.20	2.51	0.00

Though our results are specific to a particular set of parameter values--in most cases estimated on the basis of historical data, however--they are suggestive of the following conclusions. First, the possibility of significantly limiting deviations of real exchange rates from their equilibrium levels--assuming that these are known--seems extremely limited. Though our estimation results show a statistically significant effect of intervention, the economic significance of the result seems small. Evidence presented in other papers cited also gives very little support for the effectiveness of intervention. Second, to the extent that intervention does have an effect, resisting movements in the real exchange rate may have perverse effects on other variables; it may slow down their adjustment toward equilibrium levels. This is the case for the simulations that we performed. The authorities, by intervening to resist real exchange rate misalignments, would have caused interest rates to be higher after 20 quarters than they would otherwise have been, and the level of net foreign claims to be higher than their equilibrium value, implying subsequent current account deficits.

More generally, whatever the reason for the lagged adjustment present in the economy--price stickiness, slow adjustment of trade volumes, gestation lags for investment--the dynamic effects of an intervention rule will be very complex, and may have unintended consequences for other variables. An evaluation of the consequences for economic welfare must go beyond just considering the costs of the real exchange rate being misaligned. Even if sterilized intervention is effective as an independent policy instrument additional to monetary policy itself, then it is still the case that using that instrument incurs costs and not just benefits. Inhibiting movements in one variable has repercussions for the rest of the economy which must be evaluated from a general welfare perspective. Furthermore, our simulation results suggest that an intervention rule such as the one we have specified may be the source of cyclical fluctuations, as the eigenvalues in this case include an extra pair of complex roots. If there is a cost to such fluctuations, then it must be set against the costs of the misalignment which are being reduced by the intervention.

IV. Conclusion

In this paper, the Dornbusch overshooting model was extended to include a role for asset supplies through a risk premium variable, and the dynamics of an intervention rule whereby the authorities attempt to resist movements in the real exchange rate were examined analytically under assumptions of both regressive and rational exchange rate expectations. It was shown that the generalized model was stable under regressive expectations, whether or not the authorities intervened, and that the intervention rule did not of itself generate cycles. Similarly, the model was shown to have the saddle point property under rational expectations and, provided that the strength of intervention was sufficiently high, cyclical patterns would also remain absent. These results tended to provide analytical support for the view that attempts to limit overshooting through intervention rules to stabilize the real exchange rate may be helpful.

To examine these results empirically, a more complete macroeconomic model was estimated for Germany under the assumption of rational expectations for both the exchange rate and the domestic GDP deflator. The risk premium parameter, through which intervention may have an impact on the exchange rate, was shown to be small but statistically well determined. The estimation results also suggest that during the first decade of generalized floating the intervention behavior of the Bundesbank, while possibly motivated by other concerns, has been consistent with resistance to real exchange rate movements. This model was then solved under the perfect foresight assumption for a 10 percent permanent increase in the domestic money supply.

The model did not produce overshooting of the nominal exchange rate when subjected to a domestic monetary shock, but the real exchange rate did depreciate substantially as prices took time to adjust. The intervention rule did tend to limit the deviation of the real exchange rate from its equilibrium level--which was unaffected by the monetary shock. However, the effects were small, especially initially, when they were negligible. If the purpose of intervention is to limit nominal exchange rate overshooting, the model simulations provide little justification for its use. Furthermore, over a medium run the intervention rule produced adverse side-effects, in particular slower adjustment of some other variables and an increased tendency for cyclical fluctuations. The greater complexity of the empirical model, including a J-curve phenomenon on current balances, would seem to explain why a tendency toward cyclical behavior was present here even though it was not found in the simplest analytical examination of intervention.

It is important to underline the limitations of our analysis. We have examined a particularly simple strategy for intervention--though one which on occasion has been advocated. If intervention does indeed have some identifiable effect, however small, other more complicated feedback rules--perhaps involving much larger intervention operations--might have clearly beneficial effects. Put somewhat differently, in a deterministic context, if there is an additional independent instrument, then its use will generally help to attain a higher value for the objective function that policymakers maximize. We have not tried to derive optimal feedback rules, however, because such a deterministic setting is clearly not appropriate for that purpose. In particular, we have not attempted to model how individuals' behavior might change in response to changing levels of uncertainty. The intervention rule, in our model, only affects agents' expectations, as the private sector correctly anticipates the authorities' actions. However, it may be a deliberate part of an intervention strategy to change the degree of uncertainty concerning exchange rate fluctuations: either by limiting transitory fluctuations and hence providing a more stable planning environment, or on the contrary adding an erratic element to exchange rate movements in order to discourage speculation.

Data Definitions and Sources

All data, unless otherwise stated, are for the Federal Republic of Germany and are taken directly from the magnetic tape corresponding to the series shown in the Monthly Report of the Deutsche Bundesbank.

Endogenous

E	Effective exchange rate against 23 trading partners
F	Net external assets of the Deutsche Bundesbank, in billions of deutsche marks
P	GDP deflator
Y	Real GDP
M	M3
R	three-month interbank interest rate
K	Cumulated current account, in deutsche mark, calculated by summing current account flows from a benchmark figure
Q	Synthetic competitiveness variable, calculated from data for the real exchange rate and parameters derived from the OECD's INTERLINK model.

Exogenous

R*	three-month Eurodollar deposit rate
P*	Import price index in foreign currency terms
Y*	Real GDP of the seven major OECD economies excluding Germany (source: OECD Main Economic Indicators)
t	time trend, equals 0 in 1973 Q3, 1 in 1973 Q4, etc.

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