NBER WORKING PAPER SERIES

EXCHANGE RATES, INFLATION, AND THE STERILIZATION PROBLEM: GERMANY, 1975-1981

Maurice Obstfeld

Working Paper No. 963

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge MA 02138

August 1982

Paper prepared for the International Seminar on Macroeconomics sponsored by the Maison des Sciences de l'Homme and the National Bureau of Economic Research, University of Mannheim, June 20-22, 1982. I am grateful to Rama Seth for capable research assistance. Valuable comments and suggestions were made by the ISOM discussants and participants and by participants in the NBER's 1982 Summer Institute in International Studies, where this paper was also presented. Conversations with Steve Symansky led to improvements in the paper. Financial support provided under National Science Foundation grant SES-8023081 is acknowledged with thanks. The research reported here is part of the NBER's research program in International Studies. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

NBER Working Paper #963
August 1982

Exchange Rates, Inflation, and the Sterilization Problem: Germany, 1975-1981

Abstract

When the goals of internal and external macroeconomic equilibrium are in conflict, sterilized intervention in the foreign exchange market may provide an independent policy instrument through which the central bank can resolve its dilemma in the short run. This paper is concerned with the West German Bundesbank's use of sterilization during the recent years of exchange-rate flexibility. The paper asks whether the Bundesbank pursued sterilization during the years 1975-1981, and whether sterilized foreign exchange intervention exerts a significant influence on the exchange rate in the German case. Estimation of a stylized Bundesbank reaction function suggests an affirmative answer to the first of these questions.

To assess the efficacy of sterilized intervention, a structural portfolio balance model of German asset markets and prices is estimated. Dynamic perfect-foresight simulations of the empirical model are used to ascertain whether imperfect substitutability between foreign and domestic bonds is sufficient to allow the Bundesbank to attain independent internal and external goals over the short run of about a month. The model's verdict is that the Bundesbank has little if any power to influence the exchange rate over that time span without altering current or expected future money-market conditions.

Maurice Obstfeld
Department of Economics
Columbia University
New York, NY 10027

(212) 280-5489

Maurice Obstfeld
REVISED, August 1982

1. Introduction

The conflict between internal and external equilibrium has been a recurrent theme of the balance-of-payments literature. The conflict arises when the domestic credit measures appropriate for attaining a domestic policy target move the economy away from an important external target. Central banks have often attempted to resolve such dilemmas by sterilizing the monetary effects of foreign reserve flows in the hope of temporarily divorcing their domestic policies from balance-of-payments considerations.

Sterilized or "pure" foreign exchange intervention leaves money supplies unchanged but alters privately-held stocks of outside currency-denominated debt.[1] Pure intervention can have no exchange rate effects when domestic and foreign bonds are perfectly substitutable in portfolios. If debt management policies do influence the exchange rate, however, they provide a second policy instrument (along with domestic credit policy) through which the monetary authority can simultaneously achieve its internal and external targets in the short run.[2] The extent to which sterilized intervention is effective in practice is an unresolved issue [see Genberg (1981), Mussa (1981), and Obstfeld (1982a)].

The recent experience of West Germany illustrates both the nature of the policy dilemma that may arise under flexible exchange rates and the potential role of sterilized intervention in dilemma situations. Between the end of 1980 and the end of 1981, Germany faced domestic stagnation, high foreign interest rates, massive current-account deficits, and a depreciating exchange rate. The activity slowdown required monetary expansion and a fall in home interest rates. But policies appropriate from a purely internal standpoint would have worsened inflation immediately, in spite of domestic slack, by triggering further Deutschemark depreciation. This external side-effect reduces the cumulative expansionary impact of a less stringent monetary policy, and also raises firms' real costs by increasing the prices of imported intermediate production inputs. The policy dilemma could have been avoided if sterilized official dollar sales had been capable of preventing the Deutschemark from depreciating in the face of a less restrictive domestic credit policy.

This paper is concerned with the German Bundesbank's use of sterilization during the recent years of exchange-rate flexibility. The paper asks whether the Bundesbank pursued a sterilization policy during the years 1975-1981, and whether sterilized foreign exchange intervention is effective in the German case.

The first question is answered by estimating a Bundesbank domestic credit reaction function. While the policy function postulated is certainly an over-simplified representation of Bundesbank behavior, it yields strong evidence that sterilization played an important role. The estimated sterilization coefficients indicate that only a small fraction of any change in reserves was allowed to affect the monetary base.

The second question is answered with the help of an empirical portfolio-balance model of German asset markets and prices.[3] To assess the effects of alternative financial interventions, the empirical model is simulated under the assumption that agents have perfect foresight concerning future exchange rate movements. While a transitory change in the monetary base lasting three quarters is found to have a significant effect on the exchange rate, a transitory sterilized foreign exchange intervention of equal magnitude is found to have virtually no effects. This evidence suggests that sterilization is not an effective "second instrument" in the case of Germany. The finding is consistent with Bundesbank accounts of its own recent experience with pure foreign exchange intervention.

Empirical reduced-form portfolio balance models have been estimated by a number of authors, including Branson, Halttunen, and Masson (1977, 1979), Dooley and Isard (1982), Hooper and Morton (1982), Martin and Masson (1979), and Porter (1977, 1979). In contrast to these contributions, the present study estimates a structural model of German asset markets. Structural estimation is necessary if one wishes to identify the channels through which changes in asset supplies influence the exchange rate. In addition, structural estimation makes possible direct tests of the hypotheses underlying the portfolio balance approach.[4]

The remainder of this paper is organized as follows. Section 2 is a short summary of macroeconomic developments in the Federal Republic of Germany between 1975 and 1981. Section 3 briefly reviews the portfolio balance model of exchange rates and describes the effects of sterilized foreign exchange intervention. Section 4 reports estimates of a Bundesbank domestic credit policy reaction function. A portfolio balance model of Germany is set out and estimated in section 5. In section 6, the effects of sterilized and nonsterilized foreign reserve sales are studied through dynamic perfect-foresight simulations of the empirical model. Section 7 offers concluding remarks. An appendix contains a detailed description of the data and definitions used in this study.

2. The conflict between internal and external balance during 1975-1981

The traditional case for flexible exchange rates, as made by Johnson (1969), held that the abandonment of fixed parities would free governments "to use their instruments of domestic policy for the pursuit of domestic objectives." The experience of the last decade has shown this view to be too sanguine, at least where monetary policy is concerned. Monetary expansion induces exchange rate depreciation which feeds into domestic prices and wages. This, in turn, shortens the short run in which easy money can keep nominal interest rates low.[5]

When external price and interest-rate shocks lead simultaneously to recession, inflation, and an external deficit, the exchange rate's sensitivity to domestic credit conditions raises a genuine policy dilemma. Internal balance demands a fall in interest rates. But the interest-rate effects of money are dissipated quite rapidly as the accompanying exchange depreciation causes domestic inflation to accelerate. Indeed, reflationary monetary policy may have some contractionary effects, for depreciation occasions an immediate rise in the production costs of industries using imported production materials. Intermediate price rises lead to lay-offs in the affected sectors while reducing profitability and discouraging investment.

The recent experience of West Germany illustrates the dilemma that may confront policy makers under flexible exchange rates. (See Table 1.) At the outset of 1975, the German economy still suffered from the contractionary and inflationary effects of the 1973-1974 price shocks. In spite of the danger of exchange rate depreciation, the Bundesbank adopted an inward-looking monetary policy, allowing the money supply to grow at a

Table 1

Economic Developments, 1975-1981

Year	1975	1976	1977	1978	1979	1980	1981
Real GNP growth (in %)	-2.0	5.3	2.8	3.6	4.4	1.8	-0.3
CPI inflation (in %)	6.0	4.3	3.7	2.7	4.1	5.5	5.9
Import price inflation (in %)	-1.7	6.7	1.5	-3.7	11.6	14.9	14.0
Change in value of DM against $[a] (in %)	-6.3	10.0	10.1	14.4	8.5	-12.1	-12.7
Central bank money growth[b] (in %)	9.9	8.3	10.0	11.8	5.5	5.3	3.0
Current account (billions of DM)	9.9	9.9	9.8	18.1	-11.0	-29.5	-17.1

Source: Deutsche Bundesbank annual and monthly reports.

[a] Changes calculated using daily averages for the last month of each period. Negative entries signify Deutschemark depreciation against the dollar.

[b] Changes calculated using daily averages for the last month of each period. Central bank money is defined as currency in circulation plus required reserves on banks' domestic liabilities at constant reserve ratios.

rapid pace. By summer, recovery was under way. The full force of the policy dilemma was not felt in 1975, however, for a favorable conjunction of external factors weakened the inflationary impact of the Bundesbank's expansionary measures. First, the current account balance, while declining considerably from its 1974 level of DM 26.6 billion, remained in surplus that year.[6] Second, the dollar prices of German imports fell as a result of the worldwide slump. Although the Deutschemark's value against the dollar dropped by 6.3 per cent during 1975, the index of import prices actually declined over that same period. At 6 per cent, Germany's 1975 inflation rate was a point lower than it had been during the previous two years.

Over the following three years, inflation decelerated and the Deutschemark appreciated strongly against both the U.S. dollar and the currencies of its major trading partners. After a strong showing in 1976, the economy grew more slowly in 1977 and 1978. But the Deutschemark's strength persisted in spite of brisk monetary growth, helping to dampen the rate of price increase. In every one of the years 1976-1978 the Bundesbank overshot its monetary-growth target--sharply so in 1978, when the central bank money stock grew by 11.8 per cent.

The decade's second round of major oil price increases began in late 1978. In spite of the Deutschemark's continuing appreciation over 1979, the import price index jumped by 11.6 per cent and inflation accelerated sharply. Contributing to the poorer price performance were the expansionary stance of fiscal policy and a boom in investment and inventory demand encouraged by the low level of interest rates over 1978. This strong increase in aggregate demand more than offset the contractionary effects of the oil price increases, and the year's GNP growth rate was high. To combat the inflationary tendencies, and in particular to prevent the price increases from being built into future wage settlements, the Bundesbank allowed central bank money to grow at a rate of only 5.5 per cent, near the bottom of the 1979 target range. As monetary policy grew more stringent, German interest rates followed world interest rates upward. The year's second quarter saw the emergence of the first in a series of quarterly current account deficits that was to continue without interruption until the final quarter of 1981. Germany's new external weakness would become a major policy problem in the following two years.

Buffeted by an escalating price of oil, the industrialized economies experienced a distinct slowdown starting in the spring of 1980. In Germany, however, the pace of economic activity remained relatively strong until the summer, and the current account accordingly worsened. After the beginning of 1980 (when the dollar stood at an all-time low in the foreign exchange market) the Deutschemark began to weaken. But U.S. interest rates were temporarily soft during the summer, and the Bundesbank took the opportunity to speed up monetary growth in the face of the emerging recession. As the U.S. slowdown ended and as U.S. monetary policy became more contractionary in the early autumn of 1980, dollar interest rates rose sharply. The rise in U.S. interest rates, coupled with an enormous third-quarter current deficit (which, at DM 12.7 billion, exceeded the deficit over the entire previous year), exerted irresistible downward pressure on the Deutschemark's market value, and forced the Bundesbank to abandon its countercyclical monetary measures. Faced with an accelerating inflation fueled by steep import price rises and unexpectedly high wage settlements, the Bundesbank would risk no worsening of the exchange-market situation.

In the third quarter of 1980, the Bundesbank found itself caught in the conflict between internal and external balance. Its initial response was to intervene heavily in the foreign exchange market in support of the Deutschemark while at the same time increasing domestic credit to offset the contractionary effect of reserve losses on liquidity. Over the course of the year, the Bundesbank's net external assets fell by DM 25.7 billion as a result of foreign exchange operations. But between September 1980 and February 1981, the Deutschemark-dollar exchange rate plummeted by nearly 17 per cent. In the latter month, the Bundesbank decided that in view of inflationary dangers it could no longer continue to hold German interest rates constant as U.S. rates increased. Although the economy continued to stagnate, the authorities adopted a decidedly stringent monetary stance and pushed interest rates upward.

The policy dilemma that arose in late 1980 required a choice between internal and external balance; the Bundesbank chose the latter. This course was followed, in the face of strong domestic criticism, until the final quarter of 1981. With the current account once again in surplus, with U.S. interest rates on a seeming downward trend, and with unemployment growing, the Bundesbank initiated a relaxation of domestic credit conditions. But the relaxation was a cautious one. As the Bundesbank explained in its February 1982 <u>Monthly Report</u>:

> ....accelerated cuts in interest rates, with the consequence of a depreciation of the Deutsche Mark, would increase the importation of inflation and quicken the pace of domestic price rises. A deteriorating price climate would undoubtedly lead to new fears of inflation, and hence inevitably trigger another upturn in interest rates. The Bundesbank cannot take these risks.

3. Foreign exchange intervention under imperfect asset substitutability

When home and foreign bonds are imperfect substitutes, debt management that leaves monetary aggregates unchanged may influence the exchange rate.[7] Nonmonetary or "pure" foreign exchange market intervention can take many forms, ranging from sterilized foreign asset purchases to forward exchange operations to the outright issuance of foreign-currency debt (such as Carter notes). Pure foreign exchange intervention, if effective, provides an independent central bank policy instrument and with it, a possible escape from the policy dilemma posed by domestic stagnation and a weakening exchange rate.

The portfolio-balance model of the exchange rate formalizes the idea that relative supplies of outside interest-bearing debt as well as relative money supplies influence the exchange rate. A brief review of the model illustrates the potential value of debt management as a policy tool and serves as background for the subsequent econometric application.[8]

The economy considered is one whose residents can hold wealth in the form of domestic money and in the form of interest-bearing bonds denominated in foreign or domestic currency units. Foreign bonds and domestic bonds issued at home are imperfect substitutes: their nominal returns (adjusted for expected exchange rate depreciation) need not be equal, and there exist well-defined demand functions for national debts as well as for national monies. Foreigners may hold domestic bonds, and so domestic money is the only nontraded asset. The relevant asset demand functions are written as:

$L(R,y,W/P)W$ = domestic demand for high-powered money

$B(R,R^* + \varepsilon,y,W/P)W$ = net domestic demand for domestic bonds[9]

$F(R,R^* + \varepsilon,y,W/P)W$ = net domestic demand for foreign bonds, expressed in terms of domestic currency

$B^*(R - \varepsilon,R^*)W^*$ = net foreign demand for domestic bonds, expressed in terms of foreign currency

where

R = nominal interest rate on domestic bonds

R^* = nominal interest rate on foreign bonds

ε = expected rate of exchange rate depreciation

P = domestic price level

y = domestic real output

W = domestic nominal wealth

W^* = foreign nominal wealth.

Assets are assumed to be gross substitutes; the variables y and W/P entering the domestic portfolio-share functions capture the effect of the transactions level on asset demands, as in Tobin (1969). The wealth constraint implies that

$$L + B + F = 1. \tag{1}$$

The foreign bond rate R* is taken to be exogenous. The domestic price level P, output y, and the wealth variables W and W* are assumed to be fixed in the short run.[10] Eq. (1) implies that domestic holdings of foreign assets need not be considered in deriving the economy's instantaneous equilibrium. Asset-market clearing requires only that residents willingly hold the stock of base money and that foreign and home demand for domestic bonds sum to the available net supply. As usual, E, the exchange rate, is the domestic-currency price of foreign exchange. With H denoting the supply of high-powered money and D the stock of outstanding government debt not held by the central bank or foreign official agencies, the asset-market equilibrium conditions are

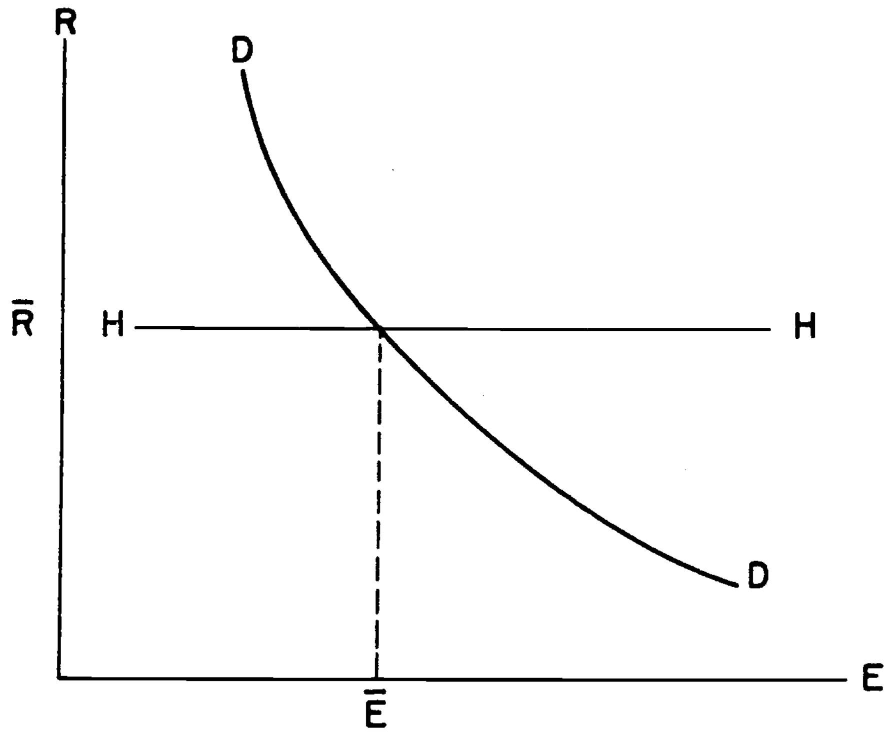
$$H = L(R, y, W/P)W, \tag{2}$$

$$D = B(R, R^* + \varepsilon, y, W/P)W + EB^*(R - \varepsilon, R^*)W^*. \tag{3}$$

Given P, y, and W, equilibrium condition (2) determines the domestic interest rate $\bar{R}$. Given the expected depreciation rate ε and W*, eq. (3) then determines the equilibrium exchange rate $\bar{E}$.

Short-run asset-market equilibrium is depicted in Fig. 1 for a fixed value of ε. The HH locus is horizontal at the unique home interest rate consistent with money-market equilibrium. The DD schedule consists of points at which the home bond market clears. A decline in R creates an excess supply of domestic debt, while a rise in E restores equi-

Figure 1

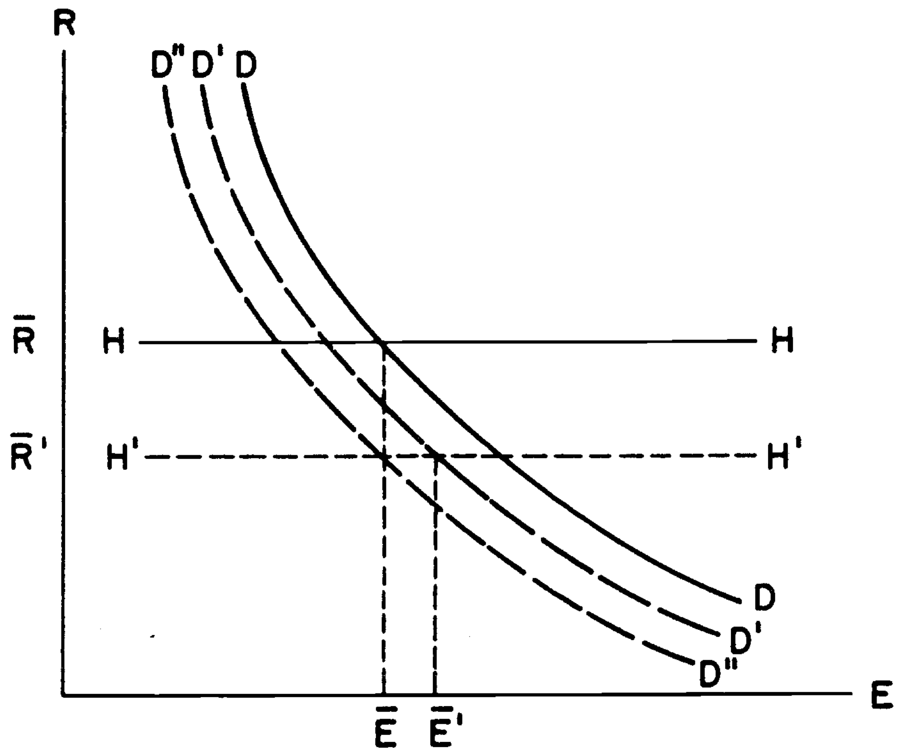


librium by increasing the home-currency value of the foreign demand. Thus, DD has a negative slope.[11] Momentary equilibrium occurs at the intersection of HH and DD, where all asset markets clear simultaneously.[12]

The conflict between internal and external equilibrium becomes apparent when we consider the effects of domestic credit expansion. These effects are depicted in Fig. 2 on the assumption that the expected depreciation rate ε does not change. A purchase of domestic assets by the central bank shifts the HH schedule downward to H'H'. Because the central bank finances its purchase by issuing high-powered money, a lower nominal interest rate is necessary for money-market equilibrium. Domestic credit expansion also shifts DD to the left, to D'D', because fewer domestic bonds are available to be held in private portfolios.[13] In the new equilibrium, the interest rate is lower but the price of foreign exchange is higher. Any stimulus to investment is purchased at the cost of increased import costs and additional pressure on domestic prices.[14]

Sterilized foreign exchange intervention, when used in concert with domestic credit expansion, enables the monetary authority to lower the nominal interest rate in the short run while holding the exchange rate constant at $\bar{E}$. A sterilized sale of foreign exchange is a pure debt swap which leaves the monetary base unchanged. The central bank uses foreign reserves to purchase high-powered domestic money, but at the same time prevents any decrease in liquidity through an exactly offsetting expansion of domestic credit. The intervention has no effect on H but decreases D. It thus shifts D'D' leftward to D"D", which intersects H'H' at the initial exchange rate $\bar{E}$. In effect, the central bank prevents the depreciation implied by its expansionary domestic policy through "pure"

Figure 2



A-ED-0125 W.L.

foreign exchange intervention in support of the exchange rate. This policy would be self-defeating under perfect asset substitutability, for sterilized intervention would then have no effect on the external value of the currency.

The foregoing discussion raises two empirical questions concerning the recent German experience. First, did the Bundesbank in fact employ sterilized intervention in an attempt to simultaneously achieve its internal and external objectives? And second, are the actual effects of sterilized intervention of sufficient importance to offer an escape from the policy dilemma? These questions are addressed in the next three sections.

4. Did the Bundesbank sterilize?

Estimation of the Bundesbank's domestic credit policy reaction function provides evidence on the extent to which sterilized intervention was practiced during 1975-1981. If the Bundesbank indeed followed a strategy similar to that described in the previous section, domestic credit should respond positively to cyclical shortfalls in output but negatively to increases in foreign exchange reserves. Under complete sterilization the coefficient of the change in foreign reserves is -1, for domestic credit is systematically varied to offset the effect of reserve acquisitions on domestic liquidity.

An issue of considerable importance is the precise definition of the reaction function's dependent variable. The change in the Bundesbank's net domestic assets does not provide a complete picture of the stance of domestic credit policy. In addition, variations in reserve requirements on banks have played an important part in domestic credit control. The change in domestic credit, ΔDC, is therefore defined as the increase in net domestic assets minus the reserves impounded by any increase in required reserves. The latter component is calculated as

$$[REQ(t) - REQ(t-1)]\cdot M3(t-1), \tag{4}$$

where REQ is the average reserve ratio and M3 is the broadly-defined money stock. ΔDC includes open-market purchases as well as Bundesbank lending to private banks (through discount and Lombard facilities) and to the central and Länder governments. All variables are defined in detail in the appendix.[15]

Domestic credit is assumed to respond to the increase in reserves, the current output gap, and lagged price-level inflation.[16] The reaction function therefore takes the form

$$\Delta DC(t) = \pi_1 \Delta \tilde{NFA}(t) + \pi_2 GAP(t) + \pi_3 INF(t-1) + u(t). \tag{5}$$

In (5), $\Delta \tilde{NFA}$ is the change in the Bundesbank's net foreign assets, valued in Deutschemarks at a constant exchange rate; GAP is the percent excess of trend over actual output; and INF is the month-to-month percent increase in the price level. Because exchange rate fluctuations entail changes in the Deutschemark value of reserves which are not reflected as changes in the monetary base, the measure $\Delta \tilde{NFA}$ excludes the periodic reserve valuation adjustments made by the Bundesbank. The reaction function was estimated by nonlinear least squares, with a correction for first-order serial correlation in u(t).[17] The first row of Table 2 reports the result of estimating (5) over the entire sample period.

The estimated equation supports the hypothesis that the Bundesbank has used domestic credit policy to attain domestic policy objectives

Table 2

The Bundesbank's Domestic Credit Policy Reaction Function

(Monthly Data)

Sample	Dependent Variable	$\Delta\tilde{NFA}(t)$	GAP(t)	INF(t-1)	$\hat{\rho}$	$\bar{R}^2$	D.W.
1975:2–1981:10	$\Delta DC(t)$	-.9245 (.0730)	.5277 (.2326)	-.6942 (1.1667)	-.7044 (.0884)	.7426	2.13
1975:2–1979:3	$\Delta DC(t)$	-.8634 (.0903)	.1114 (.2076)	-.2952 (1.3817)	-.7537 (.1240)	.7681	1.74
1979:4–1981:10	$\Delta DC(t)$	-1.0091 (.1370)	1.9866 (.5986)	-1.2178 (3.1865)	-.7659 (.1495)	.7696	1.94

Note: Standard errors appear in parentheses. In estimation, all equations included eleven seasonal dummy variables and a constant, but the estimated coefficients of these variables are not reported. All variables are defined in detail in the appendix. Financial aggregates are measured in billions of Deutschemarks.

while engaging in sterilized foreign exchange intervention in order to influence the exchange rate. Over the period 1975-1981, the sterilization coefficient π_1 is negative, large, and highly significant. In addition, it does not differ significantly from -1, and thus is consistent with a policy of full sterilization. The coefficient π_2 is positive and significant, providing evidence that countercyclical considerations influenced domestic credit policy. Further evidence along these lines is provided by the coefficient of lagged inflation, π_3, which, while statistically insignificant, is nonnegligible in magnitude and of the anticipated sign.[18]

As a check on the stability of policy response during the period under study, the reaction function (5) was estimated over two subperiods in which the Bundesbank faced on the whole quite different external conditions. The second and third rows of Table 2 report estimates of (5) over the sample periods 1975:2-1979:3 and 1979:4-1981:10. The story told by these estimates is essentially the same as the one sketched above. Over both subperiods, the sterilization coefficient is negative and close to -1. Over both subperiods, domestic credit responds in countercyclical fashion to output and price fluctuations. The reaction function does exhibit some instability over time, however. The countercyclical coefficients are of much greater magnitude over the second subperiod. Over the first subperiod, a one-tailed test indicates rejection of the hypothesis of complete sterilization. The results are unfortunately too imprecise to allow strong conclusions about policy shifts.

The econometric evidence that the Bundesbank pursued a policy of substantial sterilization is in agreement with the published record of Bundesbank measures. The year 1980, in which the Bundesbank supported the exchange rate through massive reserve sales, provides an example. In March of that year, in order to "offset foreign exchange outflows," the Bundesbank repurchased before maturity more than DM 3 billion in paper previously sold to banks. In April, minimum reserve ratios were lowered and rediscount quotas were raised in "view of the sustained outflows of foreign exchange from the Bundesbank." Minimum reserve ratios were lowered further in September to "offset the contractionary effects of the outflows of foreign exchange on bank liquidity." Rediscount quotas were again increased in October and in January 1981. A further decrease in required reserve ratios also occurred in January. "A monetary policy guided solely by external factors would have allowed the contractionary monetary effects of the balance of payments deficit to work through in full to the domestic economy," the Bundesbank stated.[19]

The finding that sterilized foreign exchange intervention was in fact pursued does not provide evidence that sterilized intervention had a significant effect on the exchange rate. Information concerning the efficacy of policies cannot be obtained from a reaction function, which merely describes the authorities' behavior. To assess the efficacy of policies, one needs information about the structure of the economy. The next sections attempt to evaluate the effects of sterilized intervention using an empirical model of German asset markets and the price level.

5. A structural model of asset markets and prices

In this section a structural monthly macromodel of West Germany is described and estimated. The model's financial sector is patterned on the portfolio balance model set out in section 3, but it has a more complex money market comprising money supply as well as money demand. Given expectations and the price level, the financial sector determines the Deutschemark-dollar exchange rate and the three-month domestic interbank interest rate. A separate equation describes how the price level evolves over time in response to lagged inflation and lagged import-price changes. Both output and the three-month Eurodollar interest rate are taken to be exogenous. While the model does not explain the level of nominal home wealth, the potential endogeneity of that variable, along with that of the price level, is recognized in the estimation.

A key problem in estimating the model is the choice of a variable to proxy exchange-rate expectations. The financial sector submodel is based on the premise that Deutschemark bonds issued in Germany and Eurodollar deposits are imperfect substitutes in portfolios. Eurocurrency deposits differing only in their currency of denomination are assumed to be perfect substitutes, however, so that the premium on forward dollars in London may be used in estimation as a proxy for the Deutschemark's expected depreciation rate.[20] By assuming that the expected nominal return on Eurodollar deposits must always equal that on Eurodeutschemark deposits, the present study neglects the role of nondiversifiable exchange risk in determining the interest differential between onshore German assets and Eurodollar deposits.[21] Rather, that portion of the differential not explicable by expected exchange depreciation is ascribed entirely to various political risks, such as the prospect of capital controls.[22] A number of recent empirical studies have rejected the hypothesis that Eurocurrency interest differentials equal expected depreciation rates [see, for example, Cumby and Obstfeld (1981)]. In adopting the hypothesis in spite of those findings, I am assuming implicitly that as an empirical matter, the political risk premium separating covered returns on Eurocurrency and onshore deposits is large relative to the exchange risk premium separating expected nominal returns on offshore deposits denominated in different currencies. To the extent that this assumption is unjustified, the econometric results reported below are biased.

The model's first equation explains the demand for sight deposits M, defined as the money stock M1 minus currency in circulation, CURR. CURR is taken to be exogenous to the model. Long-run deposit demand is proportional to domestic nominal wealth W, with the proportionality factor depending negatively on the three-month interbank interest rate R and positively on real income y. The demand function is assumed to have the form

$$M^d = a_0 \exp(-a_1 R)(y)^{a_2} (W/P)^{a_3} \exp(u_1) W \tag{6}$$

where u_1 is a mean-zero disturbance. The equation estimated is derived from (6) by taking natural logarithms, assuming gradual adjustment of the log of nominal deposits to its long-run desired level, and subtracting log(P) from both sides. This leads to the specification

$$\log(M(t)/P(t)) = \alpha_0 - \alpha_1 R(t) + \alpha_2 \log(y(t)) + \alpha_3 \log(W(t)/P(t)) + \alpha_4 \log(M(t-1)/P(t)) + (1-\alpha_4) u_1(t). \tag{7}$$

The banking system's supply of sight deposits is proportional to the monetary base H in the long run. Supply depends positively on the difference between R and the central bank discount rate DISC, and negatively on both the currency/deposit ratio CURR/M and the average required reserve ratio REQ. A convenient specification of long-run deposit supply is

$$M^S = b_0 \exp[b_1(R - DISC)](CURR/M)^{-b_2}(REQ)^{-b_3}\exp(u_2)H, \tag{8}$$

with u_2 a mean-zero disturbance. By taking the log of (8), assuming partial nominal adjustment, and subtracting log(P), one derives the functional form

$$\log(M(t)/P(t)) = \beta_0 + \beta_1(R(t) - DISC(t)) - \beta_2\log(CURR(t)/M(t)) - \beta_3\log(REQ(t)) + (1 - \beta_4)\log(H(t)/P(t)) + \beta_4\log(M(t-1)/P(t)) + (1 - \beta_4)u_2(t). \tag{9}$$

The analogue of the money-market equilibrium condition (2) is obtained by equating the right-hand sides of (7) and (9).

Consider next the equation explaining German holdings of domestic bonds. The net supply of these bonds available to the German public ($\bar{B}^S$) is equal to the indebtedness of the German public authorities (DBT) minus the net domestic assets of the Bundesbank (NDA) minus net foreign private holdings of domestic bonds ($\bar{B}^*$):

$$\bar{B}^S = DBT - NDA - \bar{B}^* = D - \bar{B}^*. \tag{10}$$

The measure (10) ignores forward exchange operations of the Bundesbank, which alter the stock of outside domestic bonds without immediately affecting NDA. Home demand for domestic bonds is given in the long run by

$$\bar{B}^d = c_0\exp(c_1R)\exp[-c_2(R^* + \varepsilon)]\exp(-c_3DISC)(y)^{-c_4}(W/P)^{c_5}\exp(u_3)W \tag{11}$$

where R* and ε now represent the three-month London Eurodollar deposit rate and the three-month London forward premium on dollars, respectively. The variable DISC enters (11) with a negative coefficient because a rise in the central bank discount rate discourages bank lending and so decreases overall demand for domestic debt.[23] When combined with the gradual adjustment of bond holdings, eq. (11) implies the specification

$$\log(\bar{B}(t)/P(t)) = \gamma_0 + \gamma_1R(t) - \gamma_2(R^*(t) + \varepsilon(t)) - \gamma_3DISC(t) - \gamma_4\log(y(t)) + \gamma_5\log(W(t)/P(t)) + \gamma_6\log(\bar{B}(t-1)/P(t)) + (1 - \gamma_6)u_3(t). \tag{12}$$

It remains to specify a structural equation describing foreign residents' demand $\bar{B}^{*d}$ for domestic bonds. This demand has actually been negative over the entire sample period, for foreigners have been net borrowers of Deutschemarks. The equation estimated therefore explains the supply of Deutschemark bonds by nonresidents, i.e., foreign borrowing.

Specification of this structural equation is complicated by the fact that the borrowers are residents of many countries besides the U.S. Thus, exchange rates other than the DM-dollar rate enter into the determination of asset-market equilibrium. The foregoing problem can be avoided by making the admittedly stringent assumption that all currency areas have essentially identical DM-bond supply functions. Let the long-run supply function for currency area i be given by

$$-\bar{B}_i^{*d} = E_i d_0 \exp[-d_1(R - \varepsilon)]\exp(d_2 R^*)\exp(u_4)W_i^*,$$

where E_i is the Deutschemark price of currency i, W_i^* is the nominal wealth of area i measured in local currency units, and u_4 is a stochastic disturbance common to all area supply functions. Note that the supply of bonds by area-i residents has been written as a negative demand. If S_i is the U.S. dollar price of currency i ($S_1 = 1$), aggregate foreign borrowing of Deutschemarks can be written

$$\begin{aligned} -\bar{B}^{*d} &= \sum_i(-\bar{B}_i^{*d}) \\ &= d_0\exp[-d_1(R-\varepsilon)]\exp(d_2R^*)\exp(u_4)\{\sum_i(E_i/S_i)S_iW_i^*\} \\ &= Ed_0\exp[-d_1(R - \varepsilon)]\exp(d_2R^*)\exp(u_4)W^*, \qquad (13) \end{aligned}$$

where E (= E_1) is the DM-dollar exchange rate and W* is aggregate foreign wealth measured in dollars. To obtain the equation estimated, write (13) in logarithmic form, assume gradual adjustment of nominal bond holdings, and subtract log(E) from both sides of the resulting equation. This yields

$$\begin{aligned} \log(-\bar{B}^*(t)/E(t)) = \delta_0 - \delta_1(R(t) - \varepsilon(t)) + \delta_2R^*(t) + (1 - \delta_3)\log(W^*(t)) \\ + \delta_3\log(-\bar{B}^*(t-1)/E(t)) + (1 - \delta_3)u_4(t). \qquad (14) \end{aligned}$$

The equilibrium condition $\bar{B} + \bar{B}^* = D$ corresponds to condition (3).

The results of estimating eqs. (7), (9), (12), and (14) are reported in Table 3. All equations were estimated by two-stage least squares, or, when necessary, by nonlinear two-stage least squares with a correction for first-order serial correlation in the equation disturbance.[24] The estimates are

Table 3

The Asset Market Model

(Monthly Data)

Equation number	Equation	$\hat{\rho}$	$\bar{R}^2$	D.W.
(7)	$\log(M(t)/P(t)) = \underset{(.4778)}{-1.9143} - \underset{(.0049)}{.0089}\ R(t) + \underset{(.0745)}{.3070} \log(y(t)) + \underset{(.2542)}{.4646} \log(W(t)/P(t))$ $+ \underset{(.2075)}{.3392} \log(M(t-1)/P(t))$	.5320 (.2483)	.8560	1.92
(9)	$\log(M(t)/P(t)) = \underset{(.2057)}{-1.2459} + \underset{(.0055)}{.0124}\ (R(t) - DISC(t)) - \underset{(.1528)}{.9058} \log(CURR(t)/M(t))$ $- \underset{(.0799)}{.3079} \log(REQ(t)) + \underset{(.1104)}{.9809} \log(H(t)/P(t)) + \underset{(.1104)}{.0191} \log(M(t-1)/P(t))$	.3778 (.1126)	.9008	2.38
(12)	$\log(\bar{B}(t)/P(t)) = \underset{(.1084)}{.1332} + \underset{(.0248)}{.0172}\ R(t) - \underset{(.0248)}{.0133}\ (R^*(t) + \varepsilon(t)) - \underset{(.0050)}{.0047}\ DISC(t)$ $- \underset{(.0251)}{.0357} \log(y(t)) + \underset{(.1208)}{.3020} \log(W(t)/P(t)) + \underset{(.1095)}{.6617} \log(\bar{B}(t-1)/P(t))$	-----	.9777	2.25
(14)	$\log(-\bar{B}^*(t)/E(t)) = \underset{(.3503)}{-.4379} - \underset{(.5237)}{1.4346}\ (R(t) - \varepsilon(t)) + \underset{(.5354)}{1.4223}\ R^*(t)$ $+ \underset{(.0995)}{.1923} \log(W^*(t)) + \underset{(.0995)}{.8077} \log(-\bar{B}^*(t-1)/E(t))$	-----	.6660	2.28

Note: Standard errors appear in parentheses. All variables are defined in detail in the appendix.

based on monthly observations over the sample period 1975:1 - 1981:10.[25]

The estimated coefficients have the signs predicted by theory, but they are not always statistically significant. In particular, the rate-of-return coefficients in eq. (12) are insignificant and quite small: home and foreign bonds do not appear to be highly substitutable from the standpoint of resident bond-holders. In contrast, the interest elasticities of foreign borrowing are quite large. The short-run elasticity of foreign borrowing with respect to the covered return $R - \varepsilon$ (calculated at the sample mean of that variable) is -14.9; the corresponding short-run elasticity with respect to R^* is 14.2. These elasticities rise to -77.7 and 73.8, respectively, in the long run, i.e., after foreign borrowing has fully adjusted to its long-run desired level.

The equations in Table 3 are consistent with the hypotheses underlying the portfolio balance approach, but they do indicate the existence of lags in asset-market adjustment. Adjustment of deposit supply to its long-run level appears to be immediate, for the coefficient of lagged deposits in eq. (9) is small and insignificant. Eqs. (12) and (14) provide strong evidence of slow bond-market adjustment, however, while eq. (7) provides somewhat weaker evidence that deposit demand adjusts gradually.

As an input to the simulation experiments of the next section, an equation explaining CPI inflation was estimated. General price-level inflation was related to its own lagged values and lagged foreign price inflation by the equation

$$\log\left(\frac{P(t)}{P(t-1)}\right) = \sum_{i=1}^{9} \lambda_i \log\left(\frac{P(t-i)}{P(t-i-1)}\right) + \sum_{i=1}^{9} \theta_i \log\left(\frac{E(t-i)P^*(t-i)}{E(t-i-1)P^*(t-i-1)}\right) + u_5(t), \quad (15)$$

where P^* is the U.S. consumer price index.

Table 4 reports the result of estimating the inflation equation (15) by

Table 4

The Inflation Equation

(Monthly Data)

Lag	Domestic CPI Inflation	Foreign Price Inflation	$\bar{R}^2$	D.W.
1	.2921 (.1255)	.0084 (.0079)	.3491	1.90
2	.1411 (.1229)	.0133 (.0081)		
3	.0440 (.1221)	.0011 (.0083)		
4	-.0172 (.1106)	-.0026 (.0082)		
5	-.0850 (.1095)	.0042 (.0082)		
6	-.5290 (.1101)	.0011 (.0083)		
7	.1887 (.1290)	.0059 (.0082)		
8	.0425 (.1229)	.0191 (.0082)		
9	.0571 (.1188)	.0004 (.0083)		

Note: Standard errors appear in parentheses. A constant was included in estimation, but its coefficient is not reported.

ordinary least squares over the sample period 1975:1 to 1981:10. The equation gives no information about the contemporaneous correlation between the home inflation rate and international prices; that information is impounded in the disturbance term $u_5(t)$ of (15). The simulations reported below are based on the identifying assumption that the domestic price level is predetermined.

6. The effects of intervention policies: Simulation results

This section compares the effects of sterilized foreign exchange intervention, which is not allowed to affect the monetary base, and nonsterilized or monetary intervention, which is fully reflected in the supply of high-powered money. The policy comparisons are made by simulating the empirical model of the previous section under different assumptions about the time paths of the supplies of base money H and domestic debt D. Exchange rate expectations play a central role in any evaluation of the effects of alternative policies. The simulations reported below are based on the assumption that agents have perfect foresight concerning future exchange rate movements. Thus, the values for ε fed into the simulation are the same as the actual depreciation rates that the simulation predicts.[26] Simulations of this type serve primarily to elucidate the empirical model's structure. The perfect foresight assumption ensures that the simulated effects of policies are not the result of arbitrary expectational hypotheses.

Because many foreign exchange interventions are explicitly temporary in nature, I compare the effects of two transitory interventions, each of which occurs in January 1979 and is reversed after nine months. The first of these is an official foreign exchange sale that decreases the monetary base by 10 percent (DM 13.25 billion). The second is a sterilized

Table 5
Intervention Policies and the Exchange Rate

Period	Monetary intervention	Benchmark simulation	Sterilized intervention
1979:1	2.5349	2.6126	2.6115
2	2.5330	2.6082	2.6079
3	2.5479	2.6283	2.6266
4	2.5261	2.5710	2.5722
5	2.5120	2.5602	2.5599
6	2.5634	2.6162	2.6148
7	2.5274	2.5470	2.5482
8	2.5177	2.5403	2.5401
9	2.5587	2.5866	2.5855
10	2.5234	2.5174	2.5191
11	2.4943	2.4928	2.4928
12	2.5731	2.5726	2.5726
1980:1	2.4619	2.4620	2.4619
2	2.4559	2.4558	2.4558
3	2.5031	2.5030	2.5030
4	2.4390	2.4390	2.4390
5	2.4171	2.4171	2.4171
6	2.4543	2.4542	2.4542

foreign exchange sale of equal magnitude, the net effect of which is to decrease the stock of privately-held outside DM-denominated debt by DM 13.25 billion while leaving the monetary base unchanged. Both interventions are unanticipated, but their transitory nature is fully understood. A third, reference exchange rate path is provided by a benchmark simulation experiment that uses as input historical values of the base and the outside debt supply.

The simulation procedure is iterative and works as follows.[27] All simulations begin in 1979:1 and end in 1981:9. The three-month forward premium is written as 400[log(F/E)], where F is the three-month forward rate, and in each round of simulation, the forward rates for 1981:7, 1981:8, and 1981:9 are set equal to the spot exchange rates prevailing in 1981:10, 1981:11, and 1981:12.[28] In the first round of simulation, the remaining forward rates (1979:1-1981:6) are set at their historical values. Simulation with the foregoing forward-rate series as input produces a simulated exchange rate path over 1979:1-1981:9; and that series, led three periods, serves as the input for F over 1979:1-1981:6 in the next simulation round. The procedure is continued until the simulated exchange rate series agrees with the exchange rate series produced in the previous round.

Table 5 reports the results of the three perfect-foresight simulation experiments. The benchmark simulation gives the exchange rate's perfect-foresight path in the absence of intervention. The benchmark exchange rate path is high relative to its historical level. For example, the benchmark simulation predicts an exchange rate of 2.6126 marks per dollar in January 1979, whereas the actual exchange rate was 1.8616. The disparity reflects the fact that many of the events that impinged on the exchange market over the simulation period were in fact unanticipated. Had its subsequent depreciation been foreseen at the outset, the Deutschemark would have been much weaker over that period. While the perfect-foresight assumption produces unrealistic exchange rate levels, the simulation procedure is nonetheless useful for exercises in comparative dynamics.

Consider the effect of a 10 percent decline in the monetary base lasting three quarters. As Table 5 shows, this monetary intervention causes an immediate 3.0 percent appreciation of the currency relative to its benchmark value. Because it is known that the base will rise to its benchmark level after 1979:9, the exchange rate begins to depreciate toward the benchmark rate. When the base rises abruptly in 1979:10 the interest rate falls, and because the price level is slightly below the benchmark level, the interest rate is lower as well. The exchange rate is above its benchmark level in 1979:10 because a greater expected appreciation of the Deutschemark must offset this lower home interest rate.

A DM 13.25 billion foreign exchange sale whose monetary effect is sterilized causes an impact .04 percent appreciation relative to the benchmark. This effect is insignificant compared to that of the equivalent nonsterilized intervention. The exchange rate effect of the lower debt stock remains insignificant in subsequent periods, although the exchange rate does depreciate slightly relative to the benchmark in 1979:10, when the sterilized intervention is reversed. This depreciation is needed to create the expected appreciation that persuades asset-holders to demand a higher stock of DM-denominated debt.

The simulation experiments suggest that the Bundesbank's ability to influence the exchange rate without altering monetary conditions is very limited. It is accurate to assert that the sterilized intervention considered above has essentially no effect on the exchange rate. In contrast, foreign exchange interventions that are allowed to affect the monetary base have a strong impact on the exchange rate, even when they are known to be transitory. While a permanent sterilized foreign exchange sale would of course have a somewhat greater exchange rate effect, the effect would remain small relative to that of a permanent nonsterilized sale. Further, permanent changes of this type may not always be feasible. A permanent sterilized foreign exchange transaction of the magnitude contemplated here would have caused a 40 per cent change in the Bundesbank's net domestic assets in January 1979.

7. Conclusion

Even under flexible exchange rates, the goals of internal and external balance can conflict. If foreign and domestic bonds are imperfect substitutes in portfolios, sterilized foreign exchange intervention may provide a "second instrument" (along with domestic credit expansion) enabling the central bank to reconcile its internal and its external objectives. The econometric evidence suggests that the German Bundesbank did attempt to use sterilization in this manner over the period 1975-1981.

To assess the efficacy of sterilized intervention in the German case, a structural portfolio balance model of German asset markets and prices was estimated. Dynamic perfect-foresight simulations of the empirical model were used to ascertain whether imperfect substitutability between foreign and domestic bonds is sufficient to allow the Bundesbank to attain independent internal and external goals over the short run of about a month. The model's verdict was that the Bundesbank has little if any power to influence the exchange rate over that time span without altering current or expected future money-market conditions. These findings leave open the possibility that sterilized foreign exchange market intervention has significant but short-lived exchange rate effects which disappear within a month.

Major shortcomings of the empirical model include the sketchy treatment of price-level dynamics and the failure to explain the current account and with it, the level of domestic wealth. Adequate treatment of these factors would require a much larger model. An additional drawback of this paper's approach is the neglect of imperfect substitution between Eurocurrency deposits differing only in their currency of denomination. All these issues are left on the agenda for future research.

Appendix

This appendix describes the data and definitions used in this study. The following abbreviations will be employed: IFS = International Financial Statistics; MRDB = Monthly Report of the Deutsche Bundesbank; WFM = World Financial Markets, Morgan Guaranty Trust Co. of New York.

Data and definitions appear in alphabetical order.

$\bar{B}$: D - $\bar{B}$*.

$\bar{B}$*: Net foreign holdings of DM-denominated bonds at end of month (in billions of DM). The series was calculated as the sum of: (i) net short-term DM indebtedness of private banks to foreigners, (ii) net long-term DM indebtedness of private banks to foreigners, (iii) net DM liabilities to foreigners of private enterprises arising from short-term financial credits, (iv) net DM liabilities to foreigners of private enterprises arising from long-term financial credits, and (v) net foreign DM liabilities of private enterprises arising from advance payments. Source: MRDB, supplement no. 3.

CURR: Currency in circulation (in billions of DM). Source: MRDB, table II.1.

D: DBT - NDA.

DBT: Indebtedness of the German public authorities (in billions of DM). Quarterly data on this variable are published in MRDB, table VII.5. Most issues of MRDB contain in addition a survey of public-sector borrowing in preceding months. This information (together with information from MRDB, table II.1, on Bundesbank lending to the domestic public authorities) enables one to transform the quarterly debt series into a monthly series with only minimal interpolation.

ΔDC: ΔH - $\Delta\tilde{NFA}$ - ΔREQ$\cdot$M3(-1).

$\Delta\tilde{NFA}$: NFA - NFA(-1) minus the change in foreign reserve valuation reported until February 1982 in MRDB, Table IX.6(c), column 12.

DISC: Bundesbank discount rate (in percent per annum), at end of month. Source: WFM.

E: End-of-month exchange rate (Deutschemarks per dollar). Source: IFS.

ε: Three-month forward premium on dollars in London at or near end of month (in percent per annum). Computed as the difference between the three-month Eurodeutschemark deposit rate in London and R*. Data on the three-month EuroDM rate come from the Harris Bank (Chicago) Weekly Review (until March 1978) and from WFM thereafter.

$\bar{F}$: NEAPR + $\bar{B}$*.

GAP: Computed as 100 times the log of the ratio of the industrial production index trend cycle to the seasonally-adjusted industrial production index. For data on the industrial production index, see y.

GOVM2: Public authority holdings of money M2 at end of month (in billions of DM). Source: MRDB, table I.2.

H: Monetary base (in billions of DM). Computed as the sum of currency in circulation plus domestic banks' deposits with the Bundesbank. Source: MRDB, table II.1

INF: 100[log(P/P(-1))].

M: M1 - CURR.

M1: Money stock M1 (in billions of DM). Source: MRDB, table I.2.

M3: Money stock M3 (in billions of DM). Source: MRDB, table I.2.

NDA: Net domestic assets of Bundesbank (in billions of DM). Computed as H - NFA.

NEAPR: Net external assets of the private sector measured at end of month (in billions of DM). The series was computed as the sum of net external assets in the five categories listed in the description of $\bar{B}^*$ above. Of course, this measure aggregates external assets and liabilities regardless of currency of denomination. Source: MRDB, supplement no. 3.

NFA: Net external position of the Bundesbank at end of month (in billions of DM). Source: MRDB, table IX.6 (a), column 12.

P: German cost-of-living index. Source: OECD, Main Economic Indicators (Historical Statistics).

P*: United States price level (CPI-W). Source: Survey of Current Business.

R: German three-month interbank interest rate (in percent per annum) at end of month. Source: WFM.

R*: Three-month London Eurodollar deposit rate at or near end of month (in percent per annum). Source: WFM.

REQ: Average required reserve ratio for German banking system. Computed from MRDB, table IV.2.(a), as column 1 divided by column 8.

W: German financial wealth (in billions of DM), calculated as NEAPR + H + DBT - NDA - GOVM2.

W*: World wealth (in billions of U.S. dollars). Computed as (-NEAPR/E) plus the measure of world stock market wealth reported in Capital International Perspective (published by Capital International S.A., Geneva).

y: Index of German industrial production, seasonally unadjusted. Source: OECD, Main Economic Indicators (Historical Statistics).

Footnotes

1. A sterilized foreign exchange purchase by the central bank is one whose effect on the monetary base is offset by a simultaneous and equivalent sale of central bank domestic assets.

2. The use of Keynesian fiscal policy as a second instrument was advocated in Mundell's (1968) celebrated writing on the policy mix. The starting point of that work is the observation that monetary and fiscal expansion have opposite effects on the capital account because of their opposite effects on the interest rate. Countercyclical fiscal policy of the type envisioned by Mundell is currently unpopular in a number of countries, however. This unpopularity is due in part to the longer-run "crowding out" effects of government spending and borrowing. It is also due in part to the concern that government deficits might fuel inflationary expectations. Fiscal policy interventions of a different sort do not entail the foregoing risks, and are in fact being pursued. To stimulate investment in the face of high foreign interest rates, the German government approved a "joint initiative on jobs, growth and stability" in February 1982. The program involves a number of investment (and employment) subsidies which are to be financed for the most part by an increase in the value-added tax.

3. The portfolio balance approach to exchange rate determination under imperfect asset substitutability has been developed by Boyer (1978), Branson (1977), Flood (1983), Girton and Henderson (1977), Kenen (1976), Kouri (1982), Porter (1977), and others. The approach is the open-economy

analogue of Tobin's (1969) general-equilibrium model of domestic financial markets.

4. A further distinguishing feature of the present study is its use of data on bond holdings disaggregated by currency of denomination. The studies listed in the text use cumulated current accounts (or cumulated current accounts net of cumulated official intervention) to proxy private net external asset positions. As many of the authors point out, however, this procedure is not valid when current imbalances are financed through lending denominated in several currencies. Alternative structural models of West Germany are presented by Artus (1976, 1981), who also assumes limited asset substitution. Frankel (1981) estimates a portfolio balance model of the dollar-mark rate based on two-period mean-variance optimization.

5. For further discussion, see Dornbusch and Krugman (1976) and Goldstein (1980).

6. The precise channels through which the current account influences the exchange rate remain in dispute. Loopesko (1982) reports evidence that even anticipated German current-account imbalances have exerted significant effects on the dollar-Deutschemark exchange rate.

7. Imperfect asset substitutability is neither sufficient nor necessary to ensure the efficacy of nonmonetary financial operations that affect the relative supplies of bonds denominated in different currencies [see Henderson (1983) and Obstfeld (1982a)]. For example, if agents internalize the government and central bank budget constraints, as in Obstfeld (1982b), intervention operations that leave current and expected future money supplies un-

changed exert no effects on asset prices even when asset substitutability is limited. In setting out the portfolio-balance model and in applying it to the German data, Ricardian equivalence issues will be left aside. More precisely, it will be assumed that all government-issued debt represents outside debt and that private agents do not consider central-bank foreign asset positions in formulating their own asset demands.

Even with perfect asset substitution [as in Dornbusch (1976), for example], nonmonetary intervention policies can influence asset prices if the decision to undertake them conveys to the market new information about the future path of the money supply. Mussa (1981) in particular stresses this as a channel through which pure intervention may operate. The discussion in the text ignores the foregoing possibility without denying its potential importance in practice.

8. Henderson (1979, 1983), Kenen (1981), Marston (1980), and Obstfeld (1980) provide alternative discussions of open-economy financial policy under imperfect asset substitutability.

9. All bonds have a fixed nominal face value.

10. Exchange rate movements entail capital losses and gains for bond holders, and so cause variations in nominal wealth even in the short run. In other words, nominal wealth should be viewed as an endogenous variable. Valuation effects are omitted here, however, in order to simplify the exposition; their incorporation would raise no substantive difficulties.

11. When foreign holdings of domestic bonds are negative--as they are in the case of West Germany--the DD schedule may have a positive slope. As noted by

Branson, Halttunen, and Masson (1979), Martin and Masson (1979), Tobin and de Macedo (1981), and others, monetary expansion can have a perverse effect on the exchange rate, causing it to appreciate, when one country is a net debtor in foreign currency. Henderson and Rogoff (1982) and Kouri (1982) demonstrate, however, that this perversity disappears in more fully specified dynamic exchange rate models once rational expectations of future exchange rate depreciation are introduced. Under rational expectations, monetary expansion causes the exchange rate to depreciate even when foreigners have a short position in domestic currency. The empirical simulations reported in section 6, below, assume that agents have perfect foresight concerning future exchange rate movements. Accordingly, financial policies move the exchange rate in the expected directions.

12. The view that the exchange rate is set so as to clear markets for asset stocks does not contradict the fact that the exchange rate adjusts to ensure ex post equality between two flows, the balance of private external payments and the official capital account deficit. To see this, assume for simplicity that foreign official agencies do not purchase domestic assets. Then the capital account surplus measured in terms of home currency is just the difference between private foreign acquisitions of domestic securities and the value of private domestic acquisitions of foreign securities over any time interval $[t-1,t]$. Defining $\bar{B}^* \equiv B^*(R-\varepsilon,R^*)W^*$ and $\bar{F} \equiv F(R,R^*+\varepsilon,y,W/P)W$, we may therefore write the capital account surplus, K, as

$$K = \int_{t-1}^{t} \overline{[E(\tau)\dot{\bar{B}}^*(\tau)]}d\tau - \int_{t-1}^{t} E(\tau)\,\overline{[\dot{\bar{F}}(\tau)/E(\tau)]}d\tau,$$

where dots denote time derivatives. By integration, the capital account is

$$K = E(t)\bar{B}^*(t) - E(t-1)\bar{B}^*(t-1) - [\bar{F}(t) - \bar{F}(t-1)] + \int_{t-1}^{t} [\dot{E}(\tau)/E(\tau)]\bar{F}(\tau)d\tau$$

$$= \Delta(E\bar{B}^*) - \Delta\bar{F} + CG,$$

where $CG = \int[\dot{E}(\tau)/E(\tau)]\bar{F}(\tau)d\tau$ is the capital gain on domestically-owned foreign assets due to the change in the exchange rate between times t-1 and t. The increase in domestic wealth over the interval [t-1,t] must equal the sum of the current account surplus (CA), government dissaving (G - T), and capital gains CG. By the wealth constraint (1) and by (2), this must also equal $\Delta H + \Delta\bar{B} + \Delta\bar{F}$, where $\bar{B} \equiv B(R,R^*+\varepsilon,y,W/P)W$. Letting NDA denote the central bank's net domestic assets and FXR the foreign currency value of the central bank's net foreign assets, we infer from the central bank's balance sheet and equilibrium condition (3) that

$$CA + (G - T) + CG = \int_{t-1}^{t} E(\tau)FX\dot{R}(\tau)d\tau + \Delta NDA + \Delta\bar{B} + \Delta\bar{F}$$

$$= \int_{t-1}^{t} E(\tau)FX\dot{R}(\tau)d\tau + \Delta NDA + \Delta D - \Delta(EB^*) + \Delta\bar{F}$$

$$= \int_{t-1}^{t} E(\tau)FX\dot{R}(\tau)d\tau + (G - T) - [\Delta(E\bar{B}^*) - \Delta\bar{F}].$$

Use of the expression for the capital account surplus K derived earlier leads to the balance-of-payments identity

$$CA + K = \int_{t-1}^{t} E(\tau)FX\dot{R}(\tau)d\tau.$$

13. The principal tools of Bundesbank domestic credit policy are changes in

reserve requirements, changes in rediscount and Lombard quotas, and repurchase operations, rather than open-market transactions *per se* [see Schlesinger and Bockelmann (1973) and the discussion in section 4, below]. These policies affect the asset markets in the same manner as open-market changes in D. Changes in reserve requirements, in particular, change the willingness of the banking system to lend and so alter the excess nonbank demand for domestic debt at any interest rate and exchange rate. In addition, changes in reserve requirements shift HH by altering the derived demand for high-powered money.

14. Why must the exchange rate depreciate? The answer comes from consideration of the suppressed equilibrium condition requiring that residents willingly hold the portion of the stock of outside foreign bonds not held by foreigners. A fall in R, given E, leads to excess demand for foreign bonds. An appreciation of E would reduce the domestic-currency value of the home country's stock of foreign bonds (assuming the latter is positive), and so increase rather than decrease this excess demand. Since domestic credit expansion lowers R while leaving the stock of privately-owned foreign bonds unchanged, it must also cause E to rise. Note that the central bank could increase the base and lower R by an outright nonsterilized purchase of foreign exchange rather than through a purchase of domestic assets. This policy does not shift DD and therefore has an even greater impact on E than an equal domestic credit expansion.

15. Herring and Marston (1977) employ a formulation similar to (4) in specifying the Bundesbank reaction function they estimate over the Bretton Woods period. Note that our definition of ΔDC ignores the effects of foreign exchange swaps with domestic banks.

16. When the lagged rather than the contemporaneous output gap was used in the reaction function, its coefficient was insignificant and of the wrong sign.

17. The variable GAP is assumed to be predetermined. In the presence of a systematic foreign-exchange intervention rule, the change in reserves valued at a constant exchange rate may be correlated with the disturbance to eq. (5). If such a correlation exists, ordinary least squares estimates of (5) are inconsistent. A more thorough analysis would specify a Bundesbank intervention function [as in Artus (1976)] and estimate (5) by two-stage least squares.

18. Artus (1976) draws similar conclusions from a domestic credit policy reaction function estimated over the period 1973:4-1975:7. His estimate of the sterilization coefficient (-.745) is somewhat lower than those reported here. Darby and Stockman (1983), like Artus, find evidence of substantial but incomplete sterilization over the floating-rate period through 1976. Black (1983) also finds evidence of sterilization, but for a longer sample period (1964:2-1979:11) that includes part of the Bretton Woods era.

19. The quotations are taken from the Report of the Deutsche Bundesbank for the Year 1980.

20. Empirical studies show that covered interest parity holds quite closely in the Eurocurrency markets [see Frenkel and Levich (1981) and Herring and Marston (1976), among others]. Thus, if Eurodollar and Eurodeutschemark deposits are perfect substitutes on an uncovered basis, the forward premium on dollars in terms of DM quoted in London must equal the expected rate of depreciation of the mark against the dollar. An alternative approach that avoids

the assumption of perfect substitution among Eurocurrency deposits takes the realized depreciation rate as a proxy for the expected rate. The econometric issues raised by the alternative approach (along with appropriate estimation techniques) are described by Cumby, Huizinga, and Obstfeld (1982).

21. The exchange risk premium, which allows Eurocurrency interest differentials and expected depreciation rates to differ, is studied by Frankel (1979), Hodrick (1981), and Stulz (1982), among others.

22. Aliber (1973) has suggested that covered interest differentials between bonds issued in different political jurisdictions, and between home- and foreign-currency bonds issued in the same jurisdiction, are explicable in part by political risks. Dooley and Isard (1980) and Genberg (1981) provide more recent discussions. Kouri (1976) analyzes a stochastic model in which political/default risk generates covered interest differentials depending on outside asset stocks.

Capital controls--for example, prohibitions on asset sales or interest payments to foreigners--provide an additional instrument of central bank policy and are often imposed when the requirements of internal and external balance conflict. Use of that instrument naturally entails severe efficiency costs. Both existing capital controls and the prospect of additional future capital controls cause deviations from covered interest parity. The Bundesbank is empowered to implement capital controls under Article 23 of the Foreign Trade and Payments Law of 1961. During the closing years of the Bretton Woods period, significant barriers to capital inflow were erected in an attempt to salvage the faltering system of fixed parities. Dooley and Isard (1980) estimate that political risk can at times account for up to 200 basis points of the differential between the onshore three-month interbank interest rate and the Zurich three-month Eurodeutschemark rate during 1970-1974. Most (but not all) of these capital controls were dismantled in the early years of the float. One that remained was the prohibition on nonresident purchases of certain securities (e.g., public authority bonds and money-market paper) first imposed in June 1972. The stringency of that control was varied in subsequent years in response to the changing external situation. In January 1974, nonresident purchases of fixed-interest securities with maturities exceeding four years were again authorized. The minimum maturity was reduced to two years in September 1975 (at which time the existing authorization requirement for the payment of interest on nonresident deposits with domestic banks was also abolished); increased again to four years in December 1977; reduced to two years in March 1980; and reduced to one year in November 1980. In February 1981, the prohibition was relaxed completely. It seems reasonable to conclude that during 1975-1981, the policy environment was one in which the probability of further capital controls was significant. Transaction costs can of course explain a portion of the onshore-offshore covered interest differential, but it is unlikely that they provide a complete explanation. McCormick (1979) argues that transaction costs are smaller than has been widely believed. For an application of Dooley and Isard's (1980) model to the recent French experience, see Claassen and Wyplosz (1983).

23. A more complete specification of the home bond market would disaggregate resident domestic bond holders into banks and nonbanks. That extension has been foregone in the interest of simplicity.

24. The instrumental variables for each equation were the logarithm of the lagged nominal asset stock deflated by P(t-1)(E(t-1) in the case of eq. (14)) plus R*(t), R(t-1), log(CURR(t-1)/M(t-1)), log(REQ(t-1)), log(H(t-1)/P(t-1)), log(y(t)), log(W(t-1)/P(t-1)), log(W*(t)/P*(t)) (where P* is the U.S. CPI), DISC(t-1),

and log((DBT(t-1)/P(t-1)). This choice of instruments again reflects the assumption that y(t) may be viewed as a predetermined variable (cf. section 4); but it allows for the possible endogeneity of nominal domestic wealth and the home price level. Note, however, that foreign wealth W* and the U.S. price level P* are assumed to be exogenous.

25. The sample-period starting date was dictated by the nonavailability of data on the variable $\bar{B}^*$ prior to 1974:12.

26. The assumption of perfect foresight cannot, by itself, yield a unique exchange rate path; some terminal condition is required in addition. The terminal condition assumed in simulation is described below.

27. Simulations were performed on the Massachusetts Institute of Technology TROLL system using a linearized version of the model.

28. Note that the same terminal condition is imposed in all three simulation experiments. The assumption behind this procedure is that the transitory interventions have a negligible effect on the economy's position two years after their termination.

References

Aliber, R.Z., 1973, The interest rate parity theorem: A reinterpretation, Journal of Political Economy 81, 1451-1459.

Artus, J.R., 1976, Exchange rate stability and managed floating: The experience of the Federal Republic of Germany, International Monetary Fund Staff Papers 23, 312-333.

Artus, J.R., 1981, Monetary stabilization with and without government credibility, International Monetary Fund Staff Papers 28, 495-533.

Black, S.W., 1983, The use of monetary policy for internal and external balance in ten industrial countries, in: J.A. Frenkel, ed., Exchange rates and international macroeconomics (University of Chicago Press for the National Bureau of Economic Research, Chicago).

Boyer, R.S., 1978, Financial policies in an open economy, Economica 45, 39-57.

Branson, W.H., 1977, Asset markets and relative prices in exchange rate determination, Sozialwissenschaftliche Annalen des Instituts für Höhere Studien 1, 69-89.

Branson, W.H., H. Halttunen, and P. Masson, 1977, Exchange rates in the short run: The dollar-Deutschemark rate, European Economic Review 10, 303-324.

Branson, W.H., H. Halttunen, and P. Masson, 1979, Exchange rates in the short run: Some further results, European Economic Review 12, 395-402.

Claassen, E.M., and C. Wyplosz, 1983, Capital controls: Some principles and the French experience, Annales de l'INSEE, forthcoming.

Cumby, R.E., and M. Obstfeld, 1981, A note on exchange-rate expectations and nominal interest differentials: A test of the Fisher hypothesis, Journal of Finance 36, 697-703.

Cumby, R.E., J. Huizinga, and M. Obstfeld, 1982, Two-step two-stage least squares estimation in models with rational expectations, Journal of Econometrics, forthcoming.

Darby, M.R., and A.C. Stockman, 1983, The Mark III international transmission model: Estimates, in: M.R. Darby et. al., The international transmission of inflation (University of Chicago Press for the National Bureau of Economic Research, Chicago).

Dooley, M.P., and P. Isard, 1980, Capital controls, political risk, and deviations from interest-rate parity, Journal of Political Economy 88, 370-384.

Dooley, M.P., and P. Isard, 1982, A portfolio-balance rational expectations model of the dollar-mark exchange rate, Journal of International Economics 12, 257-276.

Dornbusch, R., 1976, Expectations and exchange rate dynamics, Journal of Political Economy 84, 1161-1176.

Dornbusch, R., and P. Krugman, 1976, Flexible exchange rates in the short run, Brookings Papers on Economic Activity 7, 537-575.

Flood, R.P., 1983 , A model of asset trade, in: P.J.K. Kouri and J.B. de Macedo, eds., Balance of payments adjustment and exchange rate dynamics: Essays on the portfolio approach , forthcoming.

Frankel, J.A., 1979, The diversifiability of exchange risk, Journal of International Economics 9, 379-394.

Frankel, J.A., 1981, Estimation of portfolio-balance functions that are mean-variance optimizing: The mark and the dollar. International Finance Discussion Paper no. 188, Federal Reserve Board.

Frenkel, J.A., and R.M. Levich, 1981, Covered interest arbitrage in the 1970's, Economics Letters 8, 267-274.

Genberg, H., 1981, Effects of central bank intervention in the foreign exchange market, International Monetary Fund Staff Papers 28, 451-476.

Girton, L., and D.W. Henderson, 1977, Central bank operations in foreign and domestic assets under fixed and flexible exchange rates, in: P. Clark, D. Logue, and R. Sweeney, eds., The effects of exchange rate adjustments (U.S. Government Printing Office, Washington).

Goldstein, M., 1980, Have flexible exchange rates handicapped macroeconomic policy? Special Papers in International Economics no. 14, International Finance Section, Department of Economics, Princeton University.

Henderson, D.W., 1979, Financial policies in open economies, American Economic Review Papers and Proceedings 69, 232-239.

Henderson, D.W., 1983, Exchange market intervention operations: Their effects and their role in financial policy, in: J.F.O. Bilson and R.C. Marston, eds., Exchange rates: Theory and practice (University of Chicago Press for the National Bureau of Economic Research, Chicago).

Henderson, D.W., and K.S. Rogoff, 1982, Net foreign asset positions and stability in a world portfolio balance model, Journal of International Economics 12, forthcoming.

Herring, R.J., and R.C. Marston, 1976, The forward market and interest rates in the Eurocurrency and national money markets, in: C. Stem, J. Makin, and D. Logue, eds., Eurocurrencies and the international monetary system (American Enterprise Institute, Washington).

Herring, R.J., and R.C. Marston, 1977, Sterilization policy: The trade-off between monetary autonomy and control over foreign exchange reserves, European Economic Review 10, 325-343.

Hodrick, R.J., 1981, International asset pricing with time-varying risk premia, Journal of International Economics 11, 573-587.

Hooper, P., and J. Morton, 1982, Fluctuations in the dollar: A model of nominal and real exchange rate determination, Journal of International Money and Finance 1, 39-56.

Johnson, H.G., 1969, The case for flexible exchange rates, 1969, Federal Reserve Bank of St. Louis Review 51, 12-24.

Kenen, P.B., 1976, Capital mobility and financial integration: A survey, Princeton Studies in International Finance no. 39, International Finance Section, Department of Economics, Princeton University.

Kenen, P.B., 1981, Effects of intervention and sterilization in the short run and the long run, in: R.N. Cooper et. al., eds., The international monetary system under flexible exchange rates: Global, regional, and national (Ballinger, Cambridge).

Kouri, P.J.K., 1976, The determinants of the forward premium, Memorandum no. 204, Center for Research in Economic Growth, Stanford University.

Kouri, P.J.K., 1982, Balance of payments and the foreign exchange market: A dynamic partial equilibrium model, in: J. Bhandari and B. Putnam, eds., The international transmission of economic disturbances under flexible exchange rates (MIT Press, Cambridge).

Loopesko, B.E., 1982, The role of current account imbalances in exchange rate determination: Competing hypotheses and empirical evidence, Columbia University, manuscript.

McCormick, F., 1979, Covered interest arbitrage: Unexploited profits? Comment, Journal of Political Economy 87, 411-417.

Marston, R.C., 1980, Cross country effects of sterilization, reserve currencies, and foreign exchange intervention, Journal of International Economics 10, 63-78.

Martin, J., and P. Masson, 1979, Exchange rates and portfolio balance, Working Paper no. 377, National Bureau of Economic Research.

Mundell, R.A., 1968, International economics (Macmillan, New York).

Mussa, M., 1981, The role of official intervention, Group of Thirty Occasional Papers no. 6 (Group of Thirty, New York).

Obstfeld, M., 1980, Imperfect asset substitutability and monetary policy under fixed exchange rates, Journal of International Economics 10, 177-200.

Obstfeld, M., 1982a, Can we sterilize? Theory and evidence, American Economic Review Papers and Proceedings 72, 45-50.

Obstfeld, M., 1982b, The capitalization of income streams and the effects of open-market policy under fixed exchange rates, Journal of Monetary Economics 9, 87-98.

Porter, M.G., 1977, The exchange rate and portfolio equilibrium, Seminar Paper no. 62, Monash University.

Porter, M.G., 1979, A portfolio model of exchange rate behavior--Results for eight currencies, Yale University, manuscript.

Schlesinger, H., and H. Bockelmann, 1973, Monetary policy in the Federal Republic of Germany, in: K. Holbik, ed., Monetary policy in twelve industrial countries (Federal Reserve Bank of Boston, Boston).

Stulz, R.M., 1982, The forward exchange rate and macroeconomics, Journal of International Economics 12, 285-299.

Tobin, J., 1969, A general equilibrium approach to monetary theory, Journal of Money, Credit and Banking 1, 15-29.

Tobin, J., and J.B. de Macedo, 1981, The short-run macroeconomics of floating exchange rates: An exposition, in: J. Chipman and C. Kindleberger, eds., Flexible exchange rates and the balance of payments: Essays in memory of Egon Sohmen (North-Holland, Amsterdam).