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# STERILIZATION AND THE OFFSETTING CAPITAL MOVEMENTS: EVIDENCE FROM WEST GERMANY, 1960-1970

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## ABSTRACT

The purpose of this paper is twofold. First, to estimate, using structural methods, the extent to which capital flows undermined West German monetary policy during the Bretton Woods years 1960 to 1970. And second, to show that earlier reduced form estimates of the capital-account offset coefficient are tainted by simultaneity bias thanks to the Deutsche Bundesbank's systematic policy of sterilization, and so overestimate the true coefficient. The paper distinguishes between the short-run or one-quarter offset coefficient and the long-run coefficient implied by the full adjustment of all asset markets. An aggregative structural model German financial markets yields short-run coefficients between .50 and .65 implying substantial Bundesbank control over the monetary base, at least in the short-run. A formal test for simultaneous-equations bias provides evidence that variations in domestic credit cannot be regarded as exogenous and that equations regressing capital flows on changes in domestic credit and other variables exaggerate the extent of the offset.

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## Introduction

An ability to sterilize or neutralize balance-of-payments disturbances in the short run is a prerequisite for the effective conduct of monetary policy in an open economy with fixed exchange rate. Even when assets denominated in different currencies are imperfect substitutes, sterilization operations may succeed only temporarily. But as the interest sensitivity of international capital movements increases, domestic monetary policy tends to become powerless. A high degree of international financial integration entails a powerful capital-account response to changes in domestic interest rates and thus substantial volatility in international reserves.

This essay attempts to estimate the extent to which the integration of the Atlantic community's financial markets undermined West Germany's ability to conduct an independent monetary policy during the years between 1960 and 1970.[1] The pioneers in this area of empirical research were Argy, Kouri, and Porter, who claimed a 'reduced-form' approach to the problem would yield clear-cut results while avoiding

[1] See Emminger (1977) for a policy-maker's account of this period.

the difficulties of structural estimation.[2] The reduced-form approach has led to a bewildering range of estimates of the 'offset coefficient', which measures the fraction of any domestic monetary expansion offset by capital outflow during the same quarter. Table 1 presents a sample of these estimates, which range from roughly 50 percent to almost 90 percent.

With the exception of the Argy-Kouri study -- which, significantly, yields the lowest offset estimate -- these reduced-form studies treat domestic monetary policy as an exogenous determinant of capital movements. They thus ignore the negative correlation between changes in the Bundesbank's domestic and foreign assets arising through systematic sterilization operations, and so introduce a potential simultaneous-equations bias into their results. These suspicions appear to be confirmed by a detailed econometric model of the West German financial sector constructed by Herring and Marston (1977). Simulation of the Herring-Marston model indicates an offset coefficient similar

[2] Their work includes Porter (1972), Argy and Kouri (1974), Kouri and Porter (1974), and Kouri (1975). The seminal paper by Willms (1971) sparked much of the interest in the econometric analysis of sterilization policies.

Table 1

Estimates of the Offset Coefficient for West Germany

| Author | Period | Dependent Variable | Offset Coefficient |
|---|---|---|---|
| Argy and Kouri (1974) | 1963:III -1970:IV | Total capital flows | 0.47 (0.24) |
| Kouri and Porter (1974) | 1960:I-1970:IV | Total capital flows | 0.77 (0.04) |
| Kouri and Porter (1974) | 1960:I-1970:IV | Short-term capital flows | 0.77 (0.05) |
| Kouri (1975) | 1960:I-1972:II | Total capital flows | 0.70 (0.04) |
| Neumann (1978) | 1960:I-1972:II | Total capital flows | 0.88 (0.06) |
| Neumann (1978) | 1961:III -1968:II | Short-term capital flows | 0.53* |

* Standard error not reported.

to those found by Kouri and Porter (1974). But the Herring-Marston offset coefficient is a long-run coefficient: because asset markets adjust gradually, the capital-account response to monetary policy is drawn out over a period of sixteen quarters. These findings suggest that the simultaneity bias in the Kouri-Porter approach exaggerates the magnitude of the one-quarter or short-run offset.

This essay presents additional evidence that the degree to which the monetary measures of the German Bundesbank were undermined by interest-sensitive capital movements during the years 1960-1970 is much smaller than the reduced-form estimates suggest. We distinguish below between the short-run offset coefficient, which measures the reserve loss associated with a monetary expansion in the same quarter, and the long-run offset coefficient, which applies only after asset markets have adjusted fully to the monetary disturbance. While the exact values of the offset coefficients vary from quarter to quarter because of changes in banks' reserve requirements, we find the typical short-run offset coefficient to be between .10 and .15, with the typical long-run offset between .50 and .65. The offsets are derived from a small quarterly econometric model, and are consistent with the findings of Herring and Marston (1977). They imply that the Bundesbank exercised substantial control over the German money stock during the Bretton Woods period, at least in the short run.

Section I presents a highly aggregative model of the financial sector of a small open economy with fixed exchange rate whose bonds are imperfect substitutes for foreign-currency bonds in asset-holders' portfolios. We derive three structural equations determining equilibrium values of the domestic interest rate, the money stock, and the stock of net external liabilities. The approach differs from that of Herring and Marston in that the structure of our model (including the lag structure) is simple enough to allow explicit calculation of short- and long-run offsets.

Section II closes the model by recognizing that the central bank's monetary policy is endogenous. We specify and estimate a monetary policy reaction function which confirms previous findings that the Bundesbank consistently sterilized changes in its foreign assets. Our measure of the impact of changes in reserve requirements on the monetary base is different from the measure proposed by Porter (1972) and used in all of the subsequent literature.

Section III presents the results of estimating the asset-demand equations, together with the implied short-run and long-run offset coefficients. These are computed as the equilibrium response of the stock of net external liabilities to a change in the domestic assets of the Bundesbank, using first short-run and then long-run elasticities. As mentioned above, the short-run coefficients are much smaller than any appearing in the existing literature on offsetting capital movements.

In Section IV we undertake a direct examination of the Kouri-Porter approach for the presence of simultaneity bias, first showing that such a bias always increases the estimated offset. Using a test suggested by Hausman (1978), we find that we can reject the hypothesis that monetary policy is exogenous in equations explaining total and short-term capital flows. This finding lends support to the offset figures computed in Section III.

Section V offers concluding remarks. In addition, there are two appendices. Appendix I derives the asymptotic bias in the reduced-form approach, while Appendix II describes the data series used in estimation.

## I. A Model of the West German Financial Sector

This section presents a highly aggregative model of financial asset markets in a small, open economy with a fixed exchange rate. The model differs from that of Kouri and Porter (1974) only in allowing for a domestic banking system.[3] By postulating gradual adjustment of asset stocks to desired levels -- a formulation that does not preclude instantaneous portfolio equilibrium -- we derive structural equations suitable for estimation.

The main building blocks are the domestic money market and a market in internationally-traded, interest-bearing claims. These markets jointly determine equilibrium values of the money stock, the domestic interest rate, and the stock of net liabilities vis-à-vis the rest of the world. The description of the central bank's policy reaction function, needed to close the model, is taken up in the next section.

### A. The International Bond Market

We assume that capital is imperfectly mobile, in the sense that bonds denominated in domestic currency (Deutsche Marks) and bonds denominated in foreign

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[3] The present model is nearly identical to one of Dornbusch (1977).

currency (dollars) are imperfect substitutes. The interest rate on dollar-denominated bonds is $r^*$, and is exogenous to the West German economy. Foreign residents' long-run desired holdings of D-Mark denominated bonds are a function $\overline{F}(r,r^*,Y^*,V^*)$ of rates of return ($r$ and $r^*$), income ($Y^*$), and wealth ($V^*$). Here, $r$ is the domestic bond rate; the function $\overline{F}$ is expressed in dollar terms. Likewise, domestic residents' desired holdings of dollar assets, in D-Mark terms, is a function $\overline{H}(r,r^*,Y,V)$ of interest rates, domestic income ($Y$), and domestic financial wealth ($V$). The long-run equilibrium level of net external liabilities, in terms of D-Marks, can be expressed as

$$\overline{NEL} = s\overline{F}(r,r^*,Y^*,V^*) - \overline{H}(r,r^*,Y,V) \qquad (1)$$

where $s$ is the D-Mark/dollar spot exchange rate. Capital flows arise as changes in the stock of net external liabilities.

We adopt the assumption that asset-holders abroad and at home adjust their holdings of foreign assets toward their long-run equilibrium levels at the same rate $\lambda$, so that if $F$ and $H$ denote actual -- as opposed to desired -- asset holdings, we have

$$F - F_{-1} = \lambda(\overline{F} - F_{-1}),$$

$$H - H_{-1} = \lambda(\overline{H} - H_{-1}) .$$

These, together with (1), imply the relation

$$NEL = \lambda(s\overline{F} - \overline{H}) + (1 - \lambda)NEL_{-1}. \qquad (2)$$

Linearizing (2), we obtain our structural equation for the stock of German net external liabilities:

$$NEL = a_1 + a_2 r + a_3 r^* + a_4 E + a_5 Y \qquad (3)$$

$$+ a_6 V + a_7 NEL_{-1} + \mu_1 .$$

In this specification, E represents a set of dummy variables corresponding to the speculative episodes of 1968:IV - 1969:IV, while foreign income and wealth have been dropped because of non-availability of data.

Portfolio theory predicts that $a_2 > 0$, for a rise in domestic interest rates leads to a capital inflow -- an increase in net foreign liabilities. Similarly, an increase in the foreign rate induces asset-holders to augment their holdings of dollar-denominated bonds, and so $a_3 < 0$. A rise in nominal income increases the transactions demand for money, and NEL rises as foreign assets are sold off to meet this demand, so that $a_5 > 0$. Finally, we expect $a_6 < 0$, and $a_7 = 1 - \lambda > 0$.

## B. Money Demand

The monetary sector is described by a money demand equation and a money supply equation.

The money demand equation assumes that long-run desired real money holdings $\overline{M}/P$ are a function of the domestic interest rate, real income, and real wealth:

$$\overline{M}/P = \overline{L}(r, Y/P, V/P) \quad . \qquad (4)$$

P is taken to be the consumer price index. Denoting deflated nominal variables by lower-case letters, we assume that wealth owners adjust actual real balances to desired real balances according to the partial adjustment rule

$$m - m_{-1} = \gamma(\overline{m} - m_{-1}) \quad .$$

Linearizing, we obtain the structural specification

$$m = b_1 + b_2 r + b_3 y + b_4 v + b_5 m_{-1} + \mu_2 \qquad (5)$$

which is similar to the one adopted by Modigliani, Rasche, and Cooper (1970) in their study of money demand in the U.S. Our expectation is that $b_2 < 0$, $b_3$ and $b_4 > 0$, and $b_5 = 1 - \gamma > 0$.

## C. Money Supply

Turning to the supply side, we hypothesize that the banking system's long-run desired money supply can be written as a function of the difference between the domestic interest rate and the central bank discount rate $\delta$ and the real monetary base, BA/P:

$$\overline{M}/P = \sigma(r-\delta, BA/P) .$$

As explained in the next section, we work in this paper with a monetary base series BA adjusted to reflect changes in reserve requirements. This allows us to avoid explicit consideration of the deposit multiplier.

As before, we assume banks adjust the money supply toward its long-run equilibrium level according to the rule

$$m - m_{-1} = \mu(\overline{m} - m_{-1}) . \qquad (6)$$

Taking a linear approximation to $\sigma$, we obtain the structural equation

$$m = c_1 + c_2(r - \delta) + c_3 ba + c_4 m_{-1} + \mu_3 . \qquad (7)$$

Theory predicts that $c_2$ and $c_3 > 0$. Also, $c_4 = 1 - \mu > 0$.

## II. The Reaction Function of the Monetary Authority

This section describes and estimates a monetary policy reaction function for the Bundesbank. The non-exogeneity of Bundesbank monetary policy was recognized in the original work on sterilization by Argy and Kouri (1974), but essentially ignored in subsequent work by Kouri and Porter (1974), Kouri (1975), Kohlhagen (1977), Neumann (1978), and others. Obviously, knowledge of the German monetary authority's behavior during the 1960s, and its role in the breakdown of the Bretton Woods system, is useful in itself. But there is also the econometric issue that parameter estimates for models of the West German financial sector will in general be inconsistent if monetary policy is falsely taken to be exogenous.

Following Argy and Kouri (1974) and Herring and Marston (1977), we take the position that Bundesbank monetary policy can be modelled as a function of a small number of targets, internal and external. In view of the large number of instruments available to the central bank -- minimum reserve policy, discount policy, open market policy, and others -- a major obstacle to estimation of such a function is the definition of a sufficiently comprehensive numerical measure of monetary policy to serve as the dependent variable.[4] This essay proposes a measure of monetary policy different from the one prevalent in the literature on neutralization and offsetting capital flows.[5]

Because of its limited holdings of domestic debt. the Bundesbank, during the period of this study, used changes in reserve requirements as its primary instrument of monetary control. Direct changes in the domestic assets of the central bank, including changes in the volume of discounting and the level of official deposits, played only secondary roles. For this reason, empirical studies of Bundesbank policy have always recognized the need for a measure of the impact of required reserve changes on the money supply.

Porter (1972), who initiated the empirical study of offsetting capital movements, approached the problem by asking what increase in the foreign assets of the central bank would have to occur after an increase in reserve requirements to completely offset that policy's

[4] On Bundesbank policy, see Schlesinger and Bockelmann (1973) and Organisation for Economic Co-operation and Development (1973). The latter contains an excellent chronology of central bank monetary measures during the period under study here.

[5] The problems raised by capital controls, 100 percent reserve requirements on foreign deposits, and similar measures are discussed in the next section.

impact on the money stock. Neglecting the influence of the currency-deposit ratio, we need only find $\Delta B$ such that

$$\frac{B + \Delta B}{\alpha} = \frac{B}{\alpha_{-1}} ,$$

where $\alpha$ is the new required reserve ratio. If $D = B/\alpha_{-1}$ is the level of deposits before the change in the reserve ratio, we can write $\Delta B$ as the change in required reserves, $(\alpha - \alpha_{-1})D$. This is the measure of monetary policy that has been used in subsequent work in this area, and is surely the right one if one's goal is to calculate a summary, reduced-form offset coefficient.

But it is harder to argue that monetary policy-makers think in these terms, and that this measure of the magnitude of minimum reserve policy therefore belongs on the left-hand side of a reaction function. Policy-makers are more likely to ask what change in the monetary base, given the existing reserve ratio, is equivalent in its impact on the money supply to a contemplated change in reserve requirements. Neglecting currency once again, the change in the base, $\Delta\tilde{B}$, equivalent to a change in the reserve ratio from $\alpha_{-1}$ to $\alpha$ is given by

$$\frac{B + \Delta\tilde{B}}{\alpha_{-1}} = \frac{B}{\alpha},$$

or $\Delta\tilde{B} = [(\alpha_{-1}/\alpha)-1]B$. We adopt this as our measure of the change in monetary policy associated with a change in required reserves.

In applying this measure, we are, in effect, systematically redefining the base each period so as to hold reserve requirements constant at their initial level, $\alpha_0$. Let DACB denote the net domestic assets of the central bank, FACB its net foreign assets, and let $\theta_{t-1} = \alpha_0/\alpha_{t-1}$. We define the adjusted base BA -- that is, the monetary base adjusted to reflect the assumption of a constant required reserve ratio $\alpha_0$ -- by

$$BA_t = BA_{t-1} + \theta_{t-1}\Delta FACB_t + \Delta MP_t \quad , \qquad (8)$$

where $\Delta MP_t = \Delta\tilde{B}_t + \theta_{t-1}\Delta DACB_t$. $\Delta MP$ is just the policy-induced change in the adjusted base, and is taken to be the dependent variable in the Bundesbank's reaction function.[6] We note that $\Delta FACB = \Delta NEL + CAB$, where CAB

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[6] Like all other variables, the base is measured at the end of each quarter. Since reserve requirement changes are announced at the beginning of each month, we take $\alpha_t$ to be the average reserve requirement announced in the last month of each quarter in the actual estimation. Note that $\Delta\tilde{B}_t = [\frac{\alpha_0}{\alpha_t} - \frac{\alpha_0}{\alpha_{t-1}}]B_t = [\frac{\alpha_{t-1}}{\alpha_t} - 1]\frac{\alpha_0}{\alpha_{t-1}} B_t$, where $B_t$ is the unadjusted base.

is the current-account balance.

We hypothesize that the reaction function has the form

$$\Delta MP = d_1 + d_2\theta_{-1}(\Delta FACB) + d_3\hat{O}_{-1} + d_4\hat{P}_{-1} + d_5S1 + d_6S4 + \mu_4 , \quad (9)$$

where $\hat{P}$ and $\hat{O}$ are the quarter-to-quarter percentage changes in the price level and manufacturing orders, respectively, and S1 and S4 are seasonal dummies for the first and fourth quarters. The coefficient $d_2$ is the sterilization coefficient, which measures the extent to which the Bundesbank attempts to neutralize the money creation resulting from its foreign exchange intervention through countervailing domestic monetary measures.[7] The price and activity variables are intended to capture the influence of domestic cyclical factors on monetary policy, and their coefficients should be negative.

During much of the period with which we deal, the Bundesbank offered domestic banks forward cover at preferential rates as an inducement to hold foreign

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[7] Of course, $d_2 < 0$ when a policy of sterilization is pursued. A positive value of $d_2$ would be evidence of a monetary policy aimed at external -- rather than internal -- balance.

rather than domestic assets. These forward swap arrangements were a useful tool from the standpoint of domestic monetary control, for by increasing the level of swap contracts outstanding, the Bundesbank was able to bring about a decrease in its net foreign assets.[8] Because these swaps assumed massive proportions relative to the monetary base in some quarters, they must be included in any assessment of central bank policy.

While the Bundesbank quoted swap rates rather than directly choosing a desired volume of swap contracts, we assume that, during the course of any quarter, it was able to vary the swap rate so as to elicit the desired quantitative response from domestic banks. This allows us to redefine our measure ΔMP of monetary policy as the sum of reserve requirement changes, changes in the Bundesbank's net domestic asset holdings, and changes in the level of forward swap commitments, ΔSWP:

$$\Delta MP_t = \Delta\tilde{B}_t + \Theta_{t-1}(\Delta DACB_t - \Delta SWP_t) . \quad (10)$$

Recognition that the swaps are a policy-induced component of net external liabilities entails an adjustment of that series. We accomplish this adjustment by redefin-

[8] For a discussion of swap policy, see Brehmer (1964).

ing NEL as the sum of total net external liabilities and outstanding swap commitments of the central bank at the end of each quarter.

Taking the current account CAB to be exogenous and using it as an instrument for ΔFACB, we obtain the following estimate of the reaction function (9) over the period 1960:I to 1972:II:

$$\Delta MP = \underset{(1.535)}{3.243} - \underset{(0.444)}{1.379}\theta_{-1}(\Delta FACB) - \underset{(0.218)}{0.522}\,\hat{O}_{-1} -$$

$$\underset{(0.779)}{0.737}\,\hat{P}_{-1} - \underset{(2.007)}{3.881}\,S1 + \underset{(1.931)}{1.893}\,S4$$

Standard error = 4.606; Durbin-Watson statistic = 2.19.

All coefficients have the expected signs. The equation provides strong evidence that the Bundesbank pursued a policy of systematic sterilization; the estimated sterilization coefficient is not significantly different from -1. The implication is that monetary policy is indeed endogenous, and should be treated as such in econometric estimation.

## III. The Offset to Monetary Policy

This section presents estimates of the three asset-demand equations described in Section I, and uses them to calculate the offset to monetary policy in the short-run and in the long run. All equations are estimated by two-stage least squares. We assume that changes in real variables have an immediate impact on financial markets, but that financial disturbances influence the level of economic activity only after some time has elapsed. We thus assume that income, the price level, wealth, and the current-account balance may be used as instruments. In addition, we use as instruments the foreign interest rate, the central-bank discount rate, the exogenous variables in the policy reaction function, GOVDEP (the level of government deposits at the Bundesbank), and GOVMON (government holdings of money M2). The data series are described in detail in Appendix II.

Our period of estimation is 1960:I to 1970:IV. Although the exchange value of the Deutsche Mark was pegged in 1971:I and again between the Smithsonian re-alignment of December 1971 and the crisis of February-March 1973, the starting point of the current period of managed floating, there seemed to be little to gain from including this particularly turbulent period in our sample.

We discuss each equation in turn.[9]

A. Net External Liabilities

We obtain the following estimate of the equation explaining net external liabilities:

$$\begin{aligned} NEL/P = & -6.540 + 0.842\ r - 1.556\ r^{*} + \\ & \ (3.039)\quad (0.371)\qquad (0.659) \\ & 0.024\ Y/P + 0.888\ NEL_{-1}/P_{-1} + \\ & (0.011)\qquad (0.067) \\ & 4.299\ D1 - 6.410\ D2 + 6.203\ D3 + \\ & (2.582)\qquad (3.008)\qquad (3.771) \\ & 8.912\ D4 - 9.416\ D5 \\ & (3.413)\qquad (3.225) \end{aligned}$$

Standard error = 2.286; Durbin-Watson statistic = 2.24.

[9] The h-statistic of Durbin was used to test for first-order serial correlation. While the asymptotic distribution of h is not standard normal in a simultaneous-equations context, it can be shown (see Godfrey (1978)) that if all instruments are exogenous, h is asymptotically normal with variance exceeding 1. This means that if we treat h as N(0,1), we are more likely to reject the hypothesis of no serial correlation. Lagged endogenous variables were not used as instruments to obtain the estimates of this section, as a precaution against more complicated forms of time-dependence in the equation residuals. In all three cases the h-statistic was less than 1 in absolute value, giving no grounds for rejecting the hypothesis of no first-order serial correlation.

Note that nominal variables have been deflated by the price level. The variables Di (i = 1,...,5) are dummies for each of the five turbulent quarters 1968:IV - 1969:IV. As explained in the previous section, NEL has been corrected for forward swap commitments of the Bundesbank.

The parameter estimates for this equation support the portfolio-balance theory. Only the coefficient of wealth was insignificantly different from zero, leading us to exclude it from the equation. The other coefficients are significant at the 5 percent level and are correctly signed.

A striking feature of the equation is the significant positive coefficient of income, indicating that a DM 1 billion rise in income (at an annual rate) leads German asset owners to repatriate DM 24 million to satisfy their increased desire for real balances. The lagged endogenous variable has a high coefficient, implying a rather slow adjustment speed of only about 11 percent per quarter.

The aggregate measure of monetary policy appearing on the left-hand side of the reaction function in (9) does not account for the effects of the sharper policy weapons deployed in an effort to discourage capital inflows rather than offset their effects on the money supply. The chief omissions are the high (at times 100 percent) marginal reserve requirements imposed on foreign-owned deposits and prohibitions on interest payments to foreigners.

Our justification for ignoring these measures in the equation for net external liabilities is that they could be, and in fact were, circumvented quite easily.[10] Thus, at the level of aggregation we have adopted, we would expect their effects to be negligible. This view is supported by a recent study on German capital controls by Hewson and Sakakibara (1977).

B. Money Demand

The money demand equation uses M2 as dependent variable. Two-stage least squares yields the estimate:

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[10] For example, Hewson and Sakakibara (1977) point out that 'A typical approach to circumventing the minimum reserve requirement was that German banks would transfer loan business vis-à-vis German residents to the books of their foreign branches. As a result German (nonbank) residents would incur liabilities to the foreign branches of German banks, and since neither these foreign branches (which legally are classified as nonresidents) nor domestic nonbank customers were subject to the minimum reserve requirement, German banks were able to circumvent the control without any loss of business. The notable expansion of the foreign branch activities of German banks throughout this period suggests the widespread use of this loophole.' The loophole was closed only in 1972 when minimum reserve requirements were imposed on nonbanks' foreign borrowings.

$$m = -69.838 - 0.289\, r + 0.229\, y + \underset{(13.831)\ (0.452)\ \ (0.049)}{}$$

$$0.654\, v + 0.496\, m_{-1}$$
$$(0.140)\quad (0.107)$$

Standard error = 4.116, Durbin-Watson statistic = 2.16.

The coefficient of the domestic interest rate, while having the correct sign, is small and insignificant at the 5 percent level. This is probably due to the fact that M2 contains some interest-bearing assets.

Both real income and real wealth have highly significant positive coefficients, however. As we would expect, an increase in either of these variables raises the demand for real cash balances. The speed of adjustment is roughly 50 percent per quarter, quite rapid by the standards of quarterly money demand equations.

C. Money Supply

The estimated money supply equation is

$$m = -4.501 + 3.252\, (r - \delta) + 0.450\, ba +$$
$$(3.126)\ (1.438)\qquad\qquad (0.146)$$

$$0.907\, m_{-1}$$
$$(0.039)$$

Standard error = 5.176, Durbin-Watson

statistic = 1.90.

The estimated coefficients for this equation have the signs predicted by theory. An increase in the domestic interbank rate increases money supply, while an increase in the Bundesbank discount rate causes banks to restrict lending. A rise in the adjusted base, of course, leads to an expansion of the money supply.

However, the coefficient of lagged money is probably too high: the implied speed of adjustment of the money supply to its long-run equilibrium level is only about 10 percent per quarter, far too low to be believable.

D. Offset Coefficients

We now use the simple econometric model we have estimated to derive the short- and long-run offsets to monetary policy. This is done by computing the total derivative of the stock of net external liabilities, NEL, with respect to DACB, the net domestic assets of the Bundesbank. In computing the long-run offset coefficients, we use the long-run derivatives implied by the asset demand equations' speeds of adjustment to steady-state equilibrium.

Differentiating the system consisting of equations (3), (5), (7), and the identity

$$BA = \Theta(FACB + DACB)$$

yields the total derivative

$$\frac{dNEL}{dDACB} = \frac{\Theta a_2 c_3}{(b_2 - c_2) - \Theta a_2 c_3}$$

The capital outflow resulting from an open market purchase is just equal to the resulting decrease in net external liabilities. Thus, -dNEL/dDACB is precisely the short-run offset coefficient. We see that it will not be the same in each quarter, for it depends on the level of reserve requirements. The offset becomes complete, of course, as $a_2$, which measures the interest-sensitivity of capital movements, becomes infinite.[11]

To compute the long-run offset, we replace the short-run derivatives in the above expression with the corresponding long-run derivatives $\bar{a}_2 = a_2/(1-a_7)$, $\bar{b}_2 = b_2/(1-b_5)$, $\bar{c}_2 = c_2/(1-c_4)$, and $\bar{c}_3 = c_3/(1-c_4)$. The two sets of offset coefficients are reported in Tables 2a and 2b.

The short-run offset coefficients are remarkably small when compared with those appearing in the literature and generally accepted. The highest is only 15.5 percent, implying that the Bundesbank had to purchase

[11] Note that the offset is also complete when $b_2 = c_2 = 0$. Thus a unit offset is in theory consistent with full central-bank control over the domestic interest rate.

Table 2a

Short-Run Offset Coefficients

| | | | |
|---|---|---|---|
| 1960 I | 0.078 | 1965 III | 0.102 |
| 1960 II | 0.072 | 1965 IV | 0.106 |
| 1960 III | 0.070 | 1966 I | 0.103 |
| 1960 IV | 0.072 | 1966 II | 0.103 |
| 1961 I | 0.080 | 1966 III | 0.104 |
| 1961 II | 0.089 | 1966 IV | 0.109 |
| 1961 III | 0.100 | 1967 I | 0.120 |
| 1961 IV | 0.106 | 1967 II | 0.126 |
| 1962 I | 0.109 | 1967 III | 0.152 |
| 1962 II | 0.109 | 1967 IV | 0.152 |
| 1962 III | 0.109 | 1968 I | 0.152 |
| 1962 IV | 0.109 | 1968 II | 0.152 |
| 1963 I | 0.110 | 1968 III | 0.155 |
| 1963 II | 0.110 | 1968 IV | 0.143 |
| 1963 III | 0.110 | 1969 I | 0.148 |
| 1963 IV | 0.110 | 1969 II | 0.123 |
| 1964 I | 0.111 | 1969 III | 0.118 |
| 1964 II | 0.110 | 1969 IV | 0.143 |
| 1964 III | 0.101 | 1970 I | 0.133 |
| 1964 IV | 0.101 | 1970 II | 0.131 |
| 1965 I | 0.102 | 1970 III | 0.104 |
| 1965 II | 0.102 | 1970 IV | 0.102 |

Table 2b

Long-Run Offset Coefficients

| | | | |
|---|---|---|---|
| 1960 I | 0.448 | 1965 III | 0.520 |
| 1960 II | 0.425 | 1965 IV | 0.532 |
| 1960 III | 0.419 | 1966 I | 0.523 |
| 1960 IV | 0.425 | 1966 II | 0.523 |
| 1961 I | 0.453 | 1966 III | 0.526 |
| 1961 II | 0.481 | 1966 IV | 0.538 |
| 1961 III | 0.514 | 1967 I | 0.565 |
| 1961 IV | 0.532 | 1967 II | 0.580 |
| 1962 I | 0.538 | 1967 III | 0.632 |
| 1962 II | 0.538 | 1967 IV | 0.632 |
| 1962 III | 0.538 | 1968 I | 0.632 |
| 1962 IV | 0.538 | 1968 II | 0.632 |
| 1963 I | 0.542 | 1968 III | 0.636 |
| 1963 II | 0.542 | 1968 IV | 0.615 |
| 1963 III | 0.542 | 1969 I | 0.623 |
| 1963 IV | 0.542 | 1969 II | 0.572 |
| 1964 I | 0.545 | 1969 III | 0.562 |
| 1964 II | 0.542 | 1969 IV | 0.615 |
| 1964 III | 0.517 | 1970 I | 0.595 |
| 1964 IV | 0.517 | 1970 II | 0.591 |
| 1965 I | 0.520 | 1970 III | 0.526 |
| 1965 II | 0.520 | 1970 IV | 0.520 |

DM 1.18 billion in domestic assets to increase the base by DM 1 billion in that quarter. As asset markets are given time to adjust, however, the offset increases: the long-run coefficients reported in Table 2b are substantial. The highest, 63.6 percent, implies that an open market purchase of DM 2.75 billion was required to bring about a permanent DM 1 billion increase in the monetary base. In general, the long-run offset figures are somewhat lower, in the neighborhood of 50 to 55 percent.

The results reported here suggest that the Bundesbank had ample leeway to conduct an independent monetary policy over a short horizon during the Bretton Woods period. In the long run, the cost of an independent policy, measured in terms of reserve volatility, appears to have been greater. But our findings indicate the short-term constraints were not nearly as severe as suggested by reduced-form estimates of the offset coefficient.

## IV. Simultaneity Bias and the Reduced-Form Approach

Although the long-run offset coefficient implied by the simple structural model estimated in the previous section is substantial, the implied short-run offset coefficient is very small compared to those reported in Table 1. How can we explain the enormous discrepancy between our results and those obtained through the reduced-form method? We shall argue in this section that existing estimates of the reduced-form offset coefficient for Germany, particularly those presented by Kouri and Porter (1974) and Kouri (1975), reflect in large part the correlation between monetary policy and capital flows arising from the sterilization policies of the central bank rather than the true capital-account response to domestic monetary policy. This reasoning is borne out by a formal test for simultaneity bias.

Returning to the notation of Section I, we follow Kouri and Porter and express total capital flows as

$$TCF = s\Delta F(r, r^{*}, Y^{*}, V^{*}) - \Delta H(r, r^{*}, Y, V) \quad (11)$$

where adjustment lags have been ignored. Abstracting from the money supply process, we can express the domestic interest rate r in terms of exogenous variables and the monetary base. This allows us to write the capital-flow equation in 'reduced form' as

$$TCF = \alpha_1 + \alpha_2 \Delta r^* + \alpha_3 \Delta Y + \alpha_4 \Delta MP + \alpha_5 CAB + \alpha_6 \Delta S4 + \alpha_7 \Delta E + u$$

where $\Delta MP$ is now the change in monetary policy defined in Porter's (1972) sense as the increase in the Bundesbank's net domestic assets minus the increase in required reserves, $S4$ is the seasonal dummy for the fourth quarter, and speculative exchange-rate expectations $E$ are represented by exogenous dummy variables. (Wealth and foreign income variables are dropped.)

The problem with this equation is that it contains $\Delta MP$, which, as we have seen, is endogenous, thanks to the central bank's sterilization policies. In other words, there exists a reaction function having the form

$$\Delta MP = \beta(TCF + \dot{C}AB) + \Delta Z\delta + v ,$$

where the variables $Z$ are exogenous targets of monetary policy. This raises the issue of the consistency of the ordinary least squares estimator, which is used by Kouri and Porter to estimate the capital-flow equation. But it also raises the issue of identifiability, for the capital-flow equation will be unidentified unless $\delta$ differs significantly from zero. We should not be too complacent on this score, for the evidence, both statistical and anecdotal, indicates that while the Bundesbank's response to foreign money inflows was stable and strong, its response to cyclical developments was weaker and more erratic.

Assuming identification, we turn to the question of bias. Denoting the offset coefficient by $\alpha$, we can write the capital-flow 'reduced form' as $TCF = \alpha \Delta MP + \Delta X\gamma + u$, where the X are exogenous, and can show (assuming $E[u'v] = 0$) that[12]

$$\text{plim } \hat{\alpha}_{OLS} = \alpha + \frac{\beta\sigma_u^2(1 - \alpha\beta)}{\beta^2\sigma_u^2 + \sigma_v^2 + Q} . \qquad (12)$$

Here, $Q = \text{plim}\left[ \frac{\delta'\Delta Z'(I - \Delta X(\Delta X'\Delta X)^{-1}\Delta X')\Delta Z\delta}{T} \right]$ and is small when the influence of the exogenous targets Z on monetary policy is weak. On the assumption that Q is indeed small and that the unexplained volatility of capital movements is much greater that that of monetary policy (so that $\sigma_u^2 >> \sigma_v^2$), we see that $\text{plim } \hat{\alpha}_{OLS} = \alpha + 1/\beta - \alpha = 1/\beta$. If, as our evidence indicates, sterilization is complete, the OLS estimate of the offset coefficient will be biased toward -1 when the variance of u is high, and will thus reflect the behavior of the central bank rather than that of private asset-holders.

[12] Formula (12) is derived in Appendix I. Note that the condition $E[u'v] = 0$ guarantees the identifiability of the reduced-form capital-flow equation's parameters.

Kouri and Porter argue that a reduction in the OLS bias can be achieved through addition to the equation of the expectational dummy variables, which assume non-zero values during speculative episodes when the reduced form predicts badly. This argument makes little sense, for while addition of dummies reduces the sample variance, the probability limit in (12) is calculated on the assumption of homoscedastic errors. To see whether the dummies do reduce the bias in the offset coefficient, we have estimated Kouri-Porter capital flow equations with and without dummy variables over our sample period, 1960:I to 1970:IV. In Table 3 we present results of estimation for both the total capital-flow equation (11) and the short-term capital-flow (STCF) equation explaining international loans maturing in less than a year; the latter differs from (11) only in that CABLTC, the sum of the current account and the long-term capital account, replaces CAB on the right-hand side.[13] The estimated offset coefficients in both sets of equations are very close -- in the neighborhood of 1 for the capital account as a whole and near .9 for short-term flows.

[13] Of course, treatment of the long-term capital account as exogenous in the equation for short-term capital movements introduces another possible source of simultaneity bias. We return to this issue below. Equations in Table 3 have been corrected for a first-order moving average error process $u = \eta - \rho\eta_{-1}$.

Table 3

The Reduced-Form Capital-Flow Equation, 1960:I-1970:IV

| Dependent Variable | Constant | $\Delta r^*$ | $\Delta Y$ | $\Delta MP$ | CAB | CABLTC | $\Delta S4$ | SPEC1 | SPEC2 | SPEC3 |
|---|---|---|---|---|---|---|---|---|---|---|
| TCF | 0.681 | -0.050 | 0.013 | -0.986 | -0.950 | ------ | 2.461 | 0.079 | 1.786 | 0.332 |
| | (0.068) | (0.139) | (0.007) | (0.030) | (0.022) | | (0.255) | (0.767) | (0.849) | (0.610) |
| | Standard error = 0.731; Durbin-Watson statistic = 2.14; $\hat{\rho}$(MA(1)) = 1.000 | | | | | | | | | |
| TCF | 0.698 | -0.036 | 0.012 | -0.995 | -0.935 | ------ | 2.619 | ----- | ----- | ----- |
| | (0.056) | (0.115) | (0.006) | (0.029) | (0.020) | | (0.247) | | | |
| | Standard error = 0.745; Durbin-Watson statistic = 2.34; $\hat{\rho}$(MA(1)) = 1.000 | | | | | | | | | |
| STCF | 0.465 | -0.067 | 0.033 | -0.900 | ------ | -0.870 | 2.236 | -0.042 | 1.719 | 1.148 |
| | (0.132) | (0.154) | (0.013) | (0.051) | | (0.072) | (0.283) | (0.729) | (0.814) | (0.677) |
| | Standard error = 0.785; Durbin-Watson statistic = 2.10; $\hat{\rho}$(MA(1)) = 0.678 | | | | | | | | | |
| STCF | 0.416 | 0.085 | 0.040 | -0.933 | ------ | -0.866 | 2.450 | ----- | ----- | ----- |
| | (0.131) | (0.124) | (0.013) | (0.043) | | (0.065) | (0.293) | | | |
| | Standard error = 0.820; Durbin-Watson statistic = 2.19; $\hat{\rho}$(MA(1)) = 0.711 | | | | | | | | | |

Any reduction in bias is quite small.

It is possible, however, to make a convincing argument that the observations corresponding to speculative attacks are 'outliers' that play a large part in worsening the OLS bias. The simplest way to see if this is so is to drop the speculative periods from the sample. Rows (a) and (b) of Table 4 report the results of estimating the total and short-term capital-flow equations over the tranquil sub-period 1961:III to 1967:IV; they show that the observations from turbulent quarters do exert a preponderant influence on the estimated offset. The latter declines from nearly 100 percent to 55 percent for the TCF equation, and from 90 percent to 46 percent for the STCF equation. For the policy maker, the difference could not be more striking. In view of this large discrepancy, it hardly seems reasonable to take the view that the normal interest response of capital flows during the Bretton Woods period entailed a nearly complete offset to domestic monetary policy.

Of course, even these lower short-run offsets are much higher than those calculated in the previous section. But they are still biased if sterilization is systematic. To get some idea of the degree of bias, we estimate the 'reduced form' over the period 1961:III to 1967:IV by 2SLS, using the instruments suggested by the

Table 4

The Reduced-Form Capital-Flow Equation, 1961:III-1967:IV

| Method | Dependent Variable | Constant | $\Delta r^*$ | $\Delta Y$ | $\Delta MP$ | CAB | CABLTC | $\Delta S4$ | |
|---|---|---|---|---|---|---|---|---|---|
| OLS | TCF | 0.361 | -0.123 | 0.019 | -0.553 | -0.872 | ------ | 2.089 | (a) |
| | | (0.162) | (0.307) | (0.017) | (0.086) | (0.088) | | (0.261) | |
| | | Standard error = 0.562, Durbin-Watson statistic = 2.22 | | | | | | | |
| OLS | STCF | 0.259 | -0.085 | 0.014 | -0.455 | ------ | -0.765 | 1.761 | (b) |
| | | (0.148) | (0.275) | (0.015) | (0.082) | | (0.084) | (0.252) | |
| | | Standard error = 0.501, Durbin-Watson statistic = 2.23 | | | | | | | |
| 2SLS | TCF | 0.275 | -0.380 | -0.022 | 0.037 | -0.857 | ------ | 0.969 | (c) |
| | | (0.305) | (0.600) | (0.045) | (0.485) | (0.162) | | (0.922) | |
| | | Standard error = 1.027, Durbin-Watson statistic = 2.27 | | | | | | | |
| 2SLS | STCF | 0.208 | -0.145 | 0.004 | -0.263 | ------ | -0.695 | 1.364 | (d) |
| | | (0.181) | (0.320) | (0.023) | (0.278) | | (0.134) | (0.612) | |
| | | Standard error = 0.565; Durbin-Watson statistic = 2.12 | | | | | | | |

reaction function estimated above. The results appear in Rows (c) and (d) of Table 4. The coefficient of $\Delta MP$ in the total capital-flow equation is now slightly positive and not significantly different from zero. The estimated offset in the short-term capital flow equation falls to 26.3 percent, but the 2SLS variance is so high that the coefficient is not significant. 2SLS estimation thus seems to indicate that some simultaneity bias is still present.

We can test for the presence of such a bias using the specification test suggested by Hausman (1978). The basic idea of the test is to compare the difference between the OLS estimate $\hat{b}_{OLS}$ of the capital-flow equation's parameters, which is efficient under the null hypothesis of no simultaneity bias, and the 2SLS estimator $\hat{b}_{2SLS}$, which is consistent in the presence of simultaneity bias but inefficient when the null hypothesis is true. The appropriate metric for inference is given by the test statistic

$$(\hat{b}_{2SLS}-\hat{b}_{OLS})'[\mathrm{var}(\hat{b}_{2SLS})-\mathrm{var}(\hat{b}_{OLS})]^{-1}(\hat{b}_{2SLS}-\hat{b}_{OLS})$$

which is distributed asymptotically $\chi^2(6)$ under the null hypothesis.

Computation of this statistic would be laborious, but fortunately a simpler method of implementing the simultaneity test is available. Consider an equation

$$y = X_1\beta + X_2\gamma + \mu ,$$

where the $X_2$ are known to be uncorrelated with the error $\mu$ but the $X_1$ may be correlated. If Q is a set of instruments for $X_1$ and $\hat{X}_1 = Q(Q'Q)^{-1}Q'X_1$, we use OLS to estimate the parameters of the equation

$$y = X_1\beta + X_2\gamma + \hat{X}_1\alpha + \nu .$$

As Hausman (1978) shows, the standard F-test of the hypothesis $\alpha = 0$ is also the test for simultaneity bias.

We employ the second form of the Hausman test to test for the presence of simultaneous-equations bias in the OLS estimates of the capital-flow 'reduced forms'. The results appear as equations (a) and (b) of Table 5, where we have simply added to the capital-flow equations $\Delta\hat{M}P$, the projection of $\Delta MP$ onto the space spanned by the instruments.[14] The coefficient of $\Delta\hat{M}P$ in equation (a) is significant, and so the hypothesis of no simultaneity bias can be rejected. In equation (b), however, we cannot find evidence of bias.

[14] Again, the instruments are the right-hand side variables of the capital-flow equations other than $\Delta MP$ as well as the exogenous policy targets in the monetary authority's reaction function.

Table 5

Tests for Simultaneity Bias, 1961:III-1967:IV

| Dependent Variable | Constant | $\Delta r^*$ | $\Delta Y$ | $\Delta MP$ | CAB | CABLTC | $\Delta S4$ | $\widehat{\Delta MP}$ | $\widehat{CABLTC}$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| TCF | 0.275 | -0.380 | -0.022 | -0.623 | -0.857 | ------ | 0.968 | 0.660 | ------ | (a) |
| | (0.145) | (0.285) | (0.021) | (0.079) | (0.077) | | (0.474) | (0.245) | | |
| | Standard error = 0.490; Durbin-Watson statistic = 2.33 | | | | | | | | | |
| STCF | 0.184 | -0.173 | -0.002 | -0.485 | ------ | -0.662 | 1.172 | 0.314 | ------ | (b) |
| | (0.162) | (0.284) | (0.021) | (0.086) | | (0.124) | (0.581) | (0.280) | | |
| | Standard error = 0.498; Durbin-Watson statistic = 2.28 | | | | | | | | | |
| STCF | 0.179 | -0.390 | -0.033 | -0.452 | ------ | -0.482 | 0.535 | 0.657 | -0.324 | (c) |
| | (0.099) | (0.186) | (0.014) | (0.061) | | (0.106) | (0.332) | (0.170) | (0.123) | |
| | Standard error = 0.320; Durbin-Watson statistic = 2.60 | | | | | | | | | |

This apparent contradiction disappears when we notice that we have used CABLTC as an instrument in equation (b), in accordance with the common practice of regarding long-term capital flows as exogenous in estimating offset coefficients. But there are no good grounds to believe this is a valid assumption. Since we have CAB available as an instrument, we can use it instead of CABLTC to form the instrumental variable estimate of the short-term capital-flow equation's parameters. The result is

$$\begin{aligned} STCF = \underset{(0.341)}{0.179} - \underset{(0.641)}{0.389}\,\Delta r^{*} - \underset{(0.048)}{0.032}\,\Delta Y + \\ \underset{(0.547)}{0.204}\,\Delta MP - \underset{(0.216)}{0.806}\,CABLTC + \underset{(1.145)}{0.536}\,\Delta S4 \end{aligned}$$

Standard error = 1.103; Durbin-Watson statistic = 2.45.

which is very different from equations (b) and (d) of Table 4. This shift in the coefficients suggests that long-term capital flows are indeed endogenous, and that our previous test for the endogeneity of ΔMP in the short-term capital-flow equation was invalid. We obtain a valid test by adding $\widehat{CABLTC}$ as well as $\Delta\widehat{MP}$ to this equation's regressors and applying OLS. The result, reported in Row (c) of Table 5, provides unambiguous evidence of simultaneity bias: the sum of squared residuals of equation (b) of Table 4 is 5.023, while that of equation (c) of Table 5 is only 1.839. We therefore can reject the joint hypothesis that both monetary policy and long-term capital flows are exogenous.

When examined carefully, the conclusions of the 'reduced-form' approach to capital movements provide no grounds for rejecting the offset coefficients implied by structural estimates. This section's evidence is consistent with the view that the reduced-form approach is a misleading short-cut, and that the offset coefficients it yields are seriously biased. However, the structural approach taken in this essay avoids the problems of the Kouri-Porter method. Although structural estimation is more roundabout and certainly more difficult, it is probably the only way to obtain a reliable answer to the offset question.

## V. Conclusion

This essay presented a small econometric model of the West German financial sector and used its parameters to calculate the short-run and long-run offsets to monetary policy due to interest-sensitive capital movements. The resulting series of short-run offset coefficients suggested that the offset over one quarter was quite small during the 1960-1970 period, typically between 10 and 15 percent. The long-run offset, based on full adjustment of asset markets, was found to be quite large, however, indicating an ultimate reserve loss of between 500 and 650 million Deutsche Marks for every DM 1 billion increase in the domestic source component of the monetary base. It therefore appears that the Bundesbank's conduct of monetary policy was relatively unhampered by international reserve volatility on a quarterly basis, at least during periods of tranquility in international financial markets. Only over a horizon of several quarters did monetary policy entail large reserve losses. But, thanks to a substantial degree of imperfect substitutability between DM- and foreign-currency-denominated bonds, these losses did not suffice to render monetary measures ineffective in the long run.

While consistent with the simulation results of Herring and Marston's (1977) more elaborate model, our findings contradict those of the popular 'reduced-form' approach to measuring the short-run offset, which typically yields estimates ranging from 50 to 90 percent. This essay suggested that these estimates pick up the correlation between monetary policy and capital flows resulting from the Bundesbank's sterilization operations, and do not measure the capital-account response to monetary policy. Formal statistical tests allowed us to reject the hypothesis that monetary policy can be treated as exogenous in the estimation of capital-flow equations. In addition, we found that it is improper to assume that long-term capital flows are exogenous in equations explaining short-term flows.

Our estimated offset figures must be interpreted with caution because of the imprecision of the underlying parameter estimates. In addition, we must recognize that periods of heavy speculation agains the existing exchange parities posed special problems for the Bundesbank. Our results do not imply the contrary. We have made no attempt to explain exchange-rate expectations or their connection with domestic monetary policy, and our offset coefficients measure the responsiveness of capital flows to interest-rate changes only. They are calculated on the assumption that expectations can be held constant -- a bad assumption during periods of turbulencein world financial markets.

## Appendix I: Sterilization and Simultaneity Bias[15]

In this appendix we consider the consequences of estimating $\alpha$ by ordinary least squares in the simultaneous system

$$y_1 = \alpha y_2 + X\gamma + u ,$$
$$y_2 = \beta y_1 + Z\delta + v ,$$

where X and Z are exogenous. This is of course the situation that arises when the capital account and monetary policy are simultaneously determined by the capital-flow and sterilization equations

$$TCF = \alpha \Delta MP + \Delta X\gamma + u ,$$
$$\Delta MP = \beta TCF + \Delta Z\delta + v ,$$

and $\alpha$ is the offset coefficient. (Here, $-1 \leq \alpha,\beta \leq 0$.)

Multiplying the first of the two equations by $I - X(X'X)^{-1}X$, we can write

$$\hat{\alpha}_{OLS} = [y_2'(I - X(X'X)^{-1}X')y_2]^{-1}y_2'(I - X(X'X)^{-1}X')y_1$$
$$= \alpha + [y_2'(I - X(X'X)^{-1}X')y_2]^{-1}y_2'(I - X(X'X)^{-1}X')u.$$

Noting the reduced-form relationship

$$y_2 = \frac{\beta}{1 - \alpha\beta} X\gamma + \frac{1}{1 - \alpha\beta} Z\delta + \frac{\beta u + v}{1 - \alpha\beta} ,$$

[15] The results in this appendix also appear in Murray (1978). I am grateful to Matthew Butlin for bringing this reference to my attention.

and substituting it into the expression for $\hat{\alpha}_{OLS}$, we obtain

$$\hat{\alpha}_{OLS} - \alpha =$$

$$(1-\alpha\beta)[(\delta'Z' + \beta u' + v')(I - X(X'X)^{-1}X')(Z\delta + \beta u + v)]^{-1}$$

$$\cdot \quad (\delta'Z' + \beta u' + v')(I - X(X'X)^{-1}X')u \ .$$

From this expression, we see that if $E[u'v] = 0$,

$$\underset{T}{\text{plim}}\ (\hat{\alpha}_{OLS} - \alpha) =$$

$$[\beta^2\sigma_u^2 + \sigma_v^2 + \underset{T}{\text{plim}}\ T^{-1}\delta'Z'(I - X(X'X)^{-1}X')Z\delta]^{-1}(1-\alpha\beta)\beta\sigma_u^2 =$$

$$\frac{(1-\alpha\beta)\beta}{\beta^2 + (\sigma_v^2/\sigma_u^2) + \underset{T}{\text{plim}}\ \frac{T^{-1}}{\sigma_u^2}\ \delta'Z'(I - X(X'X)^{-1}X')Z\delta} \ .$$

The calculation implies that the bias from OLS estimation will be greater the greater is $\sigma_u^2$ and the smaller is $\sigma_v^2$; it will be smaller when the Z's are orthogonal to the X's. In the context of the two-equation model of sterilization and offsetting capital flows, the expression implies that the bias will be great when the unexplained component of the capital-flow equation is large, and when the unexplained component of the reaction function is small. It will also be great when the capital-flow equation is weakly identified, so that the Z's are collinear with the X's.

## Appendix II: Notes on the Data

This appendix describes the data series underlying the estimates presented in this essay. We employ the following abbreviations:

MRDB = _Monthly Report of the Deutsche Bundesbank_

BEQB = _Bank of England Quarterly Bulletin_

IFS = International Monetary Fund, _International Financial Statistics_

Data from the Deutsche Bundesbank's data bank were kindly made available by Professor Manfred J.M. Neumann, Free University, Berlin. The generosity of Professor Richard C. Marston, University of Pennsylvania, who also shared his data with me, is acknowledged as well.

The data series are in alphabetical order.

B: End of quarter monetary base (billions of DM). The series was constructed by cumulating the sum of the current account, the capital account, and the change in the Bundesbank's net domestic assets (i.e., CAB, TCF, and ΔDACB below) on a benchmark figure of DM 29.9 billion for 1959:IV taken from the IFS 1973 Annual Supplement.

BA: End of quarter monetary base, adjusted for reserve-requirement changes (billions of DM). Calculated as θB, where θ is the base-year average reserve requirement

(.089 for 1959:IV) divided by the contemporaneous average reserve requirement.

CAB: Current account balance plus balance of official capital flows (billions of DM). Deutsche Bundesbank data bank.

CABLTC: CAB plus balance of private long-term capital flows (billions of DM). Deutsche Bundesbank.

$\delta$: Bundesbank discount rate at end of quarter, in per cent per annum. MRDB.

ΔDACB: Change in the net domestic assets of the Bundesbank (billions of DM). Deutsche Bundesbank.

ΔFACB: Change in the net foreign assets of the Bundesbank (billions of DM). Calculated as CAB + TCF.

GOVDEP: Public authority deposits with Bundesbank (billions of DM). Source: MRDB.

GOVMON: Public authority holdings of money M2 (billions of DM). Source: MRDB.

ΔMP: Increase in the domestic source components of the monetary base, including changes in required reserves (billions of DM). When calculated in the manner of Porter (1972), this is just the increase in the net domestic assets of the Bundesbank plus reserves liberated by changes in average reserve requirements. The series used in Section IV is the same as the one used in Neumann (1978); data come from the Deutsche Bundesbank.

M: End of quarter money stock (billions of DM), calculated as the sum of currency in circulation plus demand deposits plus time deposits. Source: IFS 1973 Annual Supplement.

NEL: Private net external liabilities at end of quarter (billions of DM), calculated by cumulating TCF on a benchmark figure for 1965:IV. The benchmark was calculated as the sum of net external liabilities of banks (MRDB, November 1967) and 700 firms surveyed by the Bundesbank (MRDB, November 1966).

$\hat{O}$: Percentage change over previous quarter in index of domestic manufacturing orders. Source: OECD Historical Statistics.

P: Consumer price index, 1963 = 1. Source: IFS 1973 Annual Supplement.

$\hat{P}$: Percentage change over previous quarter in industrial wholesale price index. Source: IFS 1973 Annual Supplement.

r: Three-month German interbank rate, in percent per annum, calculated as the average of weekly rates during the last month of the quarter. Source: MRDB.

$r^*$: Three-month Eurodollar interest rate in London, in percent per annum, calculated as the average of weekly rates during the last month of the quarter. Source: BEQB.

S1,S4: Seasonal dummies equalling 1 in the first and fourth quarters, respectively, and 0 in other quarters.

SPEC1: Dummy variable to capture the effect of speculation on D-Mark revaluation on the capital account. SPEC1 equals 1 in 1961:II, -1 in 1961:III, and 0 in other quarters.

SPEC2: Speculative dummy equalling 1 in 1968:IV and -1 in 1969:I.

SPEC3: Speculative dummy equalling 1 in 1969:II and 1969:III and -1 in 1969:IV.

STCF: Short-term private capital flows, in billions of DM. Source: Deutsche Bundesbank.

SWP: Bundesbank swap commitments, at end of quarter (billions of DM). Data before 1963:IV come from a graph on page 16 of the Bundesbank's Annual Report for 1962. Thereafter, data come from MRDB and its supplement on balance-of-payments statistics.

TCF: Total private capital flows (billions of DM). Source: Deutsche Bundesbank.

$\Theta$: Base adjustment factor, calculated as base-year average reserve requirements (0.089 in 1959:IV) divided by current average reserve requirements. Source: MRDB Table II.5.(b) (Table IV.3.(b) after 1968).

V: German end of quarter financial wealth (billions of DM). Calculated as D + NEL + FACB - GOVDEP - GOVMON, where D is indebtedness of the public authorities (including indebtedness to the Bundesbank). D was taken from MRDB Table VII.5 after 1965:IV. Data for 1960:I to 1965:III were obtained by interpolating the annual data given in the articles 'Recent Trends in Public Debt' (MRDB, August 1970, p. 17), and 'Indebtedness of Public Budgets' (MRDB, April 1967, p. 25). FACB was obtained by cumulating ΔFACB on the benchmark figure for 1959:IV of DM 22.688 billion, taken from MRDB.

Y: Gross national product at annual rate (billions of DM). Figures for 1960:I to 1961:IV are from IFS. Subsequent data are taken from OECD <u>Historical Statistics, 1960-1975</u>.

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