STERILIZATION POLICY: THE TRADE-OFF BETWEEN MONETARY AUTONOMY AND INTERNATIONAL RESERVE STABILITY

by

Richard J. Herring
and
Richard C. Marston

Working Paper No. 19-77

RODNEY L. WHITE CENTER
FOR FINANCIAL RESEARCH

University of Pennsylvania

The Wharton School

Philadelphia, Pa. 19104

1. Introduction

Under fixed exchange rates, private portfolio behaviour limits the control of the national monetary authorities over the domestic interest rate and money supply. If portfolio managers respond to changes in international interest rate incentives, a shift in monetary policy induces offsetting capital flows which vitiate the impact of that policy.

The response of the monetary authorities to these offsetting capital flows, however, may preserve some scope for monetary autonomy. Where sterilization policy is feasible [1], the monetary authorities may choose

[1] See Herring and Marston (1977b) for a discussion of the feasibility of sterilization policy.

to neutralize part or all of the impact of offsetting capital flows on domestic financial conditions. In gaining greater control over domestic bank reserves, the authorities pay a price in terms of diminished control over foreign exchange reserves; increased sterilization decreases the impact of capital flows on bank reserves, but it also leads to larger capital flows. Thus the authorities must weigh the advantages of increased monetary autonomy against the cost of greater fluctuations in foreign reserves.

This paper analyzes the trade-off between control over bank reserves and control over foreign exchange reserves implicit in the choice among sterilization policies. In addition, it presents empirical evidence based on German experience in the 1960's to illustrate how this trade-off was resolved in practice.

In the first section, we outline a model of the monetary sector in an open economy and show how private portfolio behaviour can modify the impact of monetary policy. We derive an estimate for the German economy of the offsetting effect of balance of payments flows. This estimate is based on a structural model of the German monetary sector which we have described in a recent book, Herring and Marston (1977a)

In the second section we introduce official behaviour and show how sterilization policy can enlarge the scope for monetary autonomy. We then report estimates of a reaction function which describes the sterilization policy of the German monetary authorities.

The third section combines the analysis of private portfolio behaviour and official behaviour to show the trade-off between monetary autonomy and stability in foreign exchange reserves which underlies the choice among sterilization policies. Our empirical investigations of offset and sterilization behaviour in Germany enable us to illustrate this trade-off explicitly. We conclude by developing a pair of curves which show how control over bank reserves and foreign exchange reserves varies with different degrees of sterilization.

2. Portfolio Decisions in an Open Economy

What distinguishes the monetary sector in an open economy is the role of international capital movements in determining the supply of money and the domestic interest rate. A complete model of monetary behaviour must incorporate portfolio decisions that give rise to capital movements in the same framework as those involving domestic assets. In addition, the capital movements arising from these portfolio decisions must be systematically related to bank reserves and the supply of money.

The model of the monetary sector which we have specified for Germany includes three sets of equations which jointly determine the balance of payments, the supply of money, and the domestic interest rate. A simplified version (using the home country balance sheets displayed in Table 1) will serve to introduce the main elements of the model.

Table 1. Sectoral balance sheets in an open economy

Private non-banks		Banks		Monetary Authorities	
DD	W	R	DD	H^{md}	R^{s}
H^{pd}		H^{bd}		RFX	
F^{pd}					

2.1. The balance of payments and the supply of bank reserves

The first set of equations includes two capital flow equations to explain changes in claims on foreigners and liabilities to foreigners. Both equations reflect the underlying portfolio behaviour represented in this model by the home demand for foreign bonds (F^{pd}) and the foreign demand for home bonds (H^{fd}).

The demand for foreign bonds by home country residents depends upon the interest rates on home bonds (i_h) and foreign bonds (i_f), the level of income (Y, to reflect a transactions demand for money), and the level of wealth (W). Foreign bonds are denominated in the foreign currency so the expected return on these bonds depends not only on the interest rate, but also on the forward premium (fp) or the speculative premium (sp) on the foreign currency:[-/]

$$F^{pd} = F^{pd}(\overset{-}{i_h}, \overset{+}{i_f}, \overset{+}{fp}, \overset{+}{sp}, \overset{-}{Y}, \overset{+}{W}). \quad (1)$$

-/ The forward premium is defined as$((r_t - r_o)/r_o) \times 4$, where r_y is the domestic currency price of a unit of foreign currency for delivery in three months, and r_o is the domestic currency price of a unit of foreign currency for spot delivery. The forward premium may be considered the return from a forward exchange contract to cover the risk of holding a bond denominated in foreign currency. The speculative premium is defined as $((r_t^e - r_o)/r_o) \times 4$, where r_t^e is the expected spot rate three months hence, and r_o is the current spot rate. The speculative premium may be considered the expected return from holding foreign currency for three months.

An increase in the covered return on foreign bonds (i_f+fp) or an increase in the uncovered return on foreign bonds (i_f+sp) induces home country residents to substitute foreign bonds for domestic bonds or money. Similarly, the foreign demand for domestic bonds depends positively on foreign wealth (W_f), and on the expected return on both covered (i_h-fp) and uncovered (i_h-sp) holdings of domestic bonds. Because domestic bonds are a substitute for foreign assets, H^{fd} will depend negatively on the interest rate on foreign bonds (i_f), and on the volume of foreign transactions (Y_f):

$$H^{fd} = H^{fd}(\overset{+}{i_h}, \overset{-}{i_f}, \overset{-}{fp}, \overset{-}{sp}, \overset{-}{Y_f}, \overset{+}{W_f}) \qquad (2)$$

The capital flow equations in the model are specified as linear versions of these asset demand functions in first difference form.[1]

---

[1] The claims equation, for example, is first specified in linear form as follows:

$$F^{pd}/W = b_o + b_1 i_h + b_2 i_f + b_3 fp + b_4 sp + b_5 W.$$

The flow form of the equation then relates ΔF^{pd} to the first differences of the product of the other variables with W.

The two capital flow equations together determine the net capital account of the balance of payments (ΔK):

$$\Delta K = \Delta H^{fd} - \Delta F^{pd}. \qquad (3)$$

As we show in the discussion of the offset coefficient below, the interest-sensitivity of the capital account is an important factor determining the extent to which domestic monetary conditions respond to foreign conditions. The other element of the balance of payments particularly sensitive to interest rates is the investment income account. We have specified separate equations for investment income receipts (IIR) and expenditures (IIE). Each equation relates the investment income flow to the stock of assets or liabilities as well as the interest rate received or paid:

$$IIR = IR(\overset{+}{F}^{pd}, \overset{+}{i_f}) \quad (4)$$

$$IIE = IE(\overset{+}{H}^{fd}, \overset{+}{i_h}) \quad (5)$$

With these equations, we can trace the impact of a change in interest rates from the capital account to the investment income flows generated by the capital account.

Since the remainder of the balance of payments, consisting primarily of the trade balance and the balance on non-financial services is unlikely to be sensitive to current interest rates, we treat these other elements (denoted by $\overline{TB}$) as exogenous in the estimation. The various elements of the balance of payments can be added together to obtain the change in foreign exchange reserves as follows:

$$\Delta RFX = \overline{TB} + (IIR - IIE) + \Delta K. \quad (6)$$

International payments imbalances (ΔRFX), in turn, induce adjustments in the rest of the monetary sector.

Changes in foreign exchange reserves reflect the authorities' intervention in the foreign exchange market in support of the exchange rate, the domestic consequence of which is a change in bank reserves. Unless other adjustments in the central bank's balance sheet take place— adjustments which we shall consider in the following section-- a balance of payments surplus (deficit) results in an expansion (contraction) of bank reserve by an identical amount. Since the balance of payments is responsive to shifts in international interest rate differentials, the link between the balance of payments and the domestic monetary sector makes bank reserves also responsive to interest rates. A higher interest rate on home bonds, for example, results in an increase in bank reserves. Thus within an open economy under fixed exchange rates, the supply of bank reserves (R^S) is positively related to the home interest rate as in Figure 1.

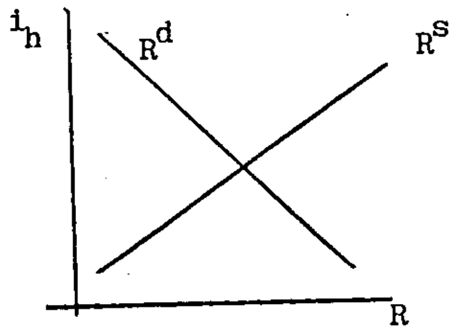


Figure 1. The supply of, and demand for, bank reserves

2.2. The demand for bank reserves and the determination of interest rate

The demand sector of our model provides a second link between bank reserves and the home interest rate. As long as we abstract from complex forms of bank behaviour, we can determine the demand for bank reserves (R^d) in a simple identity relating R^d to the level of bank deposits (DD) and the required reserve ratios (q):[✓]

$$R^d = q \times DD. \tag{7}$$

✓ If banks hold excess reserves, then bank reserves and bank deposits are no longer strictly proportional. In Herring and Marston (1977a, pp. 32-37) we show how more sophisticated bank behaviour can be incorporated in our analysis.

The level of bank deposits, in turn, is determined by the public's demand for this asset. The demand for bank deposits is positively related to income and wealth, and negatively related to the home interest rate:

$$DD = DD(\overset{-}{i_h}, \overset{-}{i_f}, \overset{-}{fp}, \overset{-}{sp}, \overset{+}{Y}, \overset{+}{W}). \tag{8}$$

In addition, because foreign securities are also substitutes for bank deposits, this demand is negatively related to the interest rate on foreign bonds and to the forward and speculative premiums.

Since the demand for bank deposits is negatively related to the home interest rate, the demand for bank reserves also must be. Thus in Figure 1, the curve labelled R^d shows the demand for bank reserves to be inversely related to i_h. The demand and supply of bank reserves together determine the level of bank reserves and the home interest rate.

How the different sectors of the monetary model fit together is illustrated in the flow chart provided in Figure 2. The chart shows the progression of the model (from left to right) from the balance of payments equations to bank reserves and finally to the interest rate. On the left side of the chart we can determine the interest-sensitive elements of the balance of payments. The home and foreign interest rates (i_h and i_f), the latter being determined outside this single country model, are the principal endogenous determinants of the change in claims (ΔF^{pd}) and liabilities (ΔH^{fd}) in the capital account, and of interest expenditures (IIE) and receipts (IIR) in the investment income account. The flow of foreign exchange reserves (ΔRFX) is obtained by summing all of the balance of payments accounts. The quantity of home securities and the quantity of foreign exchange reserves held by the domestic monetary authorities together determine the supply of bank reserves (R^s). The reserve identity ($R^d = q \times DD$) then provides a link between bank reserves and the supply of money. Finally, the interest rate is determined in a demand for deposits equation thus completing the circuit of the supply and demand sectors.

2.3. The portfolio response to changes in monetary policy: offsetting capital flows

Of central concern in this paper is the scope for domestic monetary policy when balance of payments flows are of substantial importance. In particular, we are interested in determining the extent to which monetary policy actions are "offset" through balance of payments flows.[1]

---

[1] The concept of capital flow offsets was developed in connection with reduced-foreign estimates of capital flow equations. See especially Porter (1972), Kouri and Porter (1974), and Kouri (1975).

In Figure 3 we illustrate the offset concept for the case of an open market sale of home securities designed to reduce bank reserves (and the money supply).

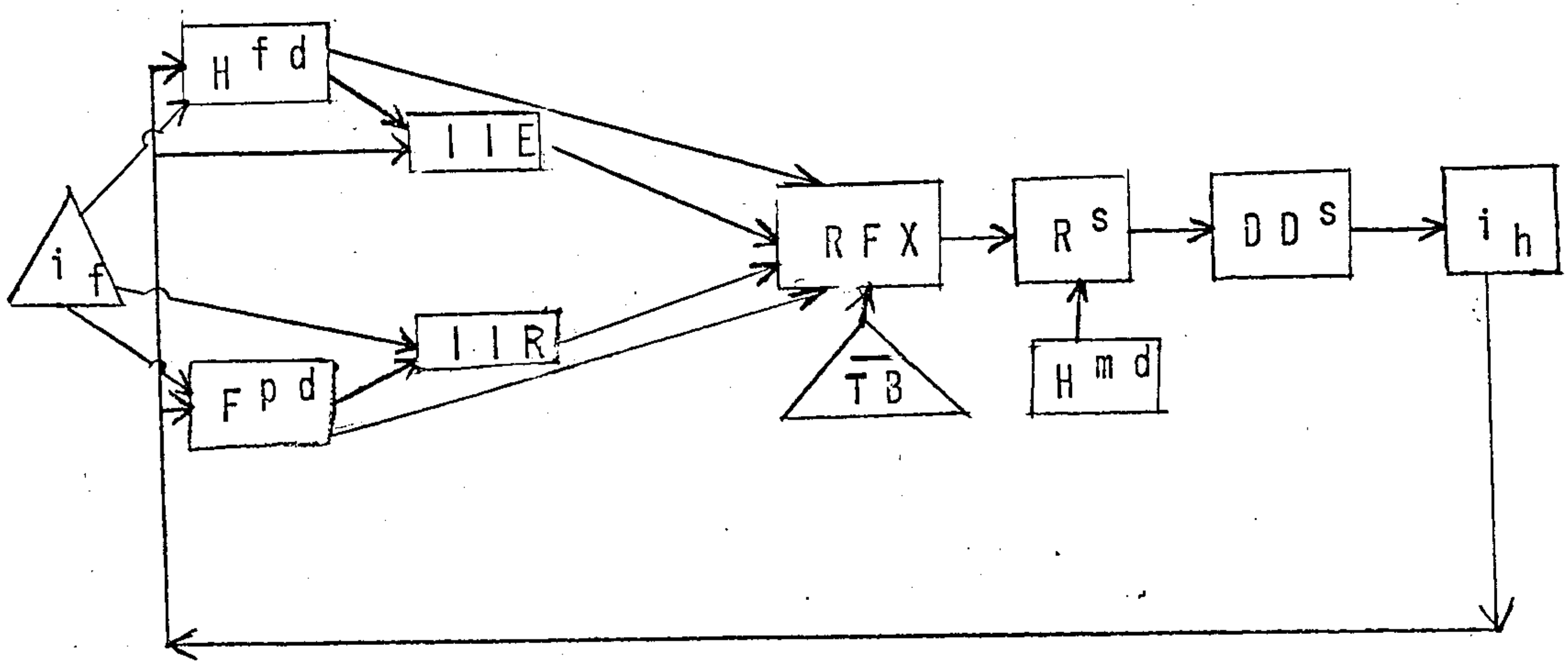


Figure 2. Flow chart of the simplified structural model

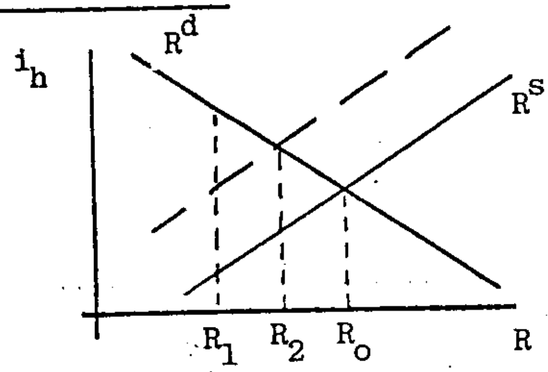


Figure 3. The offset effect in response to an open market sale of domestic securities

The attempt to reduce bank reserves through an open market sale will be only partially successful, since the contraction of bank reserves (by R_o-R_1) and resulting rise in the home interest rate will induce an inflow of capital. To maintain a fixed exchange rate, the authorities will be required to sell bank reserves in the foreign exchange market. In the example illustrated the offsetting capital flow and the corresponding increase in bank reserves will equal R_2-R_1. The final change in bank reserves, R_o-R_2, thus will be only a fraction of the initial change.

The offset can be defined more precisely by solving the supply and demand for bank reserves for the offsetting capital flow. The resulting expression relates the capital flow to the open market sale (ΔH^{md}) as well as other factors denoted by X):

$$\Delta K = a_1 \Delta H^{md} + a_2 X \tag{9}$$

The coefficient a_1 is called the offset coefficient since it measures the fraction of a policy-induced change in bank reserves which is offset through the capital account; it is defined as follows:[1]

$$a_1 = \frac{(H_h^{fd} - F_h^{pd})}{(qDD_h - (H_h^{fd} - F_h^{pd}))} \tag{10}$$

[1] "DD_h" denotes the partial derivative with respect to i_h; H_h^{fd} and F_h^{pd} are similarly defined. In deriving the expression for the offset coefficient we have omitted investment income flows in order to simplify the analysis.

The size of the coefficient depends upon the interest sensitivities of the demand for bank deposits (DD_h), home bonds held by foreign investors (H_h^{fd}), and foreign bonds held by home investors (F_h^{pd}). Of particular importance is the degree of substitutability between foreign and home bonds as reflected in H_h^{fd} and F_h^{pd}. If home and foreign bonds are perfect substitutes, for example, then these interest sensitivities will be infinite; the offset coefficient, therefore, will approach minus one, and the induced capital flow will completely offset the open market sale. In the more general case of limited substitution between assets, the offset coefficient will be between zero and minus one, and the induced capital flow will offset only a fraction of the open market sale. The size of the fraction, of course, is of crucial importance in assessing the scope for independent policy.

In our empirical analysis of the German monetary sector, we were able to obtain an estimate of the offset coefficient based on our estimates of the parameters in the structural equations. We shall not report the individual structural equations here, since they are fully described in Herring and Marston (1977a, Ch. 5 and 6). When the equations are solved to obtain a reduced form expression for balance of payments flows as in (9), we obtain an offset coefficient of -0.78; that is, we found that 78% of an open market sale (or other policy-induced change in bank reserves) is offset through balance of payments flows.[1] Thus the interest sensitivity of

---

[1] Because the structural model reflects the impact of the policy change on investment income as well as the impact on capital flows this estimate is a "balance of payments offset" rather than simply a "capital flow offset". Since the induced flow of investment income and the induced capital flow are in opposite directions, the capital flow offset alone would be somewhat higher than 78%.

---

balance of payments flows posed serious problems for the conduct of German monetary policy.

The offset coefficient alone, however, cannot indicate how successfully the authorities maintained monetary independence. The analysis is incomplete until we consider the policy response to offsetting capital flows. If foreign exchange flows can be sterilized, a high offset coefficient does not necessarily imply the loss of monetary autonomy.

3. Official Behaviour

3.1. Sterilization policy

As we noted in the preceding analysis, changes in the authorities holdings of foreign exchange reserves lead to equal changes in bank reserves unless they are neutralized by other changes in the balance sheet of the monetary authorities. Sterilization operations are systematic attempts by the authorities to neutralize the monetary impact of changes in their foreign exchange reserves by opposite movements in their holdings of domestic assets (H^{md}).[1] [2] The

[1] Recent investigations of sterilization behaviour include Argy and Kouri (1974), De Grauwe (1975, 1977) and Girton and Henderson (1976).

[2] Other adjustments in the central bank's balance sheet may also serve to neutralize the monetary impact of a change in foreign exchange reserves. For example, banks may respond to changes in reserves associated with a balance of payments surplus (deficit) by decreasing (increasing) their discount borrowings from the monetary authorities. Although we investigate this possibility as well as a wider range of monetary policy instruments in the empirical analysis in the following section, we have confined the present discussion to open market operations in order to simplify the exposition. See Herring and Marston (1977a, pp. 32-37) for a description of bank behaviour and references to the previous literature.

authorities will also vary their monetary instruments in an attempt to achieve policy targets such as full employment, price stability and rapid economic growth. We can represent such systematic policy responses in terms of a reaction function which relates changes in official holdings of bonds, ΔH^{md}, to changes in domestic policy targets (ΔZ), to changes in foreign exchange reserves (ΔRFX) and to other exogenous disturbances (ΔN):

$$\Delta H^{md} = R(\Delta Z, \Delta RFX, \Delta N) = R_1\Delta Z + R_2\Delta RFX + R_3\Delta N \tag{11}$$

Foreign exchange reserves are separated from other policy targets and disturbances because they serve a dual role: any change in RFX leads to a change in bank reserves which the authorities may wish to sterilize; but, if the authorities are concerned about external balance, ΔRFX may also signal a need for a policy action to attain external balance.

If the monetary authorities were exclusively committed to the attainment of their domestic objectives, then they would completely sterilize all changes in foreign exchange reserves in order to prevent foreign exchange flows from interfering with the attainment of their policy goals. The sterilization coefficient, R_2, would equal negative one; for example, an increase in RFX would be met by an equal sale of bonds to keep bank reserves constant. But the authorities may also be concerned with the attainment of external balance. Indeed, if external balance were the sole objective of monetary policy, the authorities might permit any change in foreign exchange reserves to be fully reflected in changes in bank reserves. The sterilization coefficient would be zero; open market operations would not respond to a change in foreign exchange reserves.[1]

---

[1] Under one interpretation of the "rules of the game" under the gold standard, the monetary authorities were supposed to reinforce the monetary impact of gold flows by making their domestic assets move in the same direction as their foreign assets. For further discussion of this point, see Yeager (1966, Ch. 15).

3.2. How sterilization modifies portfolio behaviour: the <u>net</u> offsetting impact of capital flows

The sterilization coefficient, R_2, is a crucial parameter in the financial system. It is potentially as important as the degree of substitutability between domestic and foreign assets in determining the extent to which domestic financial conditions are affected by external factors.

Sterilization has two impacts on the monetary sector: (1) it increases the capital flows associated with any disturbance or policy action, and (2) it decreases the impact of the capital flows on bank reserves. The response of capital flows to a policy-induced change in bank reserves ($R_1 \Delta Z$), for example, is enhanced when sterilization is taken into account. We can derive an expression for the impact on capital flows by substituting the reaction function (11) into the offset equation (9) to obtain:[*]

$$\Delta K = \frac{a_1}{1-a_1R_2} R_1 \Delta Z. \qquad (12)$$

[*] In deriving this expression we have ignored the other exogenous elements in the reaction function and offset equation in order to focus on the response to open market operations in pursuit of policy targets, We have also ignored the induced interest payments in the identity

$$\Delta RFX = \Delta K + IIR - IIE + \overline{TB}.$$

The capital flows induced by the shift in bank reserves will be increased if sterilization operations are undertaken (i.e., when $-1 < R_2 < 0$). Indeed, the magnitude of the induced capital flows will increase more than proportionally as the sterilization coefficient approaches negative one.

On the other hand, the impact of the capital flows on bank reserves is reduced as sterilization is increased. To derive an expression for the impact on bank reserves, we must distinguish between the final change in bank reserves (ΔR^S) and the initial change in bank reserves ($R_1 \Delta Z$), which induced the capital flows. The difference between the final change and the initial change, $\Delta R^S - R_1 \Delta Z$, is the net impact of capital flows on bank reserves:

$$\Delta R^S - R_1 \Delta Z = (\Delta H^{md} + \Delta K) - R_1 \Delta Z = (1+R_2) \frac{a_1}{1-a_1R_2} (R_1 \Delta Z). \qquad (13)$$

The coefficient of $R_1 \Delta Z$ is called the "net offset coefficient" since it reflects the offsetting impact of capital flows <u>net</u> of the sterilization that is induced. It is clear from this expression that as sterilization becomes more complete, the net offsetting impact of capital flows on bank reserves becomes smaller. In fact, when sterilization is complete, the net impact becomes nil.

Sterilization thus has opposite effects on capital flows and bank reserves. If sterilization is increased to reduce the impact of capital flows on bank reserves, a price must be paid since the capital flows induced by a disturbance are thereby increased. As a result, choosing a sterilization policy implicitly involves choosing a point on the trade-off between control over foreign exchange reserves and control over bank reserves.

Before turning to an assessment of the trade-off which faced Germany during the 1960's, we will discuss empirical evidence concerning the reaction function of the German monetary authorities. We shall examine this evidence in some detail because, in view of the large offset coefficient for Germany, sterilization behaviour is of utmost importance in assessing the effectiveness of German monetary policy The reaction function, moreover, is the crucial element that is frequently missing in traditional discussions of monetary policy under fixed exchange rates.

4. Sterilization Policy in Germany

4.1. The instruments of monetary policy

In specifying a reaction function, one of the most important decisions involves the choice of a dependent variable. The choice of this variable is implictly an assertion about what the Bundesbank controls. We have taken a very cautious approach to the question, rejecting such intermediate concepts as M1, M2, M3, bank liquidity, free liquid reserves or the interest rate — in favor of those quantities which the Bundesbank controls directly — reserve requirements, open market operations, forward swap operations, placements of official deposits, and the discount rate. In order to summarize changes in the various policy instruments in a comparable fashion, we have expressed each of the policy changes in terms of its impact on bank reserves. Our treatment of the various policy instruments of the Bundesbank is most easily understood by considering the simplified balance sheet appearing in Table 2 in which the liabilities of the Budesbank consist solely of bank reserves:

Table 2. A stylized Bundesbank balance sheet

Bundesbank	
H^{md}	R^{S}
RB	
RFX	

The assets of the Bundesbank include holdings of government securities net of government deposits placed at the Bundesbank (H^{md}), borrowed reserves (RB), and foreign exchange reserves (RFX).

4.1.1. Change in unborrowed reserves

Open market operations and shifts in government balances between the Bundesbank and the commercial banks affect bank reserves by changing the Bundesbank's net holdings of domestic assets (ΔH^{md}). Official swap operations, which provide banks with forward cover for their investment abroad, affect bank reserves by changing the

Bundesbank's holdings of foreign exchange reserves (ΔRFX).[*] Through

[*] The total change in foreign exchange reserves (ΔRFX) can be decomposed into a portion attributable to changes in swap commitments (ΔSW) and a portion attributable to other balance of payments transactions ($\Delta RFX'$):

$$\Delta RFA = \Delta RFX' - \Delta SW.$$

For further discussion of swap operations, see Herring and Marston (1977 pp. 141-42).

either type of policy, the Bundesbank can influence the level of unborrowed reserves. The policy-controlled change in unborrowed reserves, denoted by $\Delta PUR'$, is defined as

$$\Delta PUR' = \Delta H^{md} - \Delta SW , \tag{14}$$

where ΔSW is the portion of ΔRFX attributable to swap commitments. According to this expression, open market operations or shifts in government deposits (ΔH^{md}) <u>increase</u> unborrowed reserves, while increases in swap commitments (ΔSW), which lead to a fall in foreign exchange reserves, <u>reduce</u> unborrowed reserves.

4.1.2. Changes in reserve requirements

Changes in reserve requirements alter the extent to which any given quantity of bank reserves can be used to sustain deposit expansion. Changes in reserve requirements do not generally have an exact correspondence to changes in the stock of required reserves (ΔRR) since required reserves may change not only because of a change in reserve requirements (Δq), but also because of changes in the stock of deposit liabilities subject to reserve requirements (ΔDEP), The change in the stock of required reserves is, thus, the sum of two components -- the first due to a shift in monetary policy and the second due to a shift in holdings of bank deposits:

$$\Delta RR = DEP_{-1}\Delta q + q_{-1}\Delta DEP.\text{[*]} \tag{15}$$

[*] Plus the second order term, $\Delta q \cdot \Delta DEP$, which we ignore.

In order to incorporate changes in reserve requirements into the analysis, we modify $\Delta PUR'$ to include the effect of Δq on required reserves. The resulting series, called the effective change in unborrowed reserves, ΔPUR, is defined as:

$$\Delta PUR = \Delta PUR' - DEP_{-1}\Delta q = \Delta H^{md} - \Delta SW - DEP_{-1}\Delta q \qquad (16)$$

4.1.3. Changes in borrowed reserves

If borrowed reserves (RB) are also considered to be under the control of the Bundesbank, then the reserve aggregate controlled by the Bundesbank consists of borrowed plus unborrowed reserves.[1]

---

[1] In order to test whether the Bundesbank controlled ΔPUR or $\Delta PUR + \Delta RB$, we estimated a form of the reaction function in which ΔPUR was related to ΔRB and other variables. In this specification, the coefficient of ΔRB reflects the extent to which changes in borrowing are coordinated with other policy instruments or, if borrowing is not fully controlled, the extent to which changes in borrowing are neutralized by changes in other policies. We found that the estimated coefficient is not significantly different from negative one; this implies that the Bundesbank controlled the more aggregative measure of reserves, $\Delta MP = \Delta PUR + \Delta RB$. The estimated equation (for the period 1960 III - 1971 I) is:

$$\Delta PUR = \underset{(-12.0)}{-0.968}\,\Delta RB^{*} \;\underset{(-28.1)}{-\;0.903}\,\Delta RFX'^{*} + \underset{(2.4)}{4.808}\,q_{-1}\Delta Y^{tr}_{-1}$$

$$\underset{(-5.3)}{-\;2.207}\,q_{-1}\%\Delta O_{-1} \;\underset{(-2.3)}{-\;1.363}\,q_{-1}\%\Delta P_{-1} \;\underset{(-11.2)}{-\;2.912}\,S1$$

$$+\underset{(2.1)}{0.703}\,S2 + \underset{(11.4)}{2.70}\,S4 + \underset{(2.2)}{0.288},$$

$$\bar{R}^2 = 0.9812, \quad DW = 1.97, \quad SEE = 0.563, \quad RHO = \underset{(-4.2)}{-0.54}.$$

In this equation, ΔRB (like $\Delta RFX'$) is treated as an endogenous variable to avoid the simultaneous equations bias which arises if banks increase their borrowing from the Bundesbank to offset reductions in unborrowed reserves. The explanatory variables are defined and discussed in Section 4.2.

The monetary policy instrument then becomes the policy - controlled change in effective bank reserves or, more briefly, "the change in monetary policy," which we shall refer to as ΔMP:[1]

$$\Delta MP = \Delta PUR + \Delta RB \qquad (17)$$

---

[1] We also investigated the possibility that the Bundesbank allowed shifts in the demand for currency to affect bank reserves. (If the Bundesbank fails to expand the monetary base in response to an increase in the demand for currency, for example, then bank reserves must decline as currency holdings increase). We estimated a form of the reaction function in which ΔMP was regressed on the change in currency holdings (ΔCUR) and other variables. If the Bundesbank fails to react to a shift in the public's holdings of currency, then bank reserves will vary inversely with currency, and the coefficient of ΔCUR will be significantly negative. The estimated equation is reported below (for the period 1960 III - 1971 I):

$$\Delta MP = \underset{(0.5)}{-\,0.129}\,\Delta CUR \; - \underset{(-48.5)}{0.908}\,\Delta RFX'^{*} \; - \underset{(-4.7)}{0.146}\,\%\Delta O_{-1} \; - \underset{(-2.7)}{0.097}\,\%\Delta P_{-1}$$

$$+ \underset{(4.7)}{0.502}\,\Delta Y^{tr}_{-1} \; + \underset{(-11.7)}{-2.96}\,S1 \; + \underset{(2.4)}{0.888}\,S2 \; + \underset{(12.6)}{2.74}\,S4$$

$$\bar{R}^2 = 0.9867, \qquad DW = 1.83, \qquad SEE = 0.618, \qquad RHO = \underset{(-3.2)}{-0.442}\,.$$

The coefficient of ΔCUR is <u>not</u> significantly different from zero, which implies that the Bundesbank prevented shifts in currency holdings from affecting bank reserves.
The explanatory variables are defined and discussed in Section 4.2.

4.2. Estimation of the reaction function

Because of legal and institutional obstacles to the effective exercise of discretionary fiscal policy, the Bundesbank assumes principal responsibility for attaining macroeconomic objectives such as full employment, price stability, satisfactory economic growth and balance of payments equilibrium. These macroeconomic objectives are likely to influence changes in ΔMP as are the flows of foreign exchange reserves which might otherwise vitiate the Bundesbank's control over bank reserves in pursuit of these macroeconomic objectives. The reaction function, thus, relates ΔMP to current and lagged changes in domestic target variables, ΔZ, and to changes in foreign exchange reserves, ΔRFX.

$$\Delta MP = a_1 q_{-1} \Delta Z + a_2 \Delta RFX. \tag{18}$$

The monetary targets are scaled by the average reserve requirement, q_{-1}, to reflect the fact that when the reserve requirement is higher, it takes a proportionately larger increase in bank reserves to achieve a given expansionary effect.[J]

[J] It seems likely that the Bundesbank views the transmission of monetary policy as depending on some intermediate variable such as bank loans or deposits, rather than bank reserves per se. Thus the variables which represent changes in bank reserves, ΔMP and ΔRFX, are scaled by the predetermined, required reserve ratio to reflect the expansionary potential of a change in bank reserves:

$$\frac{\Delta MP}{q_{-1}} = a_1 \Delta Z + a_2 \frac{\Delta RFX}{q_{-1}}$$

After multiplying through by the predetermined, required reserve ratio, we obtain the expression for the reaction function in the text. For the derivation of a similar reaction function within the context of a formal model of policy optimization, see Herring and Marston (1977, pp. 48-52).

In the estimated equation, we have included three variables as indicators of the Bundesbank's domestic objectives:

$\%\Delta P$ = the rate of inflation,

$\%\Delta O$ = the percentage change in manufacturing orders, and

ΔY^{tr} = the change in trend income

In addition, the independent variables in the reaction function include:

$\Delta RFX'$ = the change in foreign exchange reserves,[1] and

S1, S2, S4 = seasonal dummy variables.

---

[1] Since swap commitments are an instrument of monetary policy (included in ΔMP), $\Delta RFX'$ is adjusted to exclude the corresponding capital flow. In practical terms, however, this adjustment made little difference to the values of the estimated coefficients.

Estimation of the reaction function over the period 1960 III - 1971 I[1][2] yields the following results:

$$\Delta MP = \underset{(-49.6)}{-\ 0.913}\ \Delta RFX'^{*} \ \underset{(-5.4)}{-\ 2.15}\ q_{-1}\%\Delta O_{-1} \ \underset{(-3.2)}{-\ 1.78}\ q_{-1}\%\Delta P_{-1} \qquad (19)$$

$$+ \underset{(6.8)}{8.03}\ q_{-1}\Delta Y^{tr}_{-1} \ \underset{(-15.1)}{-\ 3.14}\ S1 \ + \underset{(4.7)}{1.14}\ S2 \ + \underset{(14.4)}{2.83}\ S4$$

$\bar{R}^2 = 0.9878$, DW = 1.92, SEE = 0.582, RHO = $\underset{(-2.6)}{-0.372}$.

---

[1] This interval of time begins after the German revaluation in March 1961 and concludes before the dollar peg was abandoned in May 1971.

---

[2] Below the coefficients we have reported t-statistics. The equation is a two-stage least squares estimate obtained by using the structurally ordered instrumental variable procedure. For a discussion of this procedure, see Fisher (1965) and Mitchell and Fisher (1970). An asterisk, "*", denotes variables which were treated as endogenous.

The coefficients of the domestic variables — $\%\Delta P$ and $\%\Delta O$ — reflect a conventional monetary policy of leaning against the wind: a 1% increase in the annual rate of inflation ($\%\Delta P$) will lead to a DM 137 million decrease[1] in effective bank reserves and a 1% increase

---

[1] This calculation and the ones that follow are based on the average value of q_{-1} over the sample period, 0.077.

---

in new orders (%ΔO), a leading cyclical indicator, will lead to a DM 165 million reduction in effective bank reserves (given the trend growth in income represented by ΔY^{tr}_{-1}). A 1% increase in trend income will lead to a DM 205 million increase in effective bank reserves (given the cyclical change in income represented by %ΔO) in order to finance the increased volume of economic activity.

The significance of the seasonal dummies illustrates the point that much of the variation in the monetary policy instruments is in defence of monetary stability rather than in active pursuit of other policy goals. Indeed, much of what any central bank does is directed at offsetting the effects on bank reserves of seasonal movements in such factors as currency in circulation, government tax receipts, and float.

4.3. Sterilization policy

The value of the sterilization coefficient, -0.913, indicates that the Bundesbank placed primary emphasis on pursuit of its domestic objectives rather than on the maintenance of external balance. During each quarter, approximately 90% of the change in foreign exchange reserves was sterilized. Thus despite the high interest-sensitivity of German capital flows, the authorities maintained a substantial degree of control over the German money supply.

Tests for stability, moreover, show that this sterilization policy was remarkably steady over the estimation period._/

_/ The sterilization coefficient was tested for stability in a variant of the Chow tests for stability between sets of coefficients. The test involves entering selected observations for ΔRFX' twice in the estimated equation. The entire series is entered as in equation (19) and, in addition, the selected observations are entered as part of a dummy variable in which the other observations are set equal to zero. The estimated coefficient of this dummy variable is the amount by which the sterilization coefficient shifted in the selected period. The coefficient of the dummy variable may be submitted to a conventional t-test to determine whether the shift in the sterilization coefficient is significantly different from zero in the selected periods. The results are reported in the following table:

_/ (cont.)

Tests for shifts in the sterilization coefficient

	Hypotheses	Test coefficient[a] (t statistic)
(1)	The degree of sterilization decreased after 1968	-0.107 (-1.20)
(2)	Large foreign exchange flows (i.e., flows larger than 10% of the monetary base) were less effectively sterilized than other foreign exchange flows.	-0.037 (-0.71)
(3)	Foreign exchange inflows were less effectively sterilized than outflows.	-0.010 (-0.26)

a) The coefficient reported is a_2, the coefficient of the product of ΔRFX and the appropriate dummy variable (D), in the following regression equation:

$$\Delta MP = a_1 \Delta RFX' + a_2(\Delta RFX'.D) + a_3 q_{-1}\%\Delta O_{-1} + a_4 q_{-1}\%\Delta P_{-1} + a_5 q_{-1}\Delta Y^{tr}_{-1} + a_6 S1 + a_7 S2 + a_8 S4.$$

None of the coefficients of the dummy variables is statistically different from zero; thus there is no evidence of a shift in the sterilization coefficient.

In addition, the sample period was split at the first quarter of 1968, a year in which flows of foreign exchange increased markedly and the reaction function was estimated over each part of the sample period. The results were submitted to a Chow (1960) test; there was no evidence of a structural shift.

The Bundesbank was able to sterilize flows of foreign exchange that were greater than 10% of the monetary base as readily as smaller flows, net inflows of foreign exchange as well as net outflows, and flows during the last quarter of the decade as effectively as during the first three quarters of the decade. Our findings thus suggest that German sterilization policy was consistently effective throughout the decade.

5. The trade off between monetary aut onomy and reserve stability

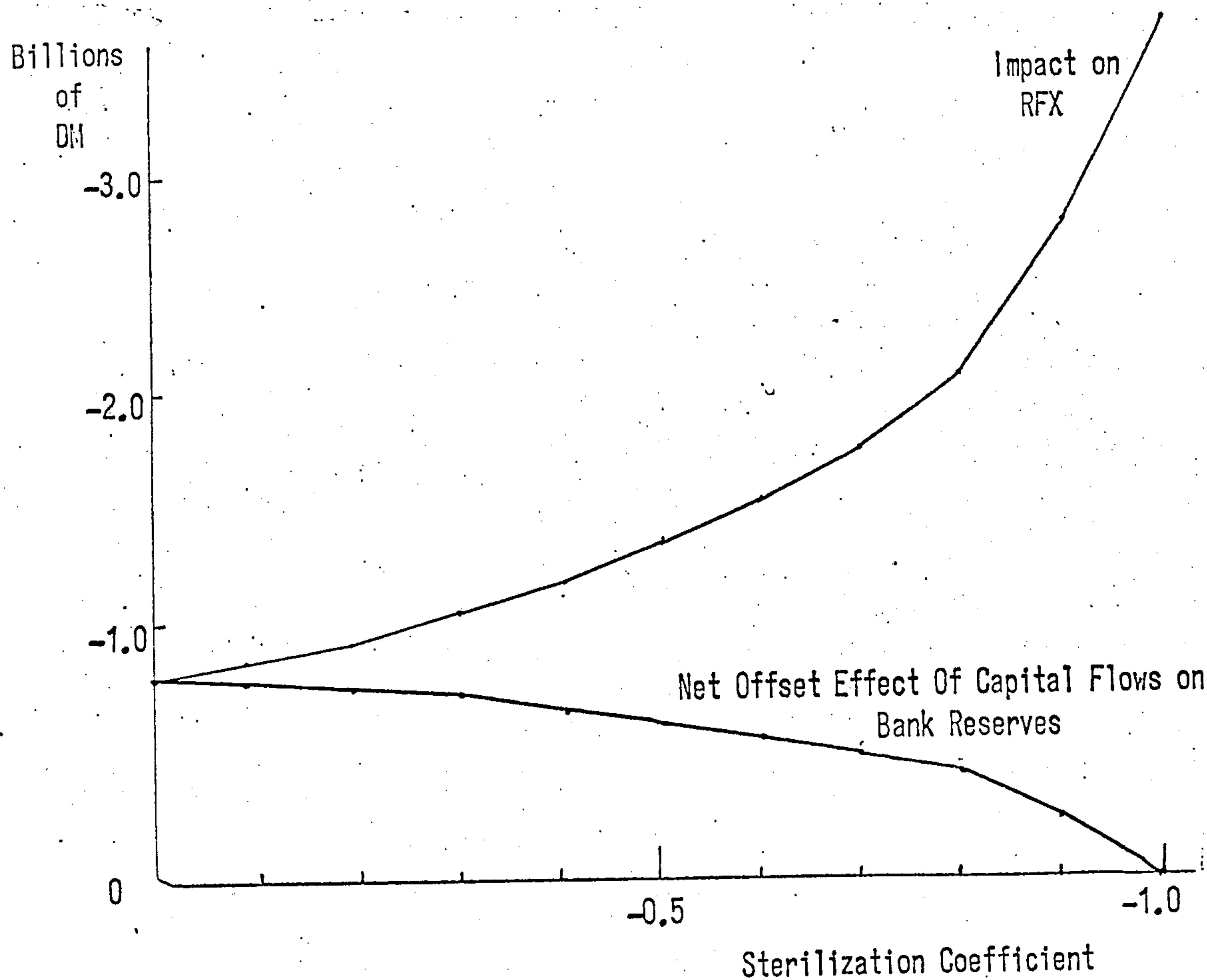
The Bundesbank's sterilization policy afforded it considerable scope to pursue domestic objectives. This degree of monetary autonomy, however, was purchased at a cost in terms of external imbalance. As shown in equation (13), an increased degree of sterilization reduces the net impact of capital flows on bank reserves, thus enabling the monetary authorities to better control bank reserves. But, as shown in equation (12), an increased degree of sterilization also amplifies the magnitude of offsetting capital flows; larger capital flows are induced because sterilization inhibits the adjustment of domestic interest rates relative to foreign rates.

Our structural model of the German monetary sector can be used to examine this trade-off between monetary autonomy and reserve stability. Figure (4) illustrates the response of the monetary sector to an initial increase in bank reserves by DM 1 billion. The two graphs show the implications of alternative sterilization policies (i.e., alternative values of the sterilization coefficient) for offsetting capital flows and for the net offsetting impact of capital flows on bank reserves.

The lower curve, representing the net offset effect on bank reserves, shows that as sterilization becomes more complete, an increasingly smaller amount of the initial increase in bank reserves is lost from the domestic banking system. In the extreme case, where sterilization is complete, the full
reserves stays in the domestic banking system and the net offsetting impact of capital flows on bank reserves is zero.

Complete sterilization, of course, would have enabled the German monetary authorities to determine bank reserves solely on the basis of domestic objectives. One reason that the Bundesbank did not choose to sterilize completely is suggested by the upper curve which shows the impact on foreign exchange reserves of alternative sterilization policies. When sterilization is complete, the impact of changes in monetary policy on foreign exchange reserves is largest. Even when no sterilization is attempted, the impact of a change in monetary policy on foreign exchange reserves is quite large: the

FIGURE 4: IMPACT OF INCREASE IN BANK RESERVES BY DM 1 BIL.



initial DM 1 billion increase in bank reserves leads to a decrease in foreign exchange reserves nearly 80% as large. The impact becomes even larger, however, as the degree of sterilization is increased. Indeed, the relationship between sterilization and the impact on reserves is non-linear; higher degrees of sterilization lead to more than proportionates losses in foreign exchange reserves.

Alternative sterilization policies thus have important implications for monetary autonomy and reserve stability. The more complete the degree of sterilization chosen, the greater the benefit in terms of enhanced control over domestic bank reserves, but also the greater the cost in terms of loss of control over foreign exchange reserves. While our empirical evidence has focused on the German economy, a similar choice between monetary autonomy and reserve stability confronts any economy where sterilization policy is feasible.

REFERENCES

Argy, V. and P. Kouri, 1974, Sterilization policies and the volatility in international reserves, in: R.Z. Aliber, ed., National monetary policies and the international financial system (University of Chicago Press, Chicago).

De Grauwe, P., 1975, The interaction of monetary policies in a group of European countries, Journal of International Economics, Aug., 207-228.

____________, 1977, Monetary independence among major European countries, in: R.Z. Aliber, ed., The Political Economy of Monetary Reform (MacMillan Press, London).

Fisher, F.M., 1965, Dynamic structure and estimation in economy - wide econometric models, in: J. Duesenberry et al., eds., The Brookings quarterly econometric model of the United States (Rand McNally, Chicago).

Girton, L. and D. Henderson, 1976, Financial capital movements and central bank behaviour in a two-country, short-run portfolio balance model, Journal of Monetary Economics, November, 33-62.

Herring, R.J. and R.C. Marston, 1977a, National monetary policies and international financial markets (North-Holland, Amsterdam).

____________________, 1977b, Sterilization policy and the stability of international capital flows, processed.

Kouri, P.J.K., 1975, The hypothesis of offsetting capital flows: A case study of Germany, Journal of Monetary Economics, 21-39

Kouri, P.J.K. and M.G. Porter, 1974, International capital flows and portfolio equilibrium, Journal of Political Economy 82, May/June, 443-467.

Mitchell, B.M. and F.M. Fisher, 1970, The choice of instrumental variables in the estimation of economy-wide econometric models: some further thoughts, International Economic Review 11, June, 226-234.

Porter, M.G., 1972, Capital flows as an offset to monetary policy: The German experience, International Monetary Fund Staff Papers XIX, July, 395-424.

Yeager, L.B., 1966, International monetary relations: Theory, history, and policy, (Harper and Row, New York).