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CROSS COUNTRY EFFECTS OF STERILIZATION, RESERVE CURRENCIES AND FOREIGN EXCHANGE INTERVENTION

Richard C. Marston

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ABSTRACT

This study examines the internaitonal repercussions of national sterilization policies under fixed exchange rates and managed flexibility. The effects of sterilization on the country pursuing the policy are well-known, but the adverse effects on other countries have not been adequately explored.

In this study, a stochastic framework is used to analyze the impact of balance of payments disturbances on key financial variables in the domestic and foreign countries. The effects of sterilization are explored under fixed rates, and the combined effects of foreign exchange intervention and sterilization are similarly investigated in a regime of managed flexibility. In either regime, sterilization by the foreign country imposes costs on the domestic country by magnifying the impact of balance of payments disturbances on the domestic financial market. The analysis has important implications for the use of reserve currencies: Countries issuing reserve currencies benefit from the automatic sterilization of their balance of payments surpluses or deficits, while countries using reserve currencies encounter the same cross country effects as with discretionary sterilization.

Richard C. Marston
W-124 Dietrich Hall
University of Pennsylvania
Philadelphia, PA 19104

215/243-7626

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The monetary authorities of many countries have adopted policies designed to shield their domestic markets from balance of payments disturbances. Under fixed exchange rates, sterilization policies have been aimed at neutralizing the impact of balance of payments disturbances on the domestic monetary sector. In the present system of managed flexibility, countries have combined more limited forms of foreign exchange intervention with sterilization to modify the impact of balance of payments disturbances on the exchange rate as well as domestic monetary variables. This paper examines the international repercussions of these policies.

In previous studies, De Grauwe (1975a, 1975b) and Aoki (1977) have investigated the cross country effects of sterilization. But these authors have confined their analyses to questions about the feasibility of sterilization and the stability of reserve flows.[1] In this paper, in contrast, sterilization behavior is evaluated in a stochastic context according to whether it increases or decreases the impact of balance of payments disturbances on each country's financial market.[2]

Sterilization is of interest not only because of its importance as a discretionary policy, but also because use of the dollar as a reserve currency results in the automatic sterilization of U.S. balance of payments surpluses or deficits.[3] In evaluating the cross country effects of sterilization, this study will also be showing how use of a reserve currency affects the behavior of interest rates and exchange rates in countries within a reserve currency system. With the coming of flexible exchange rates, sterilization and reserve currencies may seem to belong to

another era. But as this paper will show, sterilization activities have a significant influence on the behavior of interest rates and exchange rates whenever systematic intervention occurs in the foreign exchange market. The use of the dollar as a reserve currency similarly has an important bearing on how countries fare in such a system.

Section I introduces a two country financial model applicable to either fixed or flexible periods. Section II describes how balance of payments disturbances affect domestic monetary behavior, and how sterilization modifies the impact of those disturbances. The primary emphasis, however, is on how the domestic financial sector responds to increased sterilization in the foreign country. Section III extends the model to consider foreign exchange intervention under flexible exchange rates. Of particular interest is the destabilizing impact of conventional intervention on domestic interest rates, and the importance of sterilization in this setting. Cross country effects of sterilization are then examined under this modified form of flexibility. In both versions of the model, the role of a reserve currency is explored to determine how use of a reserve currency affects the stabilization task of each country.

I. A Simple Model of Monetary Equilibrium under Fixed and Flexible Rates

The model used to analyze financial policy includes four assets held by the public, all of which are imperfectly substitutable:[4] home currency or money (M), home securities (H), foreign currency (N), and foreign securities (F) denominated in the foreign currency (with exchange rate X). As indicated in Table 1, the public in the home country holds its own currency as well as both types of securities, whereas the monetary authority in the home country holds home and foreign securities, as well as

gold (G^m) and foreign currency (N^m). The monetary authority issues currency (M^s), while the home government and public both issue domestic securities. The public in the foreign country also holds both types of securities as well as its own currency. The foreign monetary authority issues the foreign currency (which is treated as a reserve currency in part of the analysis below), while the foreign government and public issue foreign securities.[5] Throughout the paper, the effects of financial disturbances on the real sector are ignored; income, employment and prices are assumed to be exogenously determined within the time frame examined.

The public's net demand for each asset is a function of the interest rate on home securities (i), the interest rate on foreign securities (r), the expected change in the exchange rate (z), and the level of wealth (W or W^f).[6] All asset demands and supplies are assumed to be strict gross substitutes; asset demands (supplies) are positively (negatively) related to the interest rate on that asset and negatively (positively) related to the returns on other assets. The equilibrium conditions for the four asset markets equate these net asset demands to the net supplies provided by the governments or the monetary authorities:

$$m(i,\ r+z)\ W = M^s = C\ G^m + H^m + X\ F^m + X\ N^m - A \tag{1}$$

$$h(i,\ r+z)\ W + X\ g(i-z,\ r)\ W^f = H^s - H^m \tag{2}$$

$$n(i-z,\ r)\ W^f = N^s = F^n + C^n\ G^n - N^m - A^n \tag{3}$$

$$e(i-z,\ r)\ W^f + f(i,\ r+z)\ W/X = F^s - F^n - F^m \tag{4}$$

Only three of these asset equilibrium conditions are independent because of the balance sheet constraints; the analysis to follow will focus on equations (1) - (3).

To simplify the study of stochastic disturbances, equations (1) - (3) are linearized around the equilibrium values of the interest rates (i_0, r_0), gold reserves (G_0^m), or the exchange rate (X_0) as follows:

$$\begin{bmatrix} M_i & -C & M_x & M_r \\ H_i & 0 & H_x & H_r \\ N_i & C^n & N_x & N_r \end{bmatrix} \begin{bmatrix} i - i_0 \\ G^m - G_0^m \\ X - X_0 \\ r - r_0 \end{bmatrix} = \begin{bmatrix} (H^m - H_0^m) + X(F^m - F_0^m) + X(N^m - N_0^m) \\ - (H^m - H_0^m) \\ (F^n - F_0^n) - (N^m - N_0^m) \end{bmatrix} \tag{5-7}$$

where M_j, H_j, N_j are the partial derivatives of the public's net asset demands with respect to j = i, X, r; for example, the derivatives of the money demand function for the home country are:

$$M_i = W\, m_i < 0, \qquad M_r = W\, m_r < 0,$$
$$M_x = [m(\ )\, F_0^P + W\, m_r\, z_x] > 0.^7$$

M_x, H_x, and N_x reflect the capital gains effects of changes in exchange rates as well as the effects of changes in exchange rate expectations on asset demands. In a fixed rate regime, the three equilibrium conditions determine the two interest rates and the gold reserves of the home monetary authority (as well as the gold reserves of the foreign monetary authority since the world supply of gold is assumed to be constant). Gold is chosen as the reserve asset under fixed exchange rates so that later in the analysis the significance of a reserve currency can be explored. Under flexible exchange rates, i, r, and X are determined.

II. Fixed Exchange Rates: Sterilization and the Reserve Currency

The behavior of the model under fixed exchange rates is summarized in Figure 1. To simplify the geometric analysis, the model has been solved in terms of the two domestic variables only: the interest rate and the gold reserves of the home country, so the curves in the figure implicitly reflect the adjustment of the foreign interest rate. MM represents the locus of points where the demand and supply of money are in equilibrium. A higher level of gold reserves (attributable, for example, to an exogenous shift in demand from foreign bonds to home bonds) increases the money supply, while a lower interest rate increases the demand for money to restore equilibrium to this market.[8] HH represents equilibrium in the home securities market. A higher level of gold reserves (attributable, for example, to a shift in demand from foreign bonds to domestic money) has no direct effect on the supply of home securities, but it increases the foreign interest rate (by reducing the supply of money in the foreign country); a higher foreign interest rate must be accompanied by a higher home interest rate to equilibrate this market, so HH is upward sloping.[9]

A. Sterilization Policy

The policy of sterilization has traditionally been designed to neutralize the domestic monetary impact of balance of payments disturbances. Section II will discuss how domestic or foreign sterilization, alternatively, modifies the impact of balance of payments disturbances on the home interest rate and the gold reserves of the domestic monetary authority.

The balance of payments disturbances to be studied are capital account disturbances involving shifts in asset demands between foreign and domestic securities.[10] The disturbances, u_h and u_f, represent random shifts in the

home and foreign securities equations (2,4) with $E(u_h) = E(u_f) = 0$, $E(u_h^2) = \sigma_h^2$, $E(u_f^2) = \sigma_f^2$, $E(u_h\ u_f) = \sigma_{hf} = -\sigma_h\sigma_f$. Both disturbances are defined as excess supply shifts so that, for example, a shift in asset demands from home to foreign securities is described by $u_h = u_f > 0$.

In the presence of such disturbances, the monetary authority in either country can institute policy rules which reduce the impact of the disturbances on financial variables. One traditional policy aimed specifically at balance of payments disturbances is the sterilization or neutralization of the effects of gold reserve flows on the money supply.[11] If the domestic monetary authority is active in sterilizing, then its holdings of home securities vary <u>inversely</u> with changes in its gold reserves:

$$H^m - H_0^m = S\ C\ (G^m - G_0^m). \tag{8}$$

Alternatively, if the foreign monetary authority sterilizes, then its holdings of foreign securities vary inversely with changes in its gold reserves:

$$F^n - F_0^n = S^f\ C^n(G^n - G_0^n) = -\ S^f\ C^n(G^m - G_0^m) \tag{9}$$

In each case, the sterilization coefficient, S or S^f, generally varies between zero and negative one (complete sterilization).

To study both own and cross country effects of sterilization, the model is solved to express the <u>home</u> interest rate and gold reserves in terms of the sterilization coefficients and the disturbances:[12]

$$i - i_0 = [X\ (1+S)\ N_r + (1+S^f)\ M_r]u_h/K \tag{10}$$

$$G^m - G_0^m = [M_i\ N_r - M_r\ N_i]u_h/(C^n\ K), \tag{11}$$

where $K = (M_i N_r - N_i M_r)XS + (H_i M_r - M_i H_r)(1+S^f) + (H_i N_r - N_i H_r)X(1+S)$. Each of these expressions incorporates the adjustment of the foreign interest rate to the other financial variables. The variances of i and G^m can be expressed as:

$$\sigma_i^2 = [X(1+S)N_r + (1+S^f)M_r]^2 \sigma_h^2/K^2 \quad (12)$$

$$\sigma_G^2 = [M_i N_r - M_r N_i]^2 \sigma_h^2/(C^n K)^2 \quad (13)$$

The own and cross country effects of sterilization are examined by differentiating these expressions with respect to the two sterilization coefficients, S and S^f, respectively.

B. Effects of Domestic Sterilization on the Domestic Country

Shifts between domestic and foreign securities lead to changes in domestic gold reserves, the domestic money supply and interest rate. Equations (12) and (13) indicate that the variances of G^m and i are proportional to the variances of the underlying disturbances ($\sigma_h^2 = \sigma_f^2 > 0$).

Greater sterilization (a lower S), however, reduces the variance of the interest rate associated with any given disturbance. This should come as no surprise, since the purpose of the sterilization policy is to shield the domestic monetary sector from that type of disturbance. What is interesting is that increased sterilization has a cost attached to it; as sterilization increases, there is an increase in the variance of foreign exchange reserves. Consider the case of a shift in asset demands from domestic securities to foreign securities: The monetary authority can neutralize the impact of any decline in gold reserves on the domestic money supply by purchasing domestic securities from the public. But these purchases of domestic securities induce additional outflows of gold through

the well-known offset effect associated with any open market purchase. The monetary authority, in effect, reduces interest rate (and money supply) variability only by incurring greater variability in its gold reserves. (This result will be illustrated below for the case of foreign sterilization). Because sterilization has this effect on foreign exchange reserves, the monetary authority may choose to stop short of complete sterilization.[13]

C. Effects of Foreign Sterilization on the Domestic Country

Sterilization has its desired effect upon the interest rate of the country pursuing the sterilization policy. But sterilization makes the task of the other monetary authority more difficult. To examine this cross country effect, the response of σ_i^2 to foreign sterilization is investigated.

The effect of foreign sterilization is illustrated in Figure 1. Foreign sterilization reduces the slope of the home securities curve from HH to H*H*, since it reduces the adjustment of the foreign interest rate to any disturbance. The MM schedule is unaffected by foreign sterilization policy if we adopt the simplifying assumption that the demand for money in each country is not directly sensitive to the interest rate in the other country.[14]

The effect of the capital account disturbance (a shift from domestic to foreign securities) is also illustrated in Figure 1. This disturbance raises the home securities curve by the same vertical distance with or without sterilization (to H'H' or H*'H*'). Without foreign sterilization, the intersection of the curves shifts to P_1. At P_1, the domestic interest rate is higher and the gold reserves of the home country lower than before

the disturbance; since the gold reserves of the foreign country correspondingly rise, the foreign interest rate falls (not shown).

If the foreign monetary authorities choose to sterilize, the outflow of reserves from the home country is larger (because of the offset effect) than with no sterilization. So the domestic money supply and interest rate must adjust even more to the capital account disturbance. With foreign sterilization, point P_2 is reached: i rises more and G^m falls more than with no sterilization.

The effects of foreign sterilization illustrated in Figure 1 hold analagously for the variances of i and G^m. Foreign sterilization increases the variances of the home interest rate as well as the foreign exchange reserves of both countries at the same time that it reduces the variance of the foreign interest rate. The choice of a sterilization policy thus inevitably involves a conflict of interest between domestic objectives and international responsibility. Increased variability of foreign exchange reserves hurts all countries collectively, while the sterilizing country alone gains the advantage of less variability in interest rates.

If the currency of the foreign country is a reserve currency, then any foreign exchange flows will be automatically sterilized as long as the home country invests its reserves in the foreign security.[15] The reserve currency country, in effect, has a sterilization coefficient of -1 even in the absence of an active sterilization policy of its own. In response to capital account disturbances, therefore, the home country experiences greater variability of interest rates and foreign exchange reserves than in a gold system. The use of a reserve currency thus creates additional problems of stabilization for countries in the system other than the reserve currency country.

III. Flexible Exchange Rates With Exchange Market Intervention

Under the flexible exchange rate system currently in effect, sterilization or the use of a reserve currency continues to be of importance since the monetary authorities of many countries pursue systematic intervention policies. Intervention in the exchange market may be quite extensive if capital account disturbances are a major problem. This section will consider the effects of exchange market intervention in the presence of sterilization or a reserve currency upon the variance of interest rates as well as exchange rates.

The behavior of the model is summarized in Figure 2. HH represents the locus of points where the market for home securities is in equilibrium. A higher exchange rate (appreciation of the foreign currency) increases the wealth of the domestic public (measured in home currency) and reduces the (foreign currency) value of the foreign public's holdings of home securities. For both reasons, the demand for home securities rises.[16] To restore equilibrium to the securities market, the interest rate must fall and thereby reduce the demand for home securities. Hence HH is downward sloping. MM similarly represents equilibrium in the home currency or money market. A higher exchange rate increases the demand for money because it raises domestic wealth. A higher interest rate on home securities serves to restore this market to equilibrium.[17]

A. Exchange market intervention

Intervention in the exchange market may take a variety of forms. Sometimes the monetary authority seeks to postpone or even prevent trend movements in the exchange rate. In that case, financial behavior resembles the fixed rate model of Section II more than a flexible model. But much of

the day to day intervention is of a different type; the monetary authorities attempt to modify fluctuations in the exchange rate with so-called "leaning against the wind" policies. The authorities seek to reduce the impact of disturbances originating in the private sector by continuous intervention designed to moderate the resulting exchange rate movements.[18]

The simplest form of intervention involves the purchase or sale of foreign currency (N^m) to counter movements in the exchange rate:[19]

$$(N^m - N_0^m) = \frac{E(X - X_0)}{X} , \tag{14}$$

where $E < 0$ is the intervention coefficient. How intervention policy affects the financial sector depends upon whether or not the impact of the foreign exchange flows on the money supply is sterilized by the monetary authority. If sterilization in the home country is pursued, then an increase in holdings of foreign currency will be accompanied by an open market sale of home securities by the monetary authority so that

$$H^m - H_0^m = S\ X(N^m - N_0^m), \tag{15}$$

where S is the sterilization coefficient. If there is complete sterilization ($S = -1$), then the foreign exchange intervention has no net impact on the domestic money supply. If the <u>foreign</u> monetary authority pursues a sterilization policy, then it purchases foreign securities when the home monetary authority buys foreign currency in the exchange market.[20]

$$F^n - F_0^n = -\ S^f(N^m - N_0^m), \tag{16}$$

The foreign money supply available to the public declines when the home monetary authority intervenes in the exchange market, but it is (partially) restored by the sterilization operation.

The effects of these policies on the stochastic behavior of the financial sector can be analysed by expressing the home interest rate and exchange rate in terms of the intervention and sterilization coefficients and the disturbances.[21] The variances of i and X can be expressed as:

$$\sigma_i^2 = [M_r(N_x + E(1+S^f)) - N_r(M_x - E(1+S))]^2 \sigma_h^2/(K')^2, \quad (17)$$

$$\sigma_x^2 = [M_i N_r - M_r N_i]^2 \sigma_h^2/(K')^2, \quad (18)$$

where $K' = (M_iN_r - N_iM_r)[H_x + ES] + (H_iM_r - M_iH_r)[N_x + E(1+S^f)]$
$+ (H_rN_i - H_iN_r)[M_x - E(1+S)]$.

B. Domestic Sterilization Policies

This section will investigate the importance to the domestic country of sterilization or the use of a reserve currency under a regime of managed flexibility. To distinguish the effects of foreign exchange intervention from sterilization, two sets of policies will be examined. First, the effects of intervention alone are analysed. Then this policy is contrasted with a policy of intervention combined with complete sterilization of reserve flows. (This combined policy is probably most easily thought of as a direct exchange of home securities for foreign currency).[22] To simplify the analysis of the two policies, the foreign interest rate is assumed to be exogenously fixed so that only i and X respond to the capital account disturbances.[23] In the next section, the cross country effects of intervention and sterilization will then be investigated.

1. Intervention without sterilization

This policy of foreign exchange intervention is designed to modify fluctuations in the exchange rate, and indeed a higher degree of intervention (E larger in absolute value) reduces the variance of the exchange rate.[24] What is not so apparent is that foreign exchange intervention increases the variance of the home interest rate. The domestic monetary authority, in effect, gains greater control over the exchange rate by accepting greater fluctuations in the interest rate.

The effect of the intervention policy is illustrated in Figure 2. Since no sterilization is involved, the intervention policy affects only the money market directly. As the degree of intervention is increased, the slope of MM increases: A rise in the exchange rate, for example, induces the domestic monetary authorities to buy domestic currency to limit the appreciation. The domestic money supply available to the public declines, so the domestic interest rate rises more than in the case of no intervention.

In response to a capital account disturbance (involving a shift from home to foreign securities), the home securities curve shifts upward to H'H'. With no intervention, point P_1 is reached, whereas intervention results in point P_2 being reached. With intervention, therefore, the exchange rate rises by less, but the interest rate rises by more because of the decline in the domestic money supply associated with foreign exchange intervention.

2. Intervention with sterilization

If sterilization operations are continued as under fixed exchange rates or if the home currency is used as a reserve currency, then foreign

exchange intervention has quite different effects than in the case of simple intervention. The effects of the combined policy of intervention and sterilization can be determined by setting S = -1 in the expressions above.

As intervention is increased (E increased in absolute value), the variance of the exchange rate is reduced as in the previous case.[25] But now the variance of the interest rate is reduced as well because of the sterilization policy.

Figure 3 illustrates the effects of the combined policy. When intervention is combined with complete sterilization, the domestic money supply is unaffected by the intervention operations, so MM is unchanged. The combined policy, however, does change the slope of the home securities curve (HH to $H^{*}H^{*}$) since this policy changes the supply of home securities available to the public.

When the exchange rate rises due to a capital account disturbance (an upward shift of HH or $H^{*}H^{*}$), the interest rate as well as the exchange rate rise less with the combined policy than without: Recall that the capital account disturbance involves a reduction in the demand for domestic bonds in favor of foreign bonds. The combined policy reduces the supply of domestic bonds held by the public, thereby helping to reduce the excess supply of domestic bonds created by the disturbance. With this policy, therefore, less adjustment of the domestic interest rate is required to restore equilibrium to the domestic bond market.

The two cases demonstrate the effectiveness of foreign exchange intervention in reducing the variance of the exchange rate. But more importantly, comparison of the two cases shows that sterilization or the use of a reserve currency continues to be effective in reducing the

variance of the home interest rate when exchange rate flexibility is combined with limited intervention. The next section investigates the cross country effects of such sterilization.

C. The Impact of Foreign Sterilization and the Reserve Currency Role

Section II showed that under fixed exchange rates, the use of a reserve currency or a sterilization policy in one country can adversely affect financial markets in other countries. This section will extend the analysis of cross country effects to a regime of flexible exchange rates with systematic intervention. We will examine how an increase in foreign sterilization affects the variances of the home interest rate and exchange rate associated with any given degree of foreign exchange intervention.

In the absence of foreign sterilization, a capital account disturbance involving a shift out of domestic bonds into foreign bonds results in a fall in the foreign interest rate along with increases in the exchange rate and domestic interest rate as shown earlier. The degree of foreign exchange intervention (E), of course, influences how much the exchange rate changes, but the qualitative effects of the disturbance on the exchange rate and interest rates remain the same whatever the degree of intervention (except in the limiting case where intervention keeps the exchange rate fixed).

Foreign sterilization (S^f) reduces the adjustment of the foreign interest rate to the disturbance by neutralizing the impact of foreign exchange intervention on the foreign money supply. As a result, more of the burden of adjustment is thrown on the domestic interest rate and the exchange rate.[26] With the adjustment of one interest rate curtailed, the other interest rate as well as the exchange rate must adjust more to

eliminate the excess supply of domestic bonds associated with the capital account disturbance.[27] Along with increased variability of the exchange rate, greater foreign sterilization increases the variability of foreign exchange reserves just as under fixed exchange rates.

These results can be obtained formally by differentiating (17) and (18) with respect to S^f. For any given level of foreign exchange intervention, foreign sterilization raises the variances of the home interest rate and the exchange rate. The foreign country succeeds in lowering the variance of its interest rate through sterilizing the foreign exchange flows associated with exchange market intervention. But as under fixed exchange rates, foreign sterilization imposes costs on the domestic country by magnifying the effects of capital account disturbances on the home interest rate; and like its domestic counterpart, sterilization by the foreign monetary authority increases the variance of the exchange rate.

As under fixed exchange rates, sterilization can be automatically achieved by the foreign country if the domestic country holds its foreign exchange reserves as interest-bearing assets in the foreign country. To avoid such automatic sterilization, the domestic country must hold its reserves in gold or other outside assets or in the currency of the foreign country. The form in which international reserves are held still matters under flexible rates as long as foreign exchange intervention remains important.

IV. Conclusion

This paper has investigated the cross country effects of sterilization in a stochastic context where the response of domestic and foreign financial markets to capital account disturbances could be explicitly

examined. The analysis has shown that sterilization by one country has adverse effects upon the financial markets of other countries. Thus an attempt to pursue an independent monetary policy imposes costs on other countries. These costs, moreover, are automatically imposed on countries using a reserve currency.

Because sterilization continues to have undesirable cross country effects under managed floating, proposals such as McKinnon's (1974) that all reserve currencies be held as (interest-bearing) deposits at central banks should be accorded renewed attention. Under these proposals, no automatic sterilization would occur in response to payments flows, and so countries using reserve currencies could avoid such cross country effects.

FOOTNOTES

[1]Both authors evaluated the effects of sterilization in multi-country difference equation models of offset and sterilization behavior; they asked whether sterilization in more than one country is consistent with a stable solution for the multi-country model.

[2]The stochastic framework is similar to that used by Poole (1970) to analyse optimal financial policies in a closed economy. A recent paper by Boyer (1978) extends Poole's analysis to consider optimal policies in an open economy, while papers by Santomero and Siegel (1978) and Siegel (1978) use a stochastic framework to analyse the effects of changes in banking regulation on monetary control.

[3]For evidence on discretionary sterilization behavior, see Herring and Marston (1977). The automatic sterilization feature of reserve currencies is discussed in Section II below.

[4]For a fixed rate version of this model, see Chapter 2 of Herring and Marston (1977). The modelling of flexible rate behavior is similar to Branson (1976) and especially Girton and Henderson (1976). For models based on the assumption of perfect substitution between assets see Dornbusch (1976a, 1976b). Isard (1978) presents an incisive survey of flexible rate models.

[5]The foreign monetary authority has an abbreviated balance sheet since the analysis below will not consider changes in its holdings of domestic currency or domestic securities.

[6]The home public's (net) demand for home securities, for example, is given by $H^{pd} - H^{ps} = h(i, r+z)W$, while the foreign public's demand for the home security is given by $H^{f} = X\ g(i-z, r)W^{f}$.

[7]The derivatives of the underlying money demand function are denoted by m_i, m_r for the first and second arguments, respectively. M_x is positive as long as z_x, the partial derivative of the expectations function, $z = z(X,...)$, is less than or equal to zero, which would be the case under a variety of expectations hypotheses. The hypothesis about exchange rate expectations will be specified below.

[8]Since MM reflects adjustments in the foreign interest rate, its slope depends upon the response of the demand for money in each country to both interest rates:

$$\left.\frac{d\,i}{d\,G^m}\right|_{MM} = \frac{(C\,N_r + C^n\,M_r)}{(M_i N_r - M_r N_i)} .$$

For MM to be negative, we require in addition to gross substitutibility that $M_i\,N_r - M_r\,N_i > 0$; this inequality will hold as long as the public in each country regards the security denominated in its own currency as a better substitute for its money than the security denominated in the other currency.

[9]The slope of HH is given by

$$\left.\frac{d\,i}{dG^m}\right|_{HH} = \frac{C^n\,H_r}{(H_i\,N_r - H_r\,N_i)} > 0.$$

[10]Other capital account disturbances involve portfolio shifts between home (or foreign) currency and the foreign (home) security. Such disturbances are likely to be of much less empirical importance, and so are ignored here.

[11]Note that in the limiting case of perfect substitution between home and foreign securities, sterlization is not feasible because (incipient) changes in interest returns brought about by sterilization operations lead to (potentially) infinite substitution between securities.

[12]The expressions describing sterlization behavior (8 and 9) are first substituted into equations (5-7) with $(X - X_0)$ set equal to zero. Then the three equations are solved for $(i - i_0)$ and $(G^m - G^m_0)$.

[13]The capital flows induced by an open market operation (through changes in interest rates) lead to offsetting changes in gold reserves and the money supply. For a description of this offset effect, see Chapter 2 of Herring and Marston (1977). Herring and Marston (1978) present empirical estimates of how sterilization affected control over bank reserves and foreign exchange reserves in Germany during the 1960's. According to these estimates, sterilization has a proportionately greater effect on foreign exchange reserves as the degree of sterilization is increased, so there is a strong incentive to adopt a policy of only partial sterilization.

[14]That is, $M_r = N_i = 0$. The conclusions below continue to hold with the less stringent assumption that $M_i\,N_r - M_r\,N_i > 0$.

[15]Consider a shift by the foreign public from foreign to home securities. In a gold reserve system, the foreign country would lose gold reserves to the home monetary authority, and its money supply would accordingly decline (in the absence of sterilization). In a reserve currency system, however, the home monetary authority invests its reserves in the foreign security, thereby restoring the foreign money supply to its initial value. McKinnon (1974, pp. 15-16) presents a clear description of how automatic sterilization takes place in a reserve currency regime.

[16]The effect of exchange rate expectations on asset demands would reinforce the wealth effect if expectations were regressive (so that a rise in the exchange rate leads to a reduction in z). With the serially uncorrelated disturbances assumed here, however, rational expectations based on this model would require that $z = 0$ (so that the exchange rate is expected to remain constant at its new value following the disturbance).

[17]For MM to have a positive slope when adjustment of the foreign interest rate is taken into account, it is necessary that $M_i N_r - M_r N_i > 0$ (the same condition required for the slope of MM under fixed exchange rates in Section II).

[18]Evidence of such intervention is widespread. At the Rambouillet summit conference in November 1975, for example, the six largest industrial countries agreed that the "monetary authorities will act to counter disorderly market conditions or erratic fluctuations in exchange rates." (See Deutsche Bundesbank, 1975, p. 49). In carrying out this policy, the Deutsche Bundesbank has "tried... not only to prevent erratic variations in the rate from day to day but also to smooth unduly large fluctuations in the rate of the Deutsche Mark against the dollar over longer periods." (Deutsche Bundesbank, 1975, p. 50). Similarly, in the United Kingdom, "official intervention on behalf of the Exchange Equalisation Account (has been) frequently used to moderate the effect of... strong influences on sterling's exchange rate." (Bank of England, 1976, p. 11).

[19]In this section, the monetary authorities are assumed to conduct their exchange market operations by selling or buying currencies, but they may still hold their foreign exchange reserves in gold (or in foreign securities when the reserve currency case is discussed).

[20]It would not make any difference to the results if the foreign monetary authority instead of the home authority intervened in the exchange market.

[21]As in Section II, the resulting equations reflect the adjustment of the foreign interest rate to the disturbances. The expressions describing intervention and sterilization behavior (14-16) are first substituted in equations (5-7) with $G^m - G_0^m$ set equal to zero. Then the three equations are solved for $(i - i_0)$ and $(X - X_0)$. Note that the intervention function (14) can be rewritten:

$$X\,(N^m - N_0^m) = X_0\,(N^m - N_0^m) + (X - X_0)(N^m - N_0^m) = E\,(X - X_0).$$

In modifying the equilibrium condition for foreign money (7) to account for intervention, we assume that the initial value of the exchange rate, X_0, is equal to unity and ignore the second order term, $(X - X_0)(N^m - N^m_0)$.

[22]The intervention operation (exchange of two currencies) and domestic sterilization operation (exchange of home securities for home currency) is equivalent to a direct exchange of home securities for foreign currency.

[23]In this case, the expressions for σ_i^2 and σ_x^2 simplify to:

$$\sigma_i^2 = [M_x - E(1+S)]^2 \sigma_h^2/(J)^2 \qquad (17')$$

$$\sigma_x^2 = M_i^2 \sigma_h^2/(J)^2 \qquad (18')$$

where $J = M_i[H_x + E\,S] - H_i[M_x - E(1 + S)] < 0$.

[24]This can be seen by differentiating (18') with respect to E (setting S=0).

[25]Note, however, that if the monetary authority opts for greater sterilization, then this policy raises the variance of the exchange rate associated with any given intervention policy (E).

[26]Throughout this section, we continue to assume that the demand for money in each country is not directly sensitive to the interest rate in the other country. The conclusions in the text about the effect of foreign sterilization on the variance of i continue to hold under the weaker assumption that $-M_rH_x < H_r(E - M_x)$. This inequality is more likely to hold the greater is the degree of foreign exchange intervention (E) and the more highly substitutable are H and F (and the less highly substitutable M and F). Even if this inequality is reversed, however, foreign sterilization still raises the variance of the home country's <u>money supply</u> (as long as $M_iN_r - M_rN_i > 0$, as assumed in Section II). That is, if σ_m^2 is the variance of the home country's money supply, then

$$\sigma_m^2 = [E(1+S)(M_iN_r - M_rN_i)]^2 \sigma_h^2/(K')^2 \qquad (19)$$

is increased when S^f is increased in absolute value. Thus increased foreign sterilization would still have a destabilizing impact on one important domestic monetary variable.

[27]This case can be illustrated with a diagram similar to Figure 3. With increased foreign sterilization, HH becomes flatter (the opposite of the domestic sterlization case illustrated in Figure 3). A capital account disturbance thus raises i and X further as foreign sterilization is increased.

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Table 1

Sectoral Balance Sheets

Home Public	
M	W
H^{pd}	H^{ps}
XF^{p}	

Home Monetary Authority	
C G^{m}	M^{s}
H^{m}	A
XF^{m}	
XN^{m}	

Foreign Public	
N	W^{f}
H^{f}/X	F^{fs}
F^{fd}	

Foreign Monetary Authority	
F^{n}	N^{s}
$C^{n}G^{n}$	A^{n}
	N^{m}

Notes: The superscript p denotes the home public, f the foreign public, d demand, s supply, m the home monetary authority, and n the foreign monetary authority. X is the home currency price of foreign currency, while C and C^{n} are the home and foreign currency prices of gold, respectively. A, A^{n} are balancing items which offset changes in X, C and C^{n} in the monetary authorities' balance sheets. The total supply of gold in the world is fixed at $\bar{G} = G^{m} + G^{n}$.

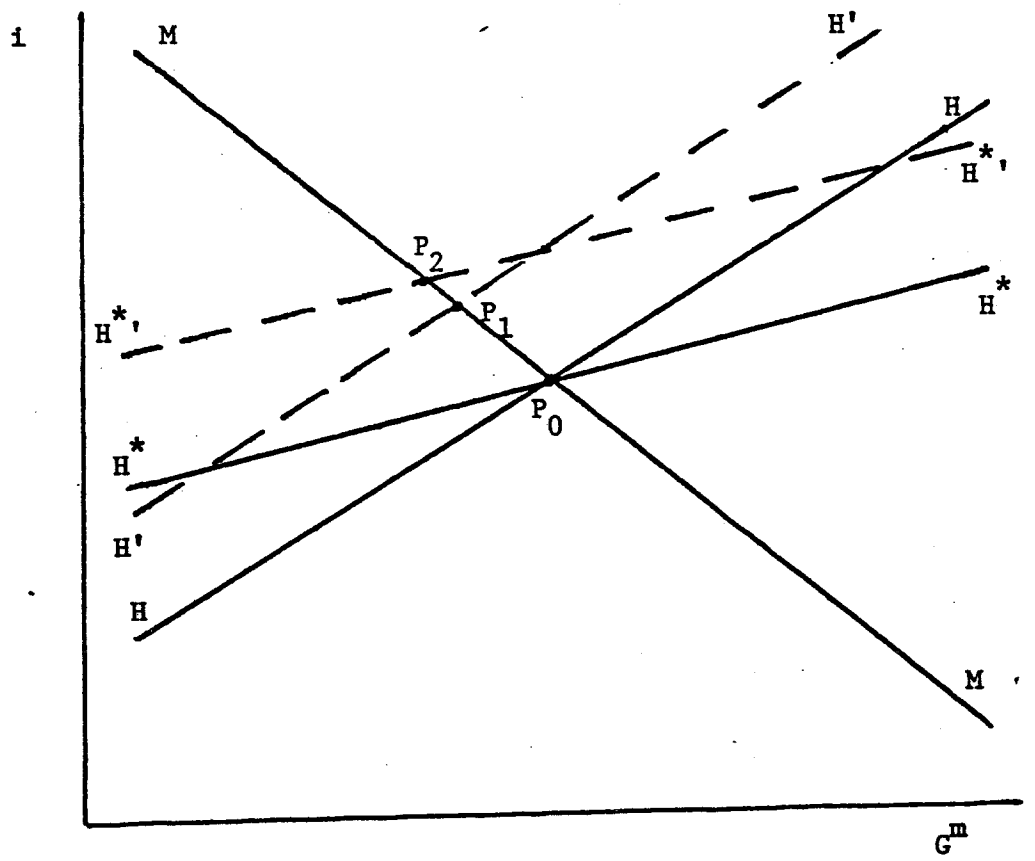

Figure 1

Impact of Capital Account Disturbances with No Sterilization and with Foreign Sterilization Policies

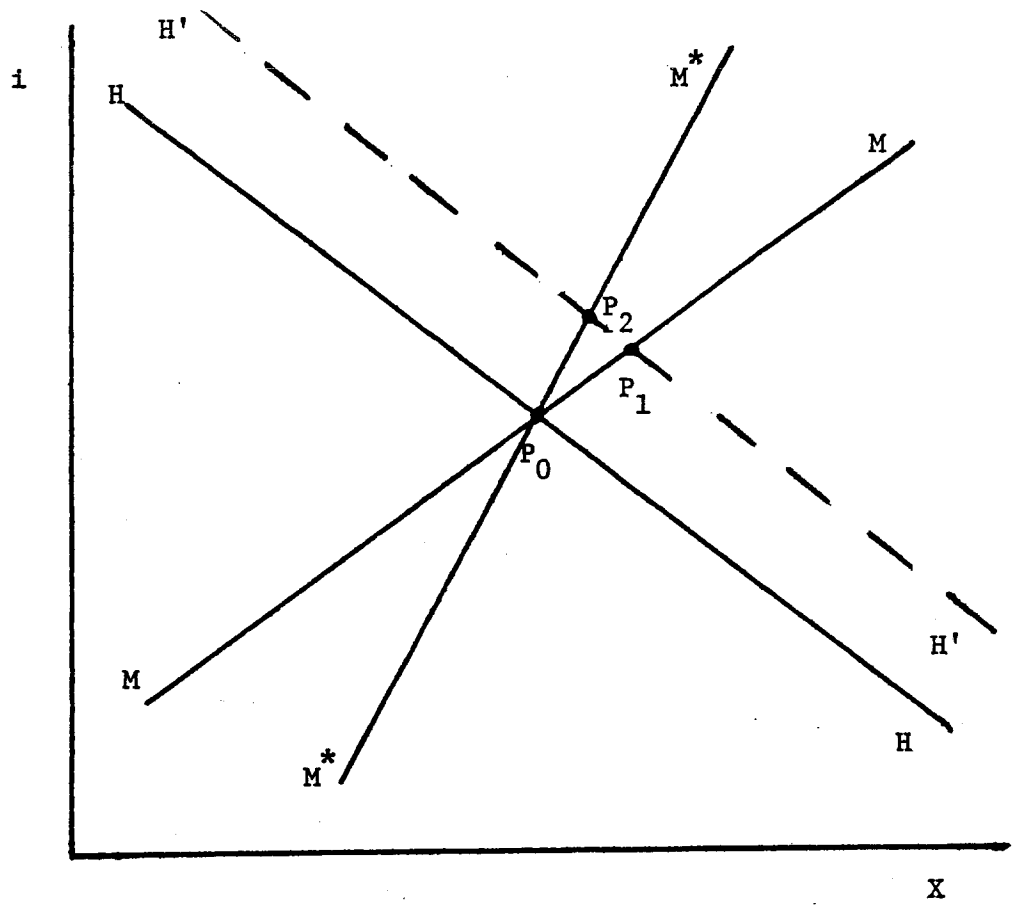

Figure 2

Impact of Disturbances with No Intervention and with Foreign Exchange Intervention

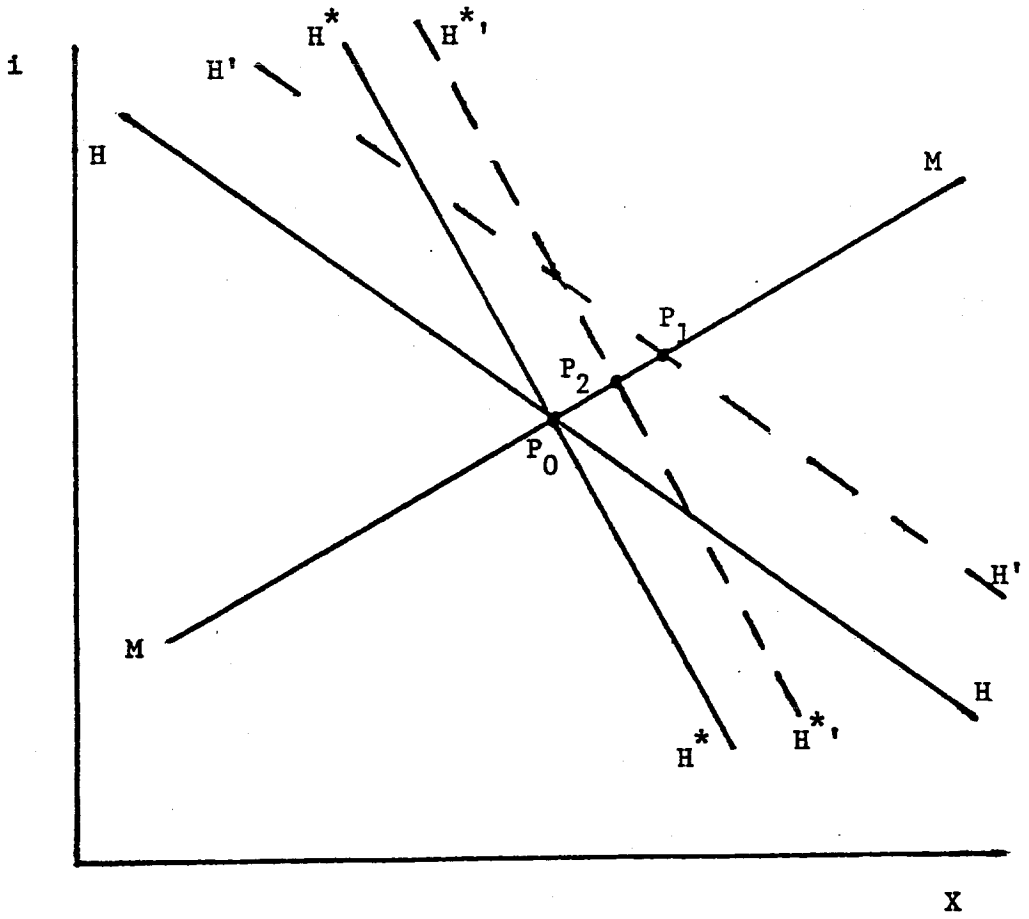

Figure 3

Impact of Disturbances with No Intervention and with a Combined Policy of Foreign Exchange Intervention and Domestic Sterilization