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10 Sterilization and Monetary Control: Concepts, Issues, and a Reduced-Form Test

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Monetary-approach models characteristically assume that goods, assets, or both are perfect substitutes internationally. For a nonreserve country maintaining pegged exchange rates, this implies that the central bank has no control over or influence on the country's money supply but only determines how the demand-determined quantity is supplied by reserve flows and domestic credit creation. The successful exercise of monetary control under pegged exchange rates therefore contradicts the monetary approach and the assumption that goods, assets, or both are perfect substitutes internationally.

The above argument provides the basis for this chapter's tests of the monetary approach to the balance of payments.[1] Before proceeding to the empirical tests, it is necessary to formulate a general model which is consistent with the possible exercise of monetary control but which subsumes the monetary approach as a special case. Because the observed negative correlation between reserve flows and domestic-credit changes can be explained by sterilization policies as well as the monetary-approach channels, it is important that the general model allow for sterilization policies whether or not monetary control is present.

Standard monetary-approach discussions assume that no sterilization operations are attempted by the central banks of nonreserve countries.[2] Although a number of authors have noted that sterilization policies may

1. These tests supplement—and confirm—the empirical results from the Mark III International Transmission Model. As reported in part II of this volume, direct structural estimates indicated that neither goods nor assets were perfect substitutes internationally. Thus, contrary to the monetary approach, nonreserve central banks exercised a degree of monetary control within the quarter.

2. To cite the locus classicus, see, for example, Frenkel and Johnson (1976, passim, esp. pp. 152–53). An important recent exception is a theoretical analysis by Boyer (1979) which uses a portfolio-balance approach.

bias empirical tests of the monetary approach,[3] adherents of the approach have argued that sterilization is neither significant in magnitude nor an important source of bias.[4] Other authors are less sanguine about the impossibility and insignificance of sterilization.[5] In particular, the estimates of the Mark III International Transmission Model, reported in chapter 6 above, indicate that the direct effects on national money supplies are very largely sterilized by offsetting transactions in domestic credit instruments.

Since the no-sterilization (or exogenous-domestic-credit) assumption is both factually untrue and controversial, it appears to be an obfuscating rather than simplifying assumption. It will be shown in section 10.1 below that a simple monetary-approach model can be presented without any reliance on this assumption or the ancillary concept of domestic credit. Only if sterilization is complete can one infer anything about the presence or absence of monetary control.

Section 10.1 outlines the general model incorporating sterilization which encompasses as a special case a modified version of the monetary approach in which both reserve flows and domestic-credit flows are endogenous variables. Generally, nonreserve central banks can exercise control over their domestic money supply in the short run unless certain conditions which imply validity of the monetary approach are met. In this monetary-approach special case, central bank attempts to exercise monetary control are futile and instead simply induce exaggerated reserve flows.

Section 10.2 presents a simple direct test of whether determinants of monetary policy other than the current balance of payments influenced the nominal money supply given foreign variables determining money demand. For quarterly data of seven countries in our sample (Canada, France, Germany, Italy, Japan, the Netherlands, and the United Kingdom), all but the Netherlands showed clear evidence that monetary control was, in fact, exercised under the Bretton Woods system of pegged exchange rates. This evidence is strongly inconsistent with the validity of

3. See, for example, Argy and Kouri (1974), Magee (1976), Maddala (1977, p. 253), and Darby (1980).

4. I can find no substantial basis for the denigration of the existence of substantial sterilization policies (implicit in money growth or interest-rate goals) beyond the assertion that they are impotent and therefore irrational (see, for example, quotations in footnotes 7 and 9). In much cited pieces, Argy and Kouri (1974) and Genberg (1976) used rudimentary reaction functions and quarterly data to obtain significant estimates of sterilization, but this did not lead to substantial changes in the relevant monetary-approach coefficients. Connolly and Taylor (1979) came to similar conclusions using both annual and biennial observations. Stockman (1979) used a sophisticated reaction function, but again came to the same conclusion. The basic flaw in these tests is discussed below in footnote 16.

5. For example, from their review of the earlier literature on sterilization and monetary control, Sweeney and Willett (1976, p. 444) conclude that "there is little evidence that such autonomy is impossible in the short-run, and considerable evidence it is possible." See especially the careful work of Herring and Marston (1977) on Germany.

the monetary approach to the balance of payments in either its standard or its modified form for analysis of quarterly data. Thus there is a relevant "short run" within which central banks can and have exercised monetary control under pegged exchange rates.

10.1 Analysis

The analysis proceeds in four steps: First, sterilization is formally defined in terms of the money supply reaction function of the central bank. Next, a modified monetary approach is presented which is consistent with partial sterilization. Then a more general model is developed in which the central bank may control its domestic money supply; if this control is not present, the model reduces to the modified monetary approach. Finally, the conditions for monetary control are interpreted in terms of responsiveness of capital flows, trade flows, and the expected depreciation of the exchange rate.

10.1.1 Sterilization and the Money Supply Reaction Function

The central bank of a nonreserve country will resist an incipient appreciation (for example) of its exchange rate by buying some foreign reserves with its domestic base money.[6] This new base money increases the domestic money supply. Standard central bank procedure involves offsetting sales of domestic assets (for example, government bonds) for base money. These offsetting transactions are said to sterilize the effect of the balance of payments on the money supply.

In the standard monetary approach, the construct of domestic credit (base money less reserves) or its change has been assumed exogenous. This assumption is unwarranted if monetary authorities sterilize the balance of payments in whole or in part so that a balance-of-payments surplus induces a decrease in domestic credit. But, of course, the immediate sterilization might be reversed so rapidly that for all practical purposes no sterilization occurred over a period of observation such as a quarter. Then the exogenous-domestic-credit assumption would be acceptable for analysis of quarterly data.

A money supply reaction function provides a formal statement of the behavior of the monetary authorities working through the banking system. The existence and extent of sterilization are measured by the coefficient of the contemporaneous scaled balance of payments in the reaction function. A general form of this reaction function is

$$\Delta \log M = \alpha \frac{B}{H} + X\beta + u, \tag{10.1}$$

6. The analysis is properly applied only to nonreserve countries if the reserve country (such as the United States) is on a fiat standard as discussed in Darby (1980).

where M is the nominal money supply, B the balance-of-payments surplus, H nominal base or high-powered money, and X a vector containing all other variables which systematically affect the monetary authority's behavior. Note in particular that lagged balances of payments may appear in X since the issue of ultimate concern is monetary control within the period of observation. If α is 1, then there is no sterilization since the balance of payments leads to a proportionate increase in the money supply. If α is zero, then complete sterilization is practiced. Values of α between 0 and 1 indicate partial sterilization. By way of information, the Mark III estimates reported in table 6.8 above suggest that α lies in the range from 0 to 0.2.

The meaning of equation (10.1) may be clarified by restating it in terms of domestic credit D. Assuming a constant money multiplier, we have

$$\Delta \log M \equiv \Delta \log H$$

$$\Delta \log M \approx \frac{B}{H} + \frac{\Delta D}{H} \tag{10.2}$$

Substituting into equation (10.1), we have

$$\frac{\Delta D}{H} = (\alpha - 1)\frac{B}{H} + X\beta + u \tag{10.3}$$

Thus we see that if $\alpha = 1$ (no sterilization), then the reaction function determines domestic credit exogenously with respect to the balance of payments. If $\alpha < 1$, then the central bank adjusts domestic credit in whole ($\alpha = 0$) or part ($0 < \alpha < 1$) to offset the effects of the balance of payments on money growth. In what follows, it will be seen that domestic credit is not a useful concept if the central bank is concerned with money growth or the level of interest rates (that is, if $\alpha < 1$).

10.1.2 A Modified Monetary Approach

While the received monetary approach has been based on the assumption that nonreserve countries do not sterilize in whole or part, this assumption is in no sense essential to the theoretical approach.[7] The really essential idea is that the domestic money supply is demand determined given the exchange-rate-converted foreign price level and foreign

7. Harry Johnson (1976, pp. 152–53) noted that the monetary approach "assumes—in some cases, asserts—that these monetary inflows or outflows associated with surpluses or deficits are not sterilized—or cannot be, within a period relevant to policy analysis—but instead influence the domestic money supply." But Mussa (1976, p. 192) rightly observes that this assumption is unnecessary: "If the monetary authorities sterilize the balance-of-payments surplus created by, say, the imposition of a tariff, then the monetary approach predicts that there will be a further surplus, equal to the reduction in the domestic source component of the base which is implied by sterilization, and so on, until the sterilization operations cease." This subsection merely works out the analytical framework sketched by Mussa.

interest rate. Any attempt of monetary authorities to vary the quantity of money from this demand-determined growth $\overline{\Delta \log M}$ will induce massive capital flows, trade flows, or both until the money supply is equated to the parity value $\overline{\Delta \log M}$.

To illustrate, suppose that the demand-determined change in money is given by

$$\overline{\Delta \log M} = Z\delta + \epsilon. \tag{10.4}$$

If the balance of payments is indeed infinitely elastic with respect to incipient deviations from $\overline{\Delta \log M}$, then

$$\frac{B}{H} = \theta(\Delta \log M - Z\delta - \epsilon), \tag{10.5}$$

where θ is negative infinity. That is, any attempt by the central bank to increase (decrease) money relative to $\overline{\Delta \log M}$ results in an unbounded balance-of-payments deficit (surplus). So equation (5) implies, given $\theta = -\infty$, that

$$\Delta \log M = Z\delta + \epsilon. \tag{10.6}$$

Equation (10.6) and the money supply reaction function (10.1) form a recursive system in which the change in money is determined by demand and this, plus the "domestic policy" portion $(X\beta + u)$ of monetary policy, determines the balance of payments:

$$\frac{B}{H} = \frac{1}{\alpha}(Z\delta + \epsilon - X\beta - u). \tag{10.7}$$

The balance of payments is the inverse of the sterilization parameter times the difference between the demand-determined money growth and the domestic-policy money growth.

The modified monetary approach is illustrated graphically in figure 10.1. The vertical line indicates the infinite elasticity of the balance of payments with respect to incipient deviations of money supply growth from its demand-determined level. The positively sloped line is the money supply reaction function.[8] Their intersection determines the equilibrium balance of payments $(B/H)^{eq}$. Note that an increase in unemployment which shifted the reaction function to the right (more money growth for a given balance of payments) results in a substantial decrease in the balance of payments which just balances the desire for more money growth.

Figure 10.2 illustrates the impotence of monetary policy under the

8. If this line were vertical ($\alpha = 0$), there would generally be no equilibrium in the modified-monetary-approach case. A negative slope ($\alpha < 0$) implies an unstable equilibrium.

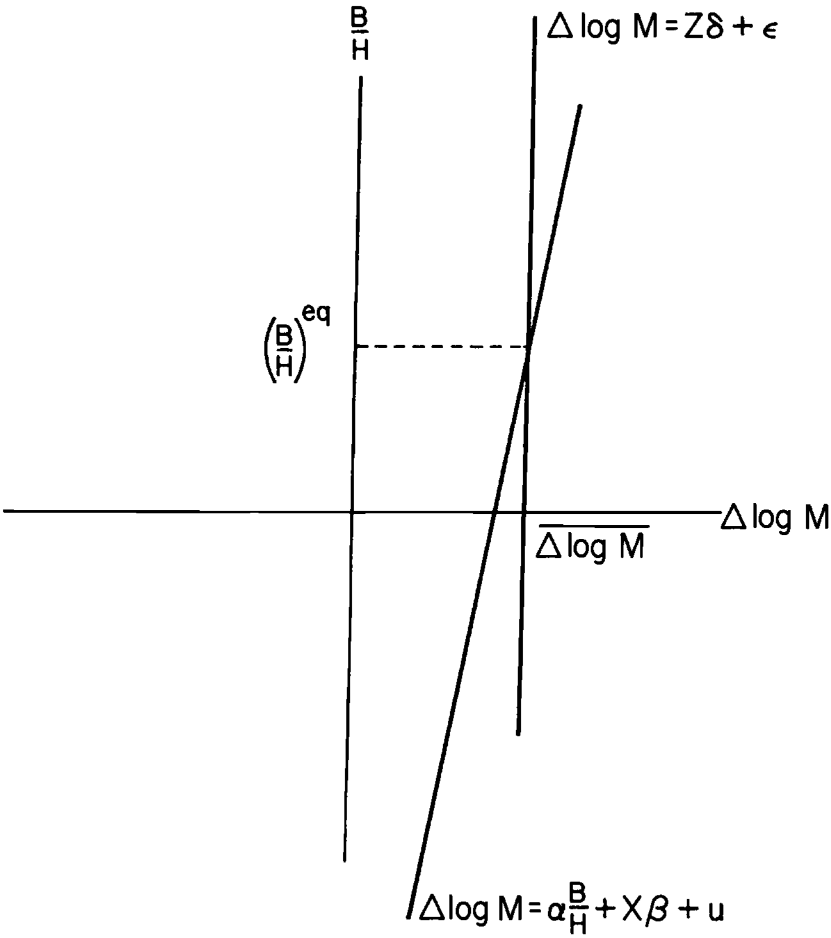

Fig. 10.1 Determination of balance of payments in the modified monetary approach.

modified monetary approach. Consider two vectors of domestic policy variables X_0 and X_1: Suppose that they differ only in the unemployment rate which is higher in case 1 so that the central bank desires a higher money growth rate, other things (i.e. B/H) being equal: $X_1\beta > X_0\beta$. In the standard monetary approach, in which domestic credit is determined without regard to the current balance of payments ($\alpha = 1$), the scaled balance of payments would fall in case 1 relative to case 0 by $X_1\beta - X_0\beta$ to maintain money growth at $\overline{\Delta \log M}$. In the modified approach with partial sterilization, the scaled balance of payments falls by much more:

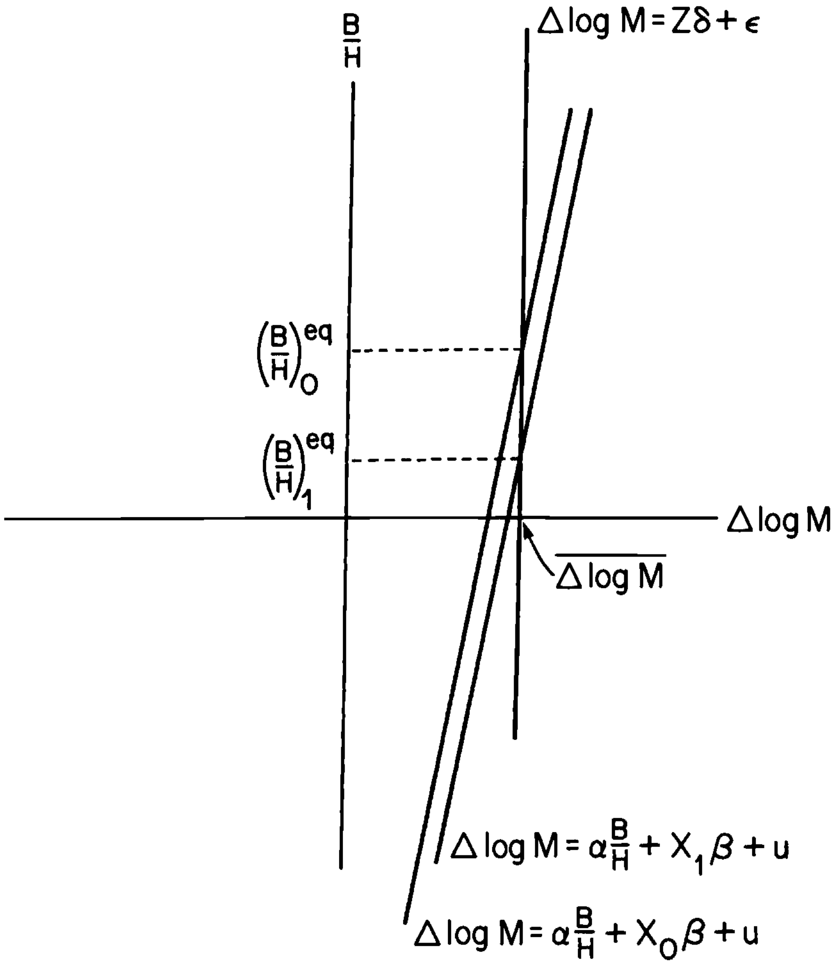

Fig. 10.2 Effect of shift in domestic policy goals in the modified monetary approach.

(10.8) $$\left(\frac{B}{H}\right)_1^{eq} - \left(\frac{B}{H}\right)_0^{eq} = -\frac{X_1\beta - X_0\beta}{\alpha}.$$

That is, the balance-of-payments multiplier is $-1/\alpha$ times the change in the domestic-policy portion of monetary policy.

In conclusion, the existence of partial sterilization does not imply any monetary control by a nonreserve central bank under pegged exchange rates. It may just result in accentuated balance-of-payments movements.

10.1.3 A More General Model

The assumption of exogenous determination of the arguments of the money demand function is deeply ingrained in the monetary-approach literature. Indeed, it is this assumption which allows one easily to transform statements about monetary equilibrium and money supply conditions into statements about the balance of payments.[9] If instead monetary and fiscal actions can move the domestic interest rate and price level relative to the foreign variables (not to mention any effect on real income), then monetary actions will cause movements in money demand with more complicated effects on the balance of payments. The remainder of this section considers such nonmonetary-approach models which are nonetheless characterized by continuous equality of money supplied and money demanded.

If neither goods nor assets are perfect substitutes, it no longer follows that the balance of payments will be infinitely elastic with respect to the money supply growth rate. The domestic interest and price level can move from the parity values which determine $\overline{\Delta \log M} = Z\delta + \epsilon$. Other factors (such as those appearing in trade supply and demand equations) represented by the vector S will also play a role in determining the balance of payments so that equation (10.5) is expanded to

$$\frac{B}{H} = \theta\,(\Delta \log M - Z\delta - \epsilon) + S\lambda, \tag{10.5'}$$

where $0 > \theta > -\infty$. If money growth were greater than $Z\delta + \epsilon$ so that interest rates fell and prices rose relative to foreign values, the balance-of-payments surplus would fall through movements along noninfinitely elastic net-capital and net-export flow schedules. The empirical tests in section 10.2 do not require a list of the elements in S so that we need not specify a full general equilibrium model here.[10]

Solving equation (10.5′) for $\Delta \log M$ yields

$$\Delta \log M = \frac{1}{\theta}\left(\frac{B}{H} - S\lambda\right) + Z\delta + \epsilon. \tag{10.9}$$

9. In a particularly relevant example, Genberg (1976, p. 322) argues that a sterilization policy "is implausible for several reasons. Firstly it implies an extraordinary stability of the central bank's behaviour with respect to policy formation. Secondly it implies that the sterilization is always of a magnitude consistent with the demand for money, *since with prices, interest rates and output determined by exogenous forces, the money market must be equilibrated through either reserve flows or domestic credit creation*" (emphasis added). We have already seen that Genberg errs in supposing any difficulty in reconciling sterilization to lack of monetary control. But note the absolute certainty that the arguments of the money demand function are exogenously determined.

10. One particular version of equation (10.5′) or (10.9) would be the semireduced form obtained by solving for B/H and $\Delta \log M$ in the non-reaction-function equations in a country submodel in the Mark III International Transmission Model. Since those results have met monetary-approach skepticism, a less model-dependent approach is followed here. In chapter 11 below, Daniel Laskar specifies a smaller-scale model and obtains similar results.

When equation (10.9) is combined with the reaction function (10.1), we obtain a truly simultaneous system determining Δ log M and B/H together. The (reduced-form) solutions for the equilibrium values are

$$\text{(10.10)} \qquad \Delta \log M = \frac{1}{1-\alpha\theta} X\beta + \frac{\alpha}{1-\alpha\theta} S\lambda + \frac{\alpha\theta}{\alpha\theta - 1} Z\delta + \frac{1}{1-\alpha\theta} u + \frac{\alpha\theta}{\alpha\theta - 1} \epsilon,$$

$$\text{(10.11)} \qquad \frac{B}{H} = \frac{\theta}{1-\alpha\theta} X\beta + \frac{1}{1-\alpha\theta} S\lambda + \frac{\theta}{\alpha\theta - 1} Z\delta + \frac{\theta}{1-\alpha\theta} u + \frac{\theta}{\alpha\theta - 1} \epsilon.$$

It can be readily verified that as the balance-of-payments elasticity goes to negative infinity, the solutions (10.10) and (10.11) go to the modified-monetary-approach solutions (10.6) and (10.7). Thus the modified monetary approach is, indeed, a special case (for $\theta = -\infty$) of this more general model.

The more general model is illustrated by figure 10.3. The vertical line of figure 10.1 is replaced with a negatively sloped line relating the balance of payments to money growth, the trade factors $S\lambda$, and the demand variables $Z\delta + \epsilon$. The intersection of this line with the reaction function determines both the balance of payments and money supply growth. In this case, as seen in figure 10.4, a desire to increase money growth (due to increased unemployment, say) in fact does increase money growth as well as decrease the balance of payments. The relative size of the two effects of course depends on the slopes of the two equations. But unlike the modified-monetary-approach case, there will be a correlation between movements in the domestic policy goals ($X\beta + u$) and changes in the money supply.

Note that our model deletes the concept of domestic credit entirely. One can derive the equilibrium value of the scaled change in domestic credit from equations (10.10) and (10.11)—or (10.6) and (10.7) in the modified-monetary-approach special case—and the usual identity (10.2). Trivial manipulations yield a domestic-credit equation, but only if it is exogenously determined ($\alpha = 1$) does domestic credit have causal or analytical significance. As an endogenous variable it adds nothing to the exposition. As will be discussed further in section 10.2, the negative correlation between the scaled change in domestic credit and the scaled balance of payments makes for easy confusion in empirical analysis.

10.1.4 Conditions for Monetary Control

Unless the balance of payments is infinitely elastic with respect to money growth, the central bank of a nonreserve country does exercise a

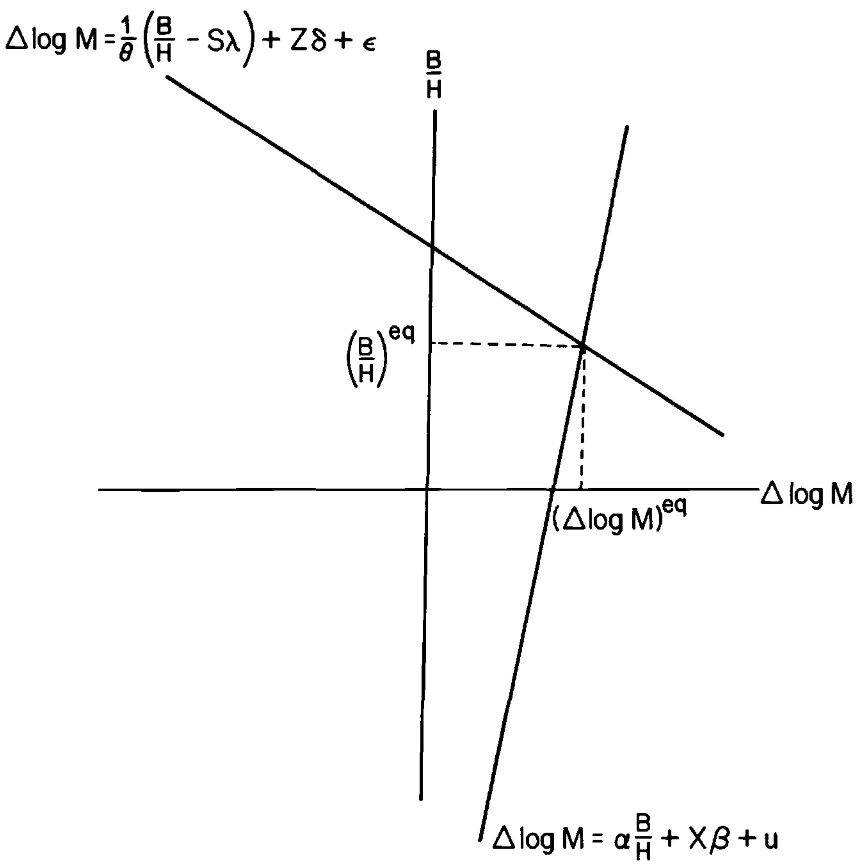

Fig. 10.3 Simultaneous determination of balance of payments and nominal money in the more general model.

degree of monetary control. This control is not absolute (if $\alpha > 0$) in the sense that the balance-of-payments effects will enter the bank's choice of money growth, but neither will these effects completely overwhelm all other influences such as domestic unemployment or inflation goals. Since lagged balances of payments may be counted among those other influences, the pegged system may be quite stable dynamically via specie-flow types of adjustments, but this is a different process than envisioned by the monetary approach. This subsection examines in more detail the crucial parameter

$$\theta = \frac{d\,(B/H)}{d\,\Delta \log M}.$$

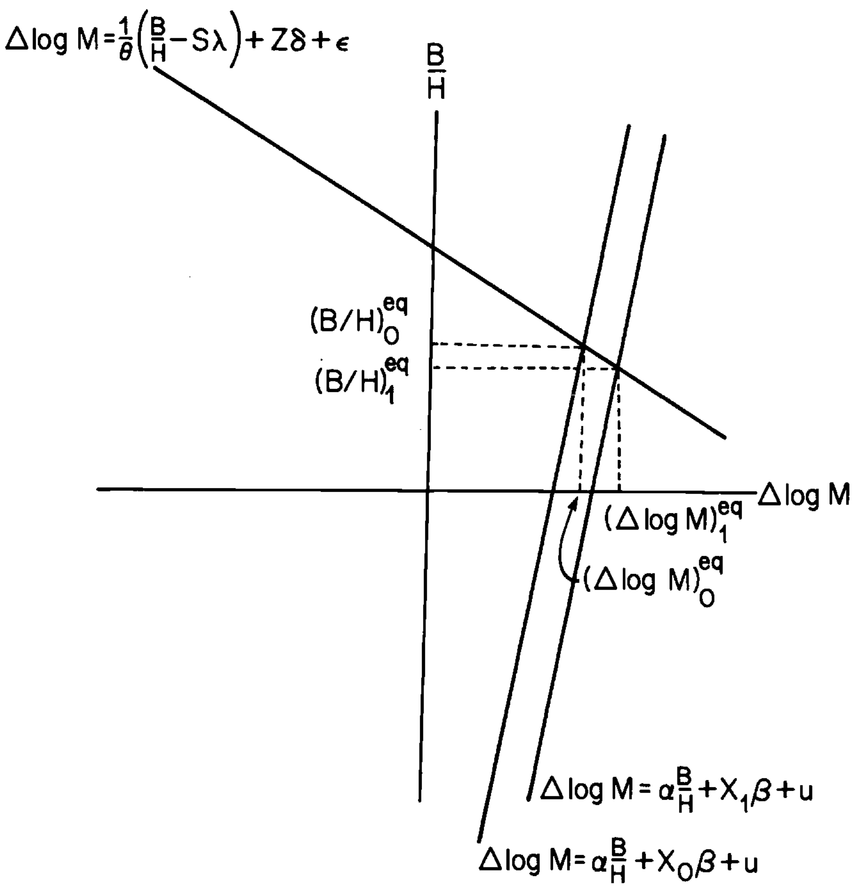

Fig. 10.4 Effect of shift in domestic policy goals in the more general model.

Whether θ is negative infinity has generally been addressed in terms of either assets or goods being perfect substitutes internationally. If assets are perfect substitutes and the derivatives of the interest rate R with respect to money growth is negative due to a liquidity effect, then overwhelming net private capital flows will force the domestic interest rate to its parity value. Similarly if goods are perfect substitutes and the derivative of the contemporaneous price level P with respect to money growth is positive, overwhelming trade flows will force the domestic price level to its parity value. Either of these cases is sufficient, but it is not necessary for either or both to hold in order to obtain $\theta = -\infty$.

To see this, write the scaled balance of payments as the difference between the scaled balance of trade and the scaled net private capital outflows:

$$(10.12) \qquad \frac{B}{H} \equiv \frac{T}{H} - \frac{C}{H}$$

Scaled net private capital outflows will be a function of the current covered interest differential (adjusted for expected exchange-rate changes) and other variables which may be taken as given for the current period:[11]

$$(10.13) \qquad \frac{C}{H} = f(R - \rho - R^F),$$

where ρ is the expected depreciation of the exchange rate ($\rho < 0$ implies an expected appreciation), R^F is the given foreign interest rate, and so f' is negative. We can find θ by differentiating equation (10.12):

$$\theta \equiv \frac{d(B/H)}{d\Delta \log M} = \frac{d(T/H)}{d\Delta \log M} - f' \frac{dR}{d\Delta \log M} + f' \frac{d\rho}{d(B/H)} \frac{d(B/H)}{d\Delta \log M},$$

$$(10.14) \qquad \theta = \frac{1}{1 - f' \dfrac{d\rho}{d(B/H)}} \left(\frac{d(T/H)}{d\Delta \log M} - f' \frac{dR}{d\Delta \log M} \right).$$

The multiplier

$$1 / \left(1 - f' \frac{d\rho}{d(B/H)} \right)$$

states that if the expected depreciation ρ responds to the size of the balance of payments (as an indicator of the probability and size of a revaluation), then the direct trade and capital-flows effects will be reinforced by induced "speculative" capital flows. These induced speculative capital flows will be overwhelming unless

$$(10.15) \qquad f' \frac{d\rho}{d(B/H)} < 1.$$

Therefore, instead of the standard two, there are three conditions required for a $\theta > -\infty$: (1) Trade flows must not be overwhelming.[12] (2) The

11. Among these other variables are, of course, the lagged covered interest differential since *changes* in the differential will cause portfolio revisions and hence net capital flows. These other variables are predetermined within the period and so implicit in the function $f(\ )$. Dooley and Isard (1980) provide a convenient recent exposition of the role of political risk in allowing $R - \rho - R^F$ to differ from 0 when the interest rates refer to domestic rates rather than Eurorates.

12. Formally,

$$\frac{\partial(T/H)}{\partial \log P} \frac{d \log P}{d\,\Delta \log M} > -\infty.$$

direct effect on capital flows must not be overwhelming.[13] (3) Speculative capital flows must not be overwhelming (condition (10.15) must be met). Note that with costs of adjustment and lags in information these three conditions may be met for certain periods of observation but not for longer periods. With longer periods, lagged values of B/H which are included in $X\beta$ in the short-period analysis would instead be included in the contemporaneous value of B/H.

Obviously it is an empirical question whether these three conditions for monetary control are met for any relevant observation length, and we shall turn to some empirical evidence shortly in section 10.2. But first, the third condition (10.15) raises an interesting possibility. Suppose that the probability of a revaluation increases with the absolute value of the scaled balance of payments and the expected (signed) magnitude of the revaluation varies with the value of the scaled balance of payments. Then the expected depreciation might be determined by a function like

$$\rho = g\left(\left|\frac{B}{H}\right| \cdot \frac{B}{H}\right), \tag{10.16}$$

where g' is, of course, negative. The derivative of interest is

$$\frac{d\rho}{d(B/H)} = 2g'\left|\frac{B}{H}\right|, \tag{10.17}$$

which increases in absolute value with the absolute value of B/H. Thus there is some reason to suppose that condition (10.15) might hold for "small" absolute values of the scaled balance of payments but fail if the central bank attempted a policy which were "too" inconsistent with international conditions. This is illustrated in figure 10.5. The central bank exercises a degree of monetary control so long as it stays in the negatively sloped portion of the international balance curve. If it shifts into the vertical range, however, overwhelming speculative capital flows result.[14]

10.2 Empirical Results

Blejer (1979) applied the Granger-Sims causality test to quarterly data for France, Germany, Italy, Sweden, and the United Kingdom and found that scaled changes in domestic credit "cause" scaled reserve flows in all five (albeit as part of a two-way feedback structure for Sweden and the

13. Formally,

$$f' \frac{dR}{d\,\Delta \log M} < \infty.$$

14. This provides another basis for Niehans's (1974) idea that nonreserve countries can exercise monetary control within a limited range.

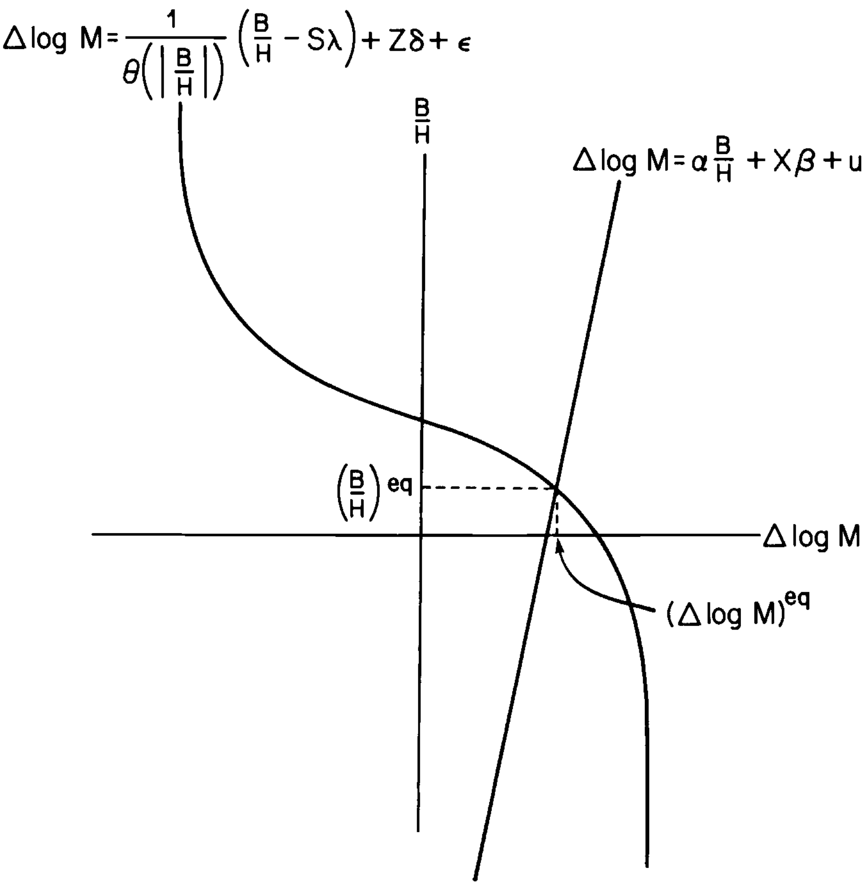

Fig. 10.5 Simultaneous determination of balance of payments and money where potential unstable speculation limits monetary control.

United Kingdom). Blejer erroneously claimed that this supports the monetary approach, but it in fact suggests short-run monetary control since the test shows that *past* changes in domestic credit affect current reserve flows. This evidence for short-run monetary control is not conclusive, however, since past changes in domestic credit might have been induced by reserve-country actions which have current effects on foreign prices and hence reserve flows.[15] It is simply not appropriate to apply an exogeneity test to two endogenous variables.

The analysis of section 10.1 suggest two research strategies which focus directly on the issue of monetary control: The first is to fully specify the more general model and estimate equations (10.1) and (10.9) by a simul-

15. See Cassese and Lothian (chapter 4 above) for this point.

taneous system method to test whether $1/\theta$ is, indeed, zero. This method is pursued in the Mark III International Transmission Model and is beyond the scope of the present chapter.[16] The second approach is to proceed on the assumption that the *null hypothesis of no monetary control* is true and perform some classical hypothesis tests. Following this second path allows us to avoid the difficulty of fully specifying the variables which belong in S.

These hypothesis tests rely on the difference between the reduced forms for $\Delta \log M$ under the null hypothesis and the alternative hypothesis. Let us rewrite the reduced forms here for comparison:

$$\Delta \log M = Z\delta + \epsilon, \tag{10.6}$$

$$\Delta \log M = \frac{1}{1-\alpha\theta} X\beta + \frac{\alpha}{1-\alpha\theta} S\lambda + \frac{\alpha\theta}{\alpha\theta - 1} Z\delta + \frac{1}{1-\alpha\theta} u + \frac{\alpha\theta}{\alpha\theta - 1} \epsilon. \tag{10.10}$$

Note that neither $X\beta$ nor $S\lambda$ enters in the reduced form if the null hypothesis is true. *One* test of the null hypothesis is to add the domestic variables $X\beta$ to the reduced form (10.6) and test whether they fail to enter as required by the null hypothesis. That is, the null hypothesis implies $\phi = 0$ in

$$\Delta \log M = \phi\, X\beta + Z\delta + \epsilon. \tag{10.18}$$

A more powerful test would also include $S\lambda$, but this requires a full specification of the alternative hypothesis as noted above.

The empirical tests are based on the quarterly data bank and the money supply reaction functions in the Mark III Model, discussed above in chapters 3 and 5, respectively. We must first specify which variables appear in the vector Z. Stockman (1979) follows the standard practice of explaining the first difference of money demand as the first difference of a Cagan or long-run money-demand function:

$$\Delta \log M = \delta_1 + \delta_2 \Delta \log y + \delta_3 \Delta R + \delta_4 \Delta \log P + \eta. \tag{10.19}$$

The further assumption is made that the change in domestic real income $\Delta \log y$ is exogenous and that the domestic interest rate R and price level

16. See chapters 5 and 6 above. Equation (10.9) can be thought of as a semireduced form of all the non-reaction-function equations in the model. Stockman (1979) dealt with this problem by implicitly assuming $S\lambda = 0$ in equation (10.9) and estimating transformations of equations (10.1) and (10.9) by two-stage least squares. Since $S\lambda \neq 0$ if the alternative hypothesis is true, his estimates of $1/\theta$ are inconsistent and likely biased toward zero. In view of this specification error, his failure to find evidence of monetary control does not seem very informative. This and other criticisms apply to Argy and Kouri (1974), Genberg (1976), and Connolly and Taylor (1979). If one is to use a simultaneous-equation approach, the general model must be fully specified. See Laskar (1980) for a formal analysis of the biases in the tests of Stockman et al.

P are exogenously determined by the foreign interest rate R_U and the exchange-rate-converted foreign price level EP_F:[17]

(10.20) $$\Delta R = \Delta R_U + \omega,$$

(10.21) $$\Delta \log P = \Delta \log(EP_F) + \psi.$$

The disturbances ω and ψ permit *exogenous* shifts in the interest and purchasing-power parities and would have variance 0 in the most extreme versions of the monetary approach. Thus the Stockman version of the reduced form (10.6) is

(10.22) $$\Delta \log M = \delta_1 + \delta_2 \Delta \log y + \delta_3 \Delta R_U + \delta_4 \Delta \log (EP_F) + \epsilon,$$

where $\epsilon = \eta + \delta_3 \omega + \delta_4 \psi$.[18] Table 10.1 reports estimates of the reduced-form (and structural) equation (10.6) for $\Delta \log M$ on this specification of Z for all seven nonreserve countries in the data bank. The pegged periods used in the estimates are indicated in the table. These regressions seem very poor compared to standard monetary-approach results. The reason is that standard estimates move domestic credit to the right-hand side on the erroneous assumption that it is exogenous. This provides a spuriously high R^2. Direct estimates (not tabulated here) of equation (10.19) with domestic variables are also insignificant for three of the countries; so the specification (10.19) is somewhat suspect.

Following Genberg (1976), we can improve the fit of the regressions by using the short-run money-demand function introduced by Chow (1966). This amounts to adding the change in the logarithm of lagged real money or $\Delta \log (M/P)_{-1}$ to the vector Z. Table 10.2 reports the results obtained using the Chow specification. These results are rather more favorable to the monetary approach although the $\bar{R}^2$ are not very impressive in an absolute sense.[19] There is some evidence of residual autocorrelation for Japan and the Netherlands, but this disappears in the more correctly specified test equations. Let us now proceed to the reduced-form tests.

17. As pointed out by Magee (1976), the assumption that $\Delta \log y$ is exogenous may unduly favor the monetary approach. The foreign interest rate R_U is the U.S. three-month treasury bill rate. Also, following Stockman (1979), P_F is an income-weighted index of foreign prices. All tables in this chapter were also computed using the exchange-rate-converted U.S. price index EP_U instead of EP_F. The standard errors were generally a bit lower for the form reported here, but the basic results were qualitatively the same. The alternate tables are available upon request from the author.

18. Obviously the estimated coefficients will be biased estimates of the values in equation (10.19) if there are exogenous shifts in the parities; this does not affect the validity of the tests conducted so long as those shifts are unrelated to the variables in X as discussed below.

19. Generally the $\bar{R}^2$ values are better when domestic variables are substituted for the foreign variables. For Italy, however, only a poor measure of the domestic interest rate is available and it does notably worse; indeed, Italy is the only regression not significant at the 10% or better level using domestic variables.

Table 10.1 **Estimates of Modified-Monetary-Approach Equation: Long-Run Money Demand Version**

$\Delta \log M = \delta_1 + \delta_2 \Delta \log y + \delta_3 \Delta R_U + \delta_4 \Delta \log (EP_F) + \epsilon$

		Coefficients						
Country	Period	δ_1	δ_2	δ_3	δ_4	S.E.E.	$\bar{R}^2$	D-W
UK	1957I–71II	0.008	0.108	0.084	0.065	0.018	−0.045	1.46
		(0.003)	(0.202)	(0.481)	(0.160)			
		2.520	0.535	0.174	0.406			
CA	1962III–70I	0.025	−0.207	−1.640	−0.608	0.011	0.188**	1.93
		(0.007)	(0.257)	(0.606)	(0.520)			
		3.794	−0.806	−2.707	−1.170			
FR	1958I–71II	0.028	0.067	−0.271	−0.218	0.013	0.094**	0.68
		(0.003)	(0.092)	(0.351)	(0.092)			
		10.664	0.720	−0.772	−2.355			
GE	1957I–7I	0.018	0.323	−0.188	0.269	0.011	0.169**	1.44
		(0.002)	(0.102)	(0.283)	(0.118)			
		8.860	3.169	−0.664	2.278			
IT	1957I–71II	0.028	0.097	−0.450	0.497	0.014	0.014	1.37
		(0.004)	(0.147)	(0.371)	(0.369)			
		7.111	0.657	−1.213	1.348			
JA	1957I–71II	0.030	0.153	0.466	0.753	0.020	0.013	0.99
		(0.006)	(0.177)	(0.527)	(0.515)			
		5.117	0.867	0.884	1.462			
NE	1957I–71I	0.017	0.369	−0.118	−0.043	0.014	0.060*	1.92
		(0.003)	(0.146)	(0.358)	(0.235)			
		6.069	2.522	−0.329	−0.183			

Notes. Standard errors appear in parentheses below the coefficient estimates; t statistics are below the standard errors.

One asterisk after the $\bar{R}^2$ indicates rejection of the hypothesis $\delta_2 = \delta_3 = \delta_4 = 0$ at better than 0.10 level, two asterisks at better than 0.05 level.

Table 10.2 **Estimates of Modified-Monetary-Approach Equation: Chow Money Demand Version**

$\Delta \log M = \delta_1 + \delta_2\Delta \log y + \delta_3\Delta R_U + \delta_4\Delta \log (EP_F) + \delta_5\Delta \log (M/P)_{-1} + \epsilon$

	Coefficients							Durbin's
Country	δ_1	δ_2	δ_3	δ_4	δ_5	S.E.E.	$\bar{R}^2$	h [D-W]†
UK	0.008	0.047	0.123	0.023	0.279	0.018	0.012	[1.95]
	(0.003)	(0.198)	(0.469)	(0.157)	(0.137)			
	2.691	0.240	0.263	0.150	2.032			
CA	0.025	−0.211	−1.667	−0.598	−0.052	0.012	0.160*	1.10
	(0.007)	(0.262)	(0.622)	(0.529)	(0.163)			
	3.731	−0.805	−2.680	−1.130	−0.316			
FR	0.015	0.050	−0.415	−0.078	0.617	0.009	0.568**	1.50
	(0.003)	(0.064)	(0.243)	(0.067)	(0.083)			
	6.137	0.776	−1.705	−1.166	7.465			
GE	0.015	0.326	−0.201	0.311	0.197	0.011	0.196**	1.05
	(0.003)	(0.100)	(0.278)	(0.119)	(0.118)			
	5.036	3.254	−0.721	2.613	1.663			
IT	0.022	0.073	−0.323	0.346	0.292	0.014	0.074*	[1.98]
	(0.005)	(0.143)	(0.364)	(0.365)	(0.138)			
	4.692	0.514	−0.887	0.950	2.116			
JA	0.021	0.032	0.128	0.320	0.486	0.018	0.219**	2.26
	(0.006)	(0.160)	(0.477)	(0.472)	(0.125)			
	3.638	0.198	0.269	0.680	3.896			
NE	0.015	0.336	−0.136	0.009	.0157	0.014	0.074*	−2.10
	(0.003)	(0.148)	(0.355)	(0.236)	(0.117)			
	4.808	2.278	−0.384	0.037	1.341			

Notes. Standard errors appear in parentheses below the coefficient estimates; t statistics are below the standard errors.

One asterisk after the $\bar{R}^2$ indicates rejection of the hypothesis $\delta_2 = \delta_3 = \delta_4 = 0$ at better than 0.10 level, two asterisks at better than 0.05 level.

†In those cases in which Durbin's h cannot be calculated (is imaginary), the (biased) Durbin-Watson statistic is reported instead in square brackets.

The reaction functions in the Mark III Model are very general in form to allow for cross-country differences in timing of response. For the pegged period, included variables, other than a scaled balance-of-payments term, are a time trend, current and lagged unexpected real government spending, lagged semiannual inflation rates, lagged unemployment rates or logarithmic transitory incomes, and lagged scaled balance of payments. When all these variables (except the current B/H) are added to the regressions reported in tables 10.1 and 10.2, we can do the joint test of whether the coefficients of the additional variables are all zero as implied by the null hypothesis. The results of these F tests are reported in table 10.3. For the Chow money demand function the modified monetary approach (no monetary control) is rejected stongly for the United Kingdom, France, and Japan and at the 10% significance level for Canada and Germany. Similar, though more erratic, results are obtained for the long-run money demand function. Consider the tests, however:

Table 10.3 ***F* Tests for Unconstrained Addition of Domestic-Policy Reaction Function Variables**

	F Statistics	
Country	Chow Money Demand Function	Long-Run Money Demand Function
UK	2.241 (12, 41) [$0.025>p>0.01$]	2.731 (12, 42) [$0.01>p>0.005$]
CA	2.085 (12, 14) [$0.10>p>0.05$]	1.495 (12, 15) [$p>0.10$]
FR	2.658 (12, 37) [$0.025>p>0.01$]	4.040 (12, 38) [$0.001>p$]
GE	1.929 (12, 40) [$0.10>p>0.05$]	2.239 (12, 41) [$0.05>p>0.025$]
IT	1.250 (12, 41) [$p>0.10$]	1.651 (12, 42) [$p>0.10$]
JA	2.643 (12, 41) [$0.025>p>0.01$]	4.287 (12, 42) [$0.001>p$]
NE	1.372 (12, 40) [$p>0.10$]	1.571 (12, 41) [$p>0.10$]

Notes. Each F statistic is followed in parentheses by the associated degree of freedom. Significance levels are indicated in brackets below the F statistics.

The significance levels refer to the level at which we would just reject the null hypothesis that the coefficients on all reaction function variables equal zero. The twelve reaction function variables are t, $\hat{g}$, $(\hat{g}_{t-1}+\hat{g}_{t-2})$, $(\hat{g}_{t-3}+\hat{g}_{t-4})$, $(\log P_{t-1}-\log P_{t-3})$, $(\log P_{t-3}-\log P_{t-5})$, u_{t-1}, u_{t-2}, u_{t-3}, u_{t-4}, $[(B/H)_{t-1}+(B/H)_{t-2}]$, and $[(B/H)_{t-3}+(B/H)_{t-4}]$, where t is time, $\hat{g}$ the innovation in real government spending, P the GNP deflator, and u either the unemployment rate (for the U.K. and France) or logarithmic transitory income.

They ask whether all the additional variables reduce the sum of squared residuals by significantly more than would be expected for such a number of unrelated random variables. Since not all of these variables enter any given reaction function, this is a low-power test (it is hard to reject the null hypothesis).

A sharper test would include only those variables which actually enter the reaction functions for each country. The Mark IV Simulation Model described in chapter 7 above is a simplified simulation version of the Mark III International Transmission Model. Its specification of X in equation (10.1) dropped all variables with t statistics less than unity. Table 10.4 reports results of the F tests based upon these country-specific money supply reaction functions. We see that only the Netherlands (the smallest and most open country in the sample) fails to exhibit significant correlation between money growth and the money supply variables. Thus these reduced-form tests generally confirm the results obtained using structural models by Herring and Marston (1977), Darby and Stockman (chapter 6 above), and Laskar (1980): Nonreserve countries exercised a significant degree of control over their domestic money supplies within a quarter. Thus even the modified monetary approach is unacceptable for analysis of quarterly data.

Table 10.4 ***F* Tests for Addition of Mark IV Model Domestic-Policy Reaction Function Variables**

	F Statistics	
Country	Chow Money Demand Function	Long-Run Money Demand Function
UK	4.071 (7, 46) [$0.005>p>0.001$]	4.999 (7, 47) [$0.001>p$]
CA	3.312 (5, 21) [$0.025>p>0.01$]	1.958 (5, 22) [$p>0.10$]
FR	3.413 (9, 40) [$0.005>p>0.001$]	4.869 (9, 41) [$0.001>p$]
GE	3.205 (3, 49) [$0.05>p>0.025$]	3.658 (3, 50) [$0.025>p>0.01$]
IT	2.401 (6, 47) [$0.05>p>0.025$]	3.082 (6, 48) [$0.025>p>0.01$]
JA	4.463 (6, 47) [$0.005>p>0.001$]	7.021 (6, 48) [$0.001>p$]
NE	1.432 (8, 44) [$p>0.10$]	1.705 (8, 45) [$p>0.10$]

Note. Each F statistic is followed in parentheses by the associated degrees of freedom. Significance levels are indicated in brackets below the F statistics.

Two reservations should be noted: (1) The money supply demand functions do not fit very well by U.S. standards and may be misspecified. However, since they are the standard forms in the literature and a stable, *known* money demand function is essential to the monetary approach, this provides little comfort to adherents of the monetary approach. (2) The variables in X might enter because they are correlated with the exogenous parity shifts ω and ψ. This could conceivably be the case, but an examination of the list in the notes to table 10.3 provides no obvious or, to this writer, even plausible candidates.

10.3 Summary and Conclusions

Recent empirical research on sterilization had demonstrated that standard monetary-approach models which assume domestic credit exogenous are invalid. This paper presents a modified-monetary-approach model which retains the message of central bank impotence despite extensive sterilization activities. A more general model was also sketched under which the central bank's policy objectives do influence the change in the money supply. Whether a nonreserve central bank can determine its domestic money supply in the short run was shown to depend on whether one or more of the conditions are met: goods are perfect substitutes, assets are perfect substitutes, or expected depreciation is too responsive to changes in the balance of payments. The responsiveness in this new third condition may depend on the size of the balance of payments so that central bank monetary control is feasible only within a limited range.

The reduced-form tests showed strong evidence of the exercise of monetary control within the quarter for the United Kingdom, Canada, France, Germany, Italy, and Japan. Only for the Netherlands could we not reject the restriction on the more general model which implies the applicability of the modified monetary approach. These results confirm in a relatively model-free manner earlier findings based on specific structural models. They therefore answer suggestions that those earlier results are due to peculiarities in the structural model. There is no reason for predetermined money supply reaction function variables to be correlated with realized money growth unless the nonreserve central bank could and did exercise a degree of monetary control.

These results need not indicate any long-run monetary control; indeed, even short-run monetary control may be feasible only between the limits at which overwhelming speculative capital flows are induced. But the strong implications of the monetary approach (in standard or modified form) no longer appear tenable for use with quarterly data. Instead, more general macroeconomic models must be specified and tested to explain the *simultaneous* determination of nominal money and the balance of payments under pegged exchange rates.

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