The Effects of Alternative Operating Procedures on Economic and Financial Relationships

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I. Introduction

On October 6, 1979, the Federal Reserve announced a significant change in the way it would henceforth conduct monetary policy. Although there was no change in the basic objectives toward which monetary policy was to be directed, the actual operating procedures used to implement policy were to be formulated in terms of reserve aggregates, rather than interest rates, as the means of controlling the supply of money. The period since the shift in operating procedures has experienced extreme increases in the volatility of interest rates and most measures of the money supply.[1] The occurrence of this historically unusual behavior subsequent to the change in the Federal Reserve's operating procedures suggests that the policy shift may have induced changes in basic economic and financial relationships so that empirical relations which held prior to October 1979 may no longer accurately describe the way the economy behaves. The extent to which the structure of financial relationships between interest rates, reserve aggregates, and the money supply depend upon the Federal Reserve's method of implementing monetary policy will be examined in this paper. Relationships which under the current operating procedures are important for the conduct of monetary policy will be studied in an attempt to determine how they might depend upon the behavior of the Federal Reserve.

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1. The apparent increase in reserve volatility may, however, be an artifact of the seasonal adjustment factors (see Lindsey and other, 1981). Unexpected changes in the money supply have also become more variable (see Roley, 1982).

Monetary policy operating procedures are usually analyzed by looking at the implications for income, interest rates, or monetary aggregates of alternative choices of an instrument variable, given a model structure. This model structure might be either a theoretical specification of behavioral relationships or an empirical model estimated over a historical time period. The perspective adopted here will be quite different; the focus will be on the ways in which the model structure may vary' in response to a change in the Federal Reserve's operating procedures. Such an analysis is necessary if, for example, the relative merits of using an interest rate or a reserve aggregate instrument are to be fully evaluated. There are two objectives in carrying out this type of analysis. First, it may suggest ways in which structural shifts induced by the October 1979 policy change may help to explain the post-October 1979 behavior of interest rates and monetary aggregates. Second,' the analysis may suggest possible structural changes which will occur if the Federal Reserve were to make further changes in its operating procedures.

The next section discusses some of the ways in which structural relationships might be affected by the Federal Reserve's operating procedures. Current operating procedures are very briefly reviewed in Section III in order to highlight the important role of bank borrowing and money demand. These relationships are then examined in Sections IV and V to suggest how they may be affected by changes in the manner in which monetary policy is implemented. An analysis of intraweek borrowing also shows how interest rate responses to the Friday money announcements depend upon Federal Reserve policy. The implications for monetary policy of the analysis of structural change are discussed in the concluding section.

II. Economic Structure and Monetary Policy

Before examining those aspects of the economic structure of the financial sector which are important for the implementation of monetary policy, it will be useful to first, briefly, review the ways in which monetary policy affects the economy. The discussion will focus on those effects which are likely to lead to structural shifts inresponse to a change in operating procedures. If policy actions 'result in shifts in some or all of the structural parameters which characterize the behavioral responses of individuals in the economy, then knowledge of such impacts will generally be necessary for the evaluation of the desirability of the policy action.

The classic discussion in the economics literature of the relationship between structural parameters, policy variables, and knowledge useful for the design of policy is contained in Marschak (1953). He defines knowledge as useful "if it helps to make the best decision" (p. 1). The example Marschak develops involves the choice of an output level by a profit maximizing firm whose product is subject to an excise tax. Useful knowledge for the firm depends upon whether the tax rate has been constant in the past and is expected to remain constant in the future, has been constant but is expected to change in the future, or has varied in the past. In general, the firm, in order to make the best decision, needs to know the past empirical relationship between its profits and its output *and* knowledge of how the parameters of this historical, statistical relationship depend upon the excise tax rate. A different tax rate will lead to a different empirical relationship between profit and output.

This basic insight, that empirical relationships estimated during a period with one setting of policy variables such as tax rates will shift if the policy variables are changed, has been recently developed further by Lucas (1976) to call into question the usefulness of econometric model simulations as a means of evaluating alternative fiscal and monetary policies. The estimated coefficients in macroeconometric models are unlikely to be policy invariant; they will change if monetary or fiscal policy is carried out in a manner that differs from that characterizing the model's estimation period. Therefore, existing macroeconometric models may be of limited use for simulating the effects of alternative policy rules. For example, models estimated using historical U.S. data may reveal little about the effects of adopting a constant growth rate rule for the money supply.

Lucas and Sargent (1981) provide a more general framework for analyzing this problem than was originally developed by Lucas (1976). They consider the problem of using historical observations to infer how the behavior of an economic agent "*would have* differed had the agent's environment been altered in some specified way."[2] This environment depends, in some complex way, on the manner in which the monetary and fiscal authorities act. Policy evaluation requires know-

2. Lucas and Sargent (1981, p. xi-xii); as italics in original:

ledge of those parameters which will be policy invariant, that is, which will remain unchanged in response to a change in the way policy is determined. Typically, only preferences and technology are assumed to be .policy invariant. Empirically estimable demand and supply curves depend on both these policy invariant aspects of the economic environment and on the behavior of monetary and fiscal policy. Also required for an evaluation of alternative policies is a knowledge of the ways in which these demand and supply curves will differ under the alternative policies.[3]

To focus the discussion on an example that will be relevant for the subsequent analysis of Sections IV and V, consider the ways in which the interest elasticity of demand for a financial asset might depend on the manner in which monetary policy is implemented. Usually the effects of monetary policy are identified with the portfolio effects caused by a policy-induced interest rate change with asset demand interest rate elasticities given. This type of effect is not analyzed here; instead, the emphasis will be on the relationship between monetary policy and the empirical value of the interest rate elasticity.

It is useful to distinguish three ways in which the response of asset holders to an interest rate change may be related to the actions of the monetary authority. Empirically estimated' interest elasticities will depend on the permanence, informational content, and riskiness of interest rate movements over the sample period used to estimate the asset demand equation.[4] Each of these three characteristics of interest rate changes will be affected by the manner in which monetary policy is implemented.

In the presence of transaction costs which render portfolio adjustments costly, the aggregate response of asset holders to a change in an interest rate will depend on the perceived permanence of the rate movement. For example, a rise in the interest rate on a fixed rate security may induce a large portfolio shift if the rate rise is viewed as temporary as individuals attempt to "lock in" the new high rate. A permanent rate increase may lead to a smaller immediate portfolio adjustment. If most interest rate changes over the sample period have been relatively permanent, the estimated interest elasticity of the de-

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3. See Sargent (1981). This problem is recognized, but not addressed, by McCallum and Hoehn (1982) and Tobin (1982).

4. These three characteristics are not mutually exclusive. It will be useful, however, to distinguish between them.

mand for the asset might be small. If the monetary authority were to change its policy so that greater interest rate volatility resulted, interest rate movements would be viewed as more transitory in nature. Empirical estimates of the demand function in the new environment would find that the interest elasticity had risen.

Recent research in macroeconomics has examined the manner in which policy can affect the informational content of price and interest rate movements. Individuals use continuously observable variables such as interest rates to make inferences about economic events which might currently be unobservable. For example, interest rates, along with the initial announced value of the money supply, might be used to estimate the actual money supply or to infer whether the economy has been subject to a real or a nominal shock. Interest rate movements might also be used to draw inferences about future monetary policy. A change in the manner in which both the open market desk and the discount window automatically respond to movements in interest rates and borrowing demand will influence the way in which market participants interpret interest rate movements. If this affects their portfolio adjustments, estimated interest rate effects will depend upon discount window management and the operational instructions given to the open market desk. Section IV will deal with an example in which the information on future interest rates contained in the weekly money supply announcement varies under alternative operating procedures.

In addition to affecting estimated interest elasticities by influencing the permanence and informational content of interest rate movements, alternative policy behavior can have an impact on the risk structure of asset returns. Theories of portfolio choice by risk averse individuals imply that interest rate elasticities will be functions of the joint probability distribution of asset holding period yields. If monetary policy is expected to react in the future to what are as yet unobservable events, the joint distribution of returns can be affected by the monetary authority's policy rule. For example, a policy rule which promises to be accommodating in the face of any future supply shocks leads to a different distribution of asset returns (and therefore a different optimal portfolio) than does a policy rule which promises to be nonaccommodating in response to such shocks. A policy which leads to greater unpredictability in interest rate movements will, by increasing the riskiness of interest yielding financial assets, tend to reduce asset demand interest elasticities. Section V shows how the slope of the money demand function will, for this reason, shift if the monetary authority is expected to tolerate greater interest rate fluctuations under its new operating procedures.[5]

This discussion has pointed out several ways in which behavioral relationships such as asset demand equations will change if the monetary authority alters its operating procedures or the rules it follows in determining policy. It should be expected, then, that a major shift in operating procedures such as was carried out by the Federal Reserve in October 1979 would alter the relationships that existed in the pre-October 1979 period between interest rates, reserve aggregates, and the money supply. This discussion also suggests that studies of the choice of an instrument for monetary policy which assume a model structure which is invariant to the choice of instrument will not fully capture the likely effects of a switch from an interest rate to a reserve aggregate operating procedure. The remainder of this paper will attempt to draw some conclusions about the structural implications of a shift in operating procedures. First, though, a brief description of current procedures will help to isolate for further examination two empirical relationships which are central to the current procedures and which are unlikely to be policy invariant.

III. Current Operating Procedures[6]

The current operating procedures of the Federal Reserve, in effect since October 6, 1979, involve using nonborrowed reserves as apolicy instrument to control the growth of monetary aggregates. The implementation of policy to achieve the targeted rates of growth of the aggregates involves estimating a path for total reserves between meetings of the Federal Open Market Committee which is consistent with the desired path for the monetary aggregates. Subtracting estimated borrowings from this total reserve path yields a path for the actual policy instrument, nonborrowed reserves. The federal funds rate is then market determined by the requirement that the reserve market clear.

Because of lagged reserve accounting, however, reserve demand in any week is predetermined, based upon deposit levels of two weeks

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5. See Walsh (1982a). Weiss (1980) and King (1982) also consider ways in which prospective monetary policy affects the economy.

6. For more complete descriptions of current operating procedures, see Axilrod and Lindsey (1981), *New Monetary Control Procedures* (1981), or Hetzel (1982).

earlier.[7] Hence, the Federal Reserve's only decision is how much of that reserve demand to meet through the discount window and how much through open market operations. The federal funds rate then adjusts until banks are satisfied with the reserve composition between borrowed and nonborrowed reserves that is supplied by the Federal Reserve. The choice of a level for nonborrowed reserves is essentially then equivalent to a choice of an expected value for the federal funds rate. If the demand for money depends upon interest rates on short-term market securities, the funds rate chosen must be consistent with interest rate levels which are expected to equate the demand for money with the Federal Reserve's targeted quantity of money.[8]

With lagged reserve accounting, shifts in money demand can result in corresponding money supply movements without producing any contemporaneous disturbance in the market for reserves. Only two weeks later will reserve demand be affected. The impact on the money supply during the week of the demand shock will be the same whether the funds rate or nonborrowed reserves is the instrument of policy. When, in two weeks, reserve demand is affected, a policy which attempts to maintain a constant federal funds rate will allow for an endogenous response of reserves which will validate the effect of the money demand shock on the quantity of money. Maintaining a nonborrowed reserve target, however, will lead to federal funds movements which will tend to partially offset the initial money demand shift, thereby keeping the money stock closer to its target.

Unpredictable movements in bank borrowing from the discount window, due to a change in expected future funds rates for example,[9] will under a federal funds operating procedure be accommodated by an adjustment in nonborrowed reserves. Because interest rates are not affected, there is no contemporaneous effect on the demand for money. Under a nonborrowed reserves policy, however, the funds rate will move in response to shifts in the borrowing function. The resulting effect on short-term interest rates will lead to a change in the quantity of money.

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7. This discussion ignores excess reserves. On June 28, 1982, the Federal Reserve announced that it planned to return to contemporaneous reserve accounting.

8. A graphical analysis of these relationships is presented in Jones (1981) and Hetzel (1982).

9. The role of the expected funds rate in determining borrowing will be discussed in the next section. See also Goodfriend (1981).

In evaluating alternative operating procedures for the implementation of monetary policy, the demand for money function and the borrowing function are of central importance. Despite this, there seems to have been little analysis of how these relationships might be altered by changes in operating procedures.[10] Instead, these two functional relationships have been assumed to be policy invariant in the face of a shift in the Federal Reserve's choice of a policy instrument. Utilizing the discussion of monetary policy in section II, the next two sections will examine the borrowing function and the money demand function to determine how they might depend on the Federal Reserve's operating procedures. In each case, some attempt will be made to hypothesize how the relationship might have shifted as a result of the October 1979 change in the Federal Reserve's behavior.

IV. Intraweek Borrowing and Money Supply Announcements

Under lagged reserve accounting, controlling the money supply requires that the Federal Reserve control money demand through interest rate movements. For a given level of nonborrowed reserves, the federal funds rate is determined by the requirement that banks be willing to borrow an amount equal to required reserves less nonborrowed reserves.[11] To control the funds rate, then, the Federal Reserve must be able to accurately estimate the borrowings function relating desired bank borrowing to the federal funds rate. This section will analyze a simple model of the intraweekly determination of the federal funds rate, focusing on the borrowing relationship and the interest rate response to the Friday money supply announcements.[12] In each case, the dependency of the observed relationships on the Federal Reserve's operating procedures will be stressed. The model used is ad hoc and ignores the role of risk in affecting bank behavior; instead, the temporary versus permanent and the inference aspects of policy, as well as the role of prospective policy, will be emphasized. A consideration of the risk effects on asset demands is postponed until Section V.

10. The exception here seems to be Goodfriend (1981) who considers the relationship between the borrowing function and Federal Reserve policy. Prior to October 1979, several authors discussed the effect on the term structure of interest rates of a shift to a reserve aggregates policy; see Pierce and Thomson (1972).

11. For simplicity, excess reserves are assumed to equal zero.

12. Prior to February 1980 the announcements were made on Thursday.

Under present reserve accounting regulations, banks[13] must hold reserves over the settlement week from Thursday to Wednesday in order to satisfy required reserves against deposits during the Thursday to Wednesday period two weeks previous to the current settlement week.[14] In order to focus on the aggregate borrowings function relating bank borrowings to the spread between the federal funds rate and the discount rate, and to analyze the effects of the weekly money supply announcements, it will prove useful to treat a settlement week as consisting of just three "days." Day 1 runs from Thursday morning until 4:10 p.m. (EST) on Friday, the time of the Federal Reserve's announcement of the estimated money supply of two weeks earlier. At the beginning of day 1, banks can choose to hold reserves, sell federal funds, purchase securities, and borrow from the discount window. The actions of the j^{th} bank are constrained by the budget identity equating its assets and liabilities:

$$R^j_{t,i} + S^j_{t,i} + F^j_{t,i} = D^j_{t,i} + B^j_{t,i} \tag{1}$$

where R = reserve holdings
S = security holdings
F = federal funds sold
D = deposits
B = borrowed reserves.

The first subscript denotes the week, the second gives the day of the week, and the superscript denotes the individual bank. Thus, $D^j_{t,i}$ equals deposits on day i of week t at bank j. The week subscript will often be deleted if no confusion will arise from so doing.

Day 2 runs from 4:10 p.m. (EST) Friday through Tuesday of the following week. Day 2 is assumed to differ from day 1 only in that an estimate of aggregate deposits during week t-2, D^a_{t-2}, is available.[15,16] If $D^a_{t-2} = E_1(D^a_{t-2})$, where $E_1(D^a_{t-2})$ is the expected value, on day 1, of D^a_{t-2}, day 2 is exactly like day 1 as the Federal Reserve is assumed to

13. The Depository Institutions Deregulation and Monetary Control Act of 1980 provides for reserve requirements against transaction deposits at nonbank institutions. All institutions subject to reserve requirements are simply referred to as banks in this paper.

14. Vault cash, ignored here, is counted toward reserves against contemporaneous deposits. This discussion also ignores the 2 percent reserve carryover provision.

15. In order to focus on deposits, currency is not dealt with here.

16. The absence of a second subscript denotes a weekly average: i.e., $X^j_t = (1/3)(X^j_{t,1}+X^j_{t,2}+X^j_{t,3})$. The absence of a superscript will denote the aggregate value for all banks: $X_{t,i} = \sum_j X^j_{t,i}$.

engage in policy actions only at the beginnings of day 1 and day 3. If $D^a_{t-2} \neq E_1(D^a_{t-2})$, banks incorporate the new information contained in $D^a_{t-2} - E_1(D^a_{t-2})$ and adjust their portfolios; interest rates and deposits change as a new equilibrium is established.

On day 3 (Wednesday)[17] banks must meet their reserve requirement, which implies that $R^j_t = kD^j_{t-2}$ or

$$R^j_{t,3} = 3kD^j_{t-2} - R^j_{t,1} - R^j_{t,2} \tag{2}$$

where k is the required reserve ratio, and average reserves over the settlement week, $(1/3)(R^j_{t,1} + R^j_{t,2} + R^j_{t,3})$, must equal kD^j_{t-2}. At the start of day 3, the monetary authority can engage in open market operations and banks reallocate their portfolios subject to (1) and (2).

On each day, the federal funds rate and the interest rate on securities adjust to equilibrate the federal funds, reserves, and security markets.[18] Given this overview of the model structure, the detailed specification of the demand and supply equations for each asset can now be described. The equilibrium expressions for the two interest rates which are then discussed are derived in detail in Walsh (1982b).

Since many banks, particularly large ones, are limited in the frequency with which they can utilize the discount window, borrowing demand during days 1 and 2 will depend positively on the current profitability of borrowing and negatively on the expected profitability of borrowing on day 3. To adopt a specification that is similar to that apparently used by the Federal Reserve staff,[19] the profitability of borrowing is measured by the spread between the funds rate and the discount rate. It is assumed that the administration of the discount window results in a marginal cost of borrowing to an individual bank that is an increasing function of the bank's borrowing level. Also, it is assumed that banks are sufficiently risk averse that they do not completely arbitrage away any difference between the current spread and the expected day 3 spread between the funds rate and the discount rate.

17. The unequal lengths of the three days will be neglected.

18. Although the reserves market and the federal funds market are not distinct, they do provide two equilibrium conditions: aggregate federal funds sold must equal zero and banks must be satisfied with the borrowed/nonborrowed reserves composition supplied by the Federal Reserve.

19. *See* Keir (1981) and Levin and Meek (1981).

The aggregate borrowings function is then approximated by

$$B_i = \alpha_0 + \alpha_1(r_i^f - r_i^d) + \alpha_2 E_i(r_3^f - r_3^d) + u;\ i = 1,2^{20} \qquad (3)$$

$$B_3 = \alpha'_0 + \alpha'_1(r_3^f - r_3^d) + u_3 \qquad (3')$$

where $B_i = \sum_j B^j_{t,i}$ is aggregate borrowing on day i, r^f is the funds rate, and r_i^d is the discount rate; u and u_3 are mean zero, serially independent, stochastic disturbance terms. The parameters α_1 and α'_1 are positive while α_2 is negative. It is assumed that $\alpha_1 + \alpha_2 > 0$; an equal rise in the current and future expected spread increases current borrowing. In order to focus on intraweekly interest rate movements, any restrictions on borrowing in future weeks implied by current borrowing have not been dealt with in specifying (3) and (3′).[21]

Within the settlement week, banks view deposits as demand determined. Given its borrowings each bank must allocate $D_i^j + B_i^j$ among reserves, securities, and net federal funds sold. Since the alternative to investing an extra dollar in securities is to sell a dollar in the federal funds market, the demand for securities should be a positive function of $r_i^s - r^f$ where r^s is the interest rate on securities. Reserve holdings should depend negatively on this variable. Since an extra dollar of reserves held on days 1 or 2 reduces the need for reserves on day 3 because of the reserve averaging procedure, the demand for reserves should depend positively (and security demand negatively) on $E_i(r_3^f) - r_i^f$ for i = 1,2.[22] If reserves are expected to be relatively expensive on day 3 ($E_i(r_3^f) - r_i^f$ is large), banks adjust in the current period by increasing their reserve holdings and selling securities.

Aggregate bank securities and reserve holdings are assumed equal to

$$S_i = \beta_0 + \beta_1(r_i^s - r_i^f) + \beta_2 E_i(r_3^f - r_i^f) + v_i^s;\ i = 1,2 \qquad (4)$$

$$S_3 = \beta'_0 + \beta'_1(r_3^s - r_3^f) + v_3^s \qquad (4')$$

$$R_i = \gamma_0 + \gamma_1(r_i^s - r_i^f) + \gamma_2 E_i(r_3^f - r_i^f) + v_i^r;\ i = 1,2 \qquad (5)$$

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20. Goodfriend (1981) obtains a somewhat similar borrowing function for weekly borrowings from a model in which the marginal cost of borrowing to an individual bank is an increasing function of the bank's previous borrowing.

21. Borrowings could also be assumed to depend positively on D_{t-2}, but this would not affect the subsequent analysis. Note that due to restrictions on the frequency with which banks can borrow, an equation similar to (3) would hold with t denoting a period between FOMC meetings and i denoting a particular week within an intermeeting period. See the discussion of temporal aggregation below.

22. This ignores any discounting of $E_i r_3^f$.

with R_3 given by (2).[23] Federal funds sold can be obtained by substituting (3), (4), and (5) into (1). The stochastic disturbance terms, v^s, v_3^s, and v^r are assumed to have mean zero and be serially independent. The previous discussion implies that $\beta_1, \beta'_1 > 0, \beta_2 < 0, \gamma_1 < 0$, and $\gamma_2 > 0$. In addition, own rate effects are assumed to dominate so that $\beta_1 + \beta_2$ and $\gamma_1 + \gamma_2$ are both positive.

The final two components of the model needed to solve for the intra-weekly equilibrium interest rates are a specification of the behavior of the nonbank public and the monetary authority. The nonbank public is assumed to hold either deposits or securities; its demand for deposits is given by:

$$D_i = \delta_0 + \delta_1 r_i^s + \epsilon_i;\ \delta_1 < 0,\ i = 1,2,3. \tag{6}$$

In order to form expectations about the day 3 federal funds rate, banks will need to forecast the amount of nonborrowed reserves that the monetary authority will add to or subtract from the reserve market on day 3. Suppose that the monetary authority has targets for total deposits, D^T, and the federal funds rate, r^T. Nonborrowed reserves on day 3 are adjusted if the money supply announcement indicates that total deposits do not equal D^T. They are also adjusted if r_3^f moves away from r^T:

$$U_{t,3} = \mu_0 + \mu_1(D_{t-2}^a - D^T) + \mu_2(r_{t,3}^f - r^T) + \eta_{t,3} \tag{7}$$

where U_i equals nonborrowed reserves on day i and η is a serially independent, mean zero disturbance term due to such random factors as float. The parameters μ_1 and μ_2 measure the monetary authority's response to deviations from its targets with $\mu_1 \leqslant 0$ and $\mu_2 \geqslant 0$. Equation (7) represents a hypothetical policy reaction function which will subsequently be used to represent various alternative policy procedures.

Equilibrium requires that r^f and r^s adjust on each day to equate the demand for and supply of federal funds and the demand for and supply of securities. The model's equilibrium conditions can be written as

$$F_{t,i} = 0 \tag{8}$$

$$U_{t,i} = R_{t,i} - B_{t,i} \tag{9}$$

for $i = 1,2,3$ and F, R, and B given by (1) – (6). $U_1 = U_2$ is treated as an exogenous parameter, while U_3 is given by (7).

23. These equations can be obtained by aggregating individual bank demand equations which depend on the same right-hand variables as long as expectations are identical across banks.

In Walsh (1982b) the model is solved for the equilibrium interest rates on days 1 and 2 and the following reduced form expressions for r_i^f and r_i^s are obtained for i = 1,2:

$$r_{t,i}^f = \pi_{f0} + \underset{-}{\pi_{f1}}U_{t,i} + \underset{+}{\pi_{f2}}r_{t,i}^d + \underset{+}{\pi_{f3}}E_i(r_{t,3}^f) + \underset{-}{\pi_{f4}}E_i(r_{t,3}^d) + e_t^f \quad (10)$$

$$r_{t,i}^s = \pi_{s0} + \underset{-}{\pi_{s1}}U_{t,i} + \underset{+}{\pi_{s2}}r_{t,i}^d + \underset{+}{\pi_{s3}}E_i(r_{t,3}^f) + \underset{-}{\pi_{s4}}E_i(r_{t,3}^d) + e_t^s \quad (11)$$

where the parameters π_{ji} are functions of the structural parameters and their signs are reported below each coefficient.

Equations (10) and (11) contain two terms, $E_i(r_{t,3}^f)$ and $E_i(r_{t,3}^d)$, which are day **i** expectations about day 3 variables. Since r_3^f will be determined on day 3 by the requirement of market equilibrium, market participants will, if expectations are rational, base $E_i(r_3^f)$ on the model's prediction of r_3^f, conditional on the information available on day i. The reduced form equation for r_3^f can be found by combining equations (2) and 3′), together with (9) to yield:

$$\begin{aligned} r_{t,3} = r_{t,3}^d - (\alpha_0'/\alpha_1') + (1/\alpha_1')(3kD_{t-2} - R_{t,1} - R_{t,2} - U_{t,3}) \\ - (1/\alpha_1')u_{t,3} \end{aligned} \quad (12)$$

Equation (12) implies that, unless $U_{t,3}$ is adjusted in response to a change in $r_{t,3}^d$ (as it would have been under the pre-October 1979 operating procedures), the spread between the funds rate and the discount rate on day 3 is unaffected by changes in the discount rate.[24]

Taking expectations of both sides of (12) as of day **i** (i= 1 or 2) and using the policy rule (7) to evaluate $E_iU_{t,3}$,

$$\begin{aligned} E_ir_{t,3}^f = (1+\mu_2/\alpha_1')^{-1}[E_ir_{t,3}^d - (\alpha_0'/\alpha_1') \\ +(1/\alpha_1')(3kE_iD_{t-2} - E_iR_{t,1} - E_iR_{t,2}) \\ - (1/\alpha_1')(\mu_0 + \mu_1E_iD_{t-2}^a - \mu_1D^T - \mu_2r^T)] \end{aligned} \quad (13)$$

where it is assumed that market participants know the values of D^T and r^T, and, if **i** = 2, $E_iD_{t-2}^a = D_{t-2}^a$ since the announcement is made at the beginning of day 2. Notice now that changes in the discount rate are expected to affect the spread if $\mu_2 \neq 0$. To forecast the day **3** funds rate requires that banks attempt to estimate the total reserve demand for the week $(3kE_iD_{t-2})$ as well as the amount of borrowing which will occur on days 1 and 2. Equation (5) could be used to express $E_iR_{t,j}$ in terms of interest rates and interest rate expectations. The expected day 3 funds

24. **Goodfriend (1981) presents some evidence that suggests increases in the discount rate have not resulted in changes in the spread between the funds rate and the discount rate.**

rate also depends upon the expected money announcement $E_iD^a_{t-2}$. This variable is, in some ways, like the "intrinsically irrelevant" variable that King (1982) analyzed. It has a direct effect on $r^f_{t,3}$ and $E_ir^f_{t,3}$ only if the monetary authority responds to it ($\mu_1 \neq 0$). However, D^a_{t-2} also has an indirect effect on the expected day 3 funds rate if it provides information that can be used to forecast D_{t-2}.[25] The money announcement gives an indication of future policy if $\mu_1 \neq 0$ and yields information on D_{t-2} as long as $E_1[(D^a_{t-2} - E_1D^a_{t-2})(D_{t-2} - E_1D_{t-2})] \neq 0$.

To see how these two roles of D^a_{t-2} affect market interest rates, consider how r^f_2 and r^s_2 will differ from r^f_1 and r^s_1. By assumption, days 1 and 2 differ only in that D^a_{t-2} is announced at the start of day 2. Equations (10) and (11) imply that

$$r^f_2 - r^f_1 = \pi_{f3}(E_2r^f_3 - E_1r^f_3) \tag{14}$$

$$r^s_2 - r^s_1 = \pi_{s3}(E_2r^f_3 - E_1r^f_3) \tag{15}$$

where it is assumed for simplicity that the discount rate is not expected to be adjusted in light of the money announcement. The interest rates on federal funds and securities move in response to revisions in expectations about the funds rate which will prevail on day 3. Since the information set relevant for forming expectations on day 2 differs from that used on day 1 only by the addition of the observed value of D^a_{t-2}, the revision in expectations can be written[26]

$$E_2r^f_3 - E_1r^f_3 = \psi_f(D^a_{t-2} - E_1D^a_{t-2}) \tag{16}$$

where $\psi_f = E_1[(r^f_3 - E_1r^f_3)(D^a_{t-2} - E_1D^a_{t-2})]/E_1(D^a_{t-2} - E_1D^a_{t-2})^2$. In Walsh (1982b) it is shown that

$$\psi_f = (3k\phi - \mu_1)/(\alpha'_1 + \mu_2 + \gamma_2(\pi_{s3} - \pi_{f3}) + \gamma_2(1 - \pi_{f3})) > 0 \tag{17}$$

with $\phi = E_1(D_{t-2})(D^a_{t-2} - E_1D^a_{t-2})/E_1(D^a_{t-2} - E_1D^a_{t-2})^2$. ϕ will be positive and, if D^a_{t-2} is an unbiased estimate of D_{t-2}, it will equal one. Substituting (16) into (14) and (15),

$$r^f_2 - r^f_1 = \pi_{f3}\psi_f(D^a_{t-2} - E_1D^a_{t-2}), \tag{18}$$

$$r^s_2 - r^s_1 = \pi_{s3}\psi_f(D^a_{t-2} - E_1D^a_{t-2}). \tag{19}$$

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25. After this paper was substantially completed, the Federal Reserve announced a return to contemporaneous reserve accounting. In this case, D^a_{t-2} no longer would provide a direct measure of the aggregate demand for reserves. Since deposit levels are serially correlated, ϕ in equation (17) below would be positive, but smaller than under lagged reserve accounting.

26. See Sargent (1979, pp. 206-208).

Since both $\pi_{f3}\psi_f$ and $\pi_{s3}\psi_f$ are positive, a positive money surprise, $D^a_{t-2} > E_1 D^a_{t-2}$, leads to a rise in both the federal funds rate and the securities interest rate. Such a positive relationship between the money announcement "surprise" and interest rates has been documented by Grossman (1981), Urich and Wachtel (1981), and Roley (1982).

The reaction coefficients, $\pi_{f3}\psi_f$ and $\pi_{s3}\psi_f$, depend upon μ_1 and μ_2, parameters which characterize the behavior of the monetary authority. Changes in operating procedures, represented here by changes in μ_1 or μ_2, will result in shifts in the response of interest rates to money surprises. Because, according to (10) and (11), day 1 and day 2 interest rates depend on the federal funds rate expected to prevail on day 3, day 1 and day 2 interest rates depend upon the expected day 3 behavior of the monetary authority. This response depends both upon the way nonborrowed reserves are to be adjusted to future as yet unobserved variables (μ_2 measures the way U_3 will respond in the future to r^f_3) and on how U_3 responds in the future to currently observed variables (μ_1 measures the way U_3 will be adjusted in light of D^a_{t-2}). Letting Δ denote the denominator in (17), the response coefficients in (18) and (19) can be written as

$$\pi_{j3}\psi_f = 3\pi_{j3}k\phi/\Delta - \pi_{j3}\mu_1/\Delta; \; j = f,s. \tag{20}$$

The first term represents the effect of the revised expectation of D_{t-2} produced by the announcement; the second represents the effects of the prospective policy reaction to the announcement.[27]

Consider how one might use this framework to represent the October 6, 1979 shift in operating procedures by the Federal Reserve. One way to do so might be to represent the pre-October 1979 policy as one with a large μ_2 and a zero μ_1; strong policy actions were taken in response to movements in the funds rate in an attempt to stabilize it, while information on past monetary aggregates produced no policy response. The new, post-October 1979, operating procedures could be characterized by a smaller μ_2, as less of an attempt is made to stabilize r^f, with μ_1 still equal to zero since the nonborrowed reserve path is rarely adjusted on an intraweekly basis. A reduction in μ_2 causes Δ to fall and, from (20), $\pi_{j3}\psi_j$ rises. The shift to a reserve aggregates

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27. **Urich and Wachtel (1981) attribute the positive response of interest rates to a policy anticipations effect. However, even if $\mu_1 = 0$, $\pi_{j3}\psi_f > 0$ since D^a_{t-2} provides information on the aggregate demand for reserves.**

operating procedure under which market participants believe the Federal Reserve will not react strongly to interest rate movements will make interest rates more responsive to money announcement surprises. This is exactly the empirical result found by Roley (1982) in comparing the pre- and post-October 1979 periods.

Suppose that the Federal Reserve changed its operating procedures and began to actively adjust the nonborrowed reserve path on an intraweekly basis in response to any deviation of the announced deposit level from its target. This type of procedure could be represented by a large, negative value of μ_1 in equation (7). According to (20), an increase in the absolute value of μ_1 increases the response coefficients; interest rates would rise even more in response to a positive money surprise.

Equations (18)–(20) can be used to evaluate recent proposals for changing the manner in which the weekly money supply announcements are made. Suppose that instead of releasing D^a_{t-2}, a new variable A, is announced, equal to a four-week moving average of past weekly deposit levels:

$$A_t = (1/4)(D^a_{t-2}+D_{t-3}+D_{t-4}+D_{t-5}). \tag{21}$$

For simplicity, it is assumed that the actual levels of deposits in weeks t-3, t-4, and t-5 are **included.**[28] In the equation $r^s_{t,2} - r^s_{t,1} = \phi_A(A_t - E_1A_t)$, how will the new response coefficient ϕ_A compare with $\pi_{s3}\psi_f$? And how will A, $- E_1A_t$ compare with $D^a_{t-2} - E_1D^a_{t-2}$?

The answer to this second question follows immediately from the assumption that D,,, D,,, and D_{t-5} are known during week t:

$$A_t - E_1A_t = (1/4)(D^a_{t-2}-E_1D^a_{t-2}). \tag{22}$$

Reporting A, rather than D^a_{t-2} leads to a less volatile series of surprises in that the conditional variance of A, is equal to $(1/16)E_1[D^a_{t-2}-E_1D^a_{t-2}]^2$. However, this does not imply that interest rate movements will be smaller. Since

$$E_1(D_{t-2}-E_1D_{t-2})(A_t-E_1A_t)/E_1(A_t-E_1A_t)^2 = (1/4)E_1(D_{t-2})(D^a_{t-2}- E_1D^a_{t-2})/(1/16)E_1(D^a_{t-2}-E_1D^a_{t-2})^2 = 4\phi, \phi_A$$

can be written as

28. **This assumes that during week t, the figure on D_{t-3} is available.**

$$\begin{aligned}\phi_A &= 3\pi_{s3}k(4\phi)/\Delta - \pi_{s3}\mu_1'/\Delta \\ &= 4(\pi_{s3}\psi_f) - \pi_{s3}(\mu_1' - 4\mu_1)/\Delta \end{aligned} \tag{23}$$

where μ_1' now measures the way the public believes the monetary authority will adjust U_3 in response to A,. If both μ_1 and μ_1' are zero or if it is believed that U_3 is still adjusted only in response to D^a_{t-2}, $\mu_1' = 4\mu_1$ and $\phi_A = 4\pi_{s3}\psi_f$. In this case,

$$\begin{aligned}r_2^s - r_1^s = \phi_A(A_t - E_1A_t) &= 4\pi_{s3}\psi_f(1/4)(D^a_{t-2} - E_1D^a_{t-2}) \\ &= \pi_{s3}\psi_f(D^a_{t-2} - E_1D^a_{t-2}). \end{aligned} \tag{24}$$

The new method of making money supply announcements reduces the volatility of surprises but has no effect on the volatility of interest rates. Only if the public interprets the new announcement procedures as indicating a change in the monetary authority's behavior, so that $\mu_1' \neq 4\mu_1$, will interest rate movements be affected.

The response of variables other than the interest rates to the money announcement can also be analyzed within this framework. As was discussed in the previous section, predicting bank borrowing from the discount window has taken on greater, importance under the current reserve aggregates operating procedures. However, by increasing, interest rate volatility, the reserve aggregates operating procedures will also reduce the day-to-day predictability of borrowings. For example, suppose at the end of day 1 the monetary authority, after observing B_1, tries to predict day 2 borrowings. The prediction error will be $B_2 - E_1B_2 = (a_1\pi_{f3} + \alpha_2)\psi_f(D^a_{t-2} - E_1D^a_{t-2})$ and the prediction error variance is given by

$$E_1(B_2 - E_1B_2)^2 = (\alpha_1\pi_{f3} + \alpha_2)^2\psi_f^2E_1(D^a_{t-2} - E_1D^a_{t-2})^2. \tag{25}$$

Since ψ_f is larger under the reserve aggregates policy, the variance of the borrowings prediction error will also be larger.

The preceding analysis also has some implications for the standard borrowings equation which relates the level of borrowings to the contemporaneous value of the spread between the funds rate and the discount rate.[29] Again, suppose that the monetary authority attempts to

29. Keir (1981) provides examples of this specification for the borrowings function using weekly data. The issue of temporal aggregation is discussed below. See also Goodfriend (1981) who reaches conclusions similar to those obtained here.

predict day 2 borrowings from the following equation estimated by OLSQ:

$$B_2 = a_0 + a_1(r_2^f - r_2^d). \tag{26}$$

From (3), the estimated value of a, will equal, given a large enough sample, a , $+\alpha_2$b where b is the regression coefficient in a regression of the expected day 3 spread on the day 2 spread.[30] The value of b, and hence the estimated slope of the borrowings function, will clearly depend upon the monetary authority's policy; if movements in the spread are relatively temporary, b will be small, while if movements in the spread tend to persist, b may be close to one. Under the old interest rate operating procedures, the Federal Reserve attempted to stabilize the funds rate, at least on an intraweekly basis. This would imply that b might be close to one and the estimated slope of the borrowings function would approximately equal α_1 + a,. Under the new procedures, interest rates are allowed to fluctuate over a wider range; r_2^f and r_3^f will be less closely related and b will be much smaller. Therefore, under current operating procedures, a, = a , + α_2b > a , + α_2. A plot of borrowings on the horizontal axis and the spread on the vertical axis would appear to be flatter under the new operating procedures.

Borrowing functions are usually estimated with weekly data whereas the conclusions reached so far refer to shifts in a daily borrowings function. However, the model suggests that the observed relationship between total weekly borrowings and the average spread between the funds rate may also be flatter under the new operating procedures. Assuming, for simplicity, that a , = a ' , and aggregating equations (3) and (3') reveals that a regression of total weekly borrowings on the average spread for the week, $r_t^f - r_t^d$, will yield a biased estimate of the true slope with the bias a function of the covariance between $r_t^f - r_t^d$ and the average of the day 1 and day *2* expectations of $r_{t,3}^f - r_{t,3}^d$.[31] This covariance is likely to be smaller under the post-October **1979** operating procedures than it was under the pre-October **1979** procedures. This again implies that the coefficient on $r_t^f - r_t^d$ in a

30. The additional bias created by the covariance between r_2^f and u, the disturbance term in equation (3), is ignored here since it is independent of the policy parameters μ_1 and μ_2; from Walsh (1982b), $\mathrm{Cov}(r_2^f,u) = \mathrm{Cov}(e^{\cdot},u) = Q(\beta_1-\delta_1)\sigma_u^2$ if u is distributed independently of v^r, v^s, and ϵ.

31. See Walsh (1982b).

weekly borrowings function will appear to have risen. That this appears to be the case is suggested by the empirical work of Levin and Meek (1981) and Keir (1981).

The results of this section are easy to summarize. Apparent structural changes in interest rate responses to money surprises and in the borrowings function can be explained, at least partially, as the result of the shift to a reserve aggregates operating procedure which allows greater interest rate fluctuations in attempting to offset deviations of monetary aggregates from their targets.

V. Interest Rate Risk and Money Demand

The money supply is determined within each week by money demand under lagged reserve accounting. It is important then to consider how money demand might be affected by the Federal Reserve's choice of operating procedures. In the previous section, because the focus was on bank borrowing, a very simple deposit demand equation was assumed, one in which the parameters were taken to be policy invariant. The present section will consider the dependency of the money demand function on the behavior of the monetary authority. The general conclusion is that a change to a reserve aggregates operating procedure induces a shift in the money demand function. This structural change tends to amplify the increase in interest rate volatility which would accompany a reserve aggregates policy.[32]

The demand for money is normally explained by appealing to transaction and portfolio motives for individuals to hold money. If the correlation between nominal interest rates and inflation is less than one, money can be held to reduce portfolio risk even though it is itself a risky asset. As shown by Boonekamp (1978) and Buiter and Armstrong (1978) in partial equilibrium frameworks and utilized in a general equilibrium, rational expectations model by Walsh (1982a), the interest elasticity of the demand for money will vary inversely with the volatility of nominal interest rates. This result follows from simple models of portfolio choice by risk averse investors. As asset returns become less predictable so that assets are riskier, portfolios are adjusted less in response to a change in expected returns.

For example, assume that individuals exhibit constant relative risk

32. A rigorous derivation of the results reported in this section is contained in Walsh (1982a).

aversion[33] and allocate their wealth between money and bonds in order to maximize a linear function of their portfolio's expected real rate of return and its variance:

$$u = E_t r_{p,t+1} - (\tfrac{1}{2})\rho E_t(r_{p,t+1} - E_t r_{p,t+1})^2 \tag{27}$$

where $E_t r_{p,t+1}$ is the expected real rate of return on the portfolio from t to t+1 and p is a measure of risk aversion which could vary across individuals. If m, is the fraction of wealth held in money, the portfolio return is given by

$$r_{p,t+1} = r_{m,t+1} m_t + (1-m_t) r_{b,t+1} \tag{28}$$

where $r_{m,t+1}$ and $r_{b,t+1}$ are the real returns on money and bonds, respectively. If $r_{m,t+1} = -\pi_{t+1}$ where π_{t+1} is the rate of inflation from t to t+1, and $r_{b,t+1} = i_{t+1} - \pi_{t+1}$ where i_{t+1} is the nominal bond return (including both interest and capital gain) from t to t+1, the optimal proportion of wealth to hold in the form of money, m_t^d, is given by[34]

$$m_t^d = (\sigma_i^2 - \sigma_{i\pi})/\sigma_i^2 - (1/\rho\sigma_i^2)E_t i_{t+1} \tag{29}$$

where $\sigma_{i\pi} = E_t(i_{t+1} - E_t i_{t+1})(\pi_{t+1} - E_t \pi_{t+1})$ and $\sigma_i^2 = E_t(i_{t+1} - E_t i_{t+1})^2$. If market interest rates follow a martingale, $E_t i_{t+1} = i_t^n$ where i_t^n is the nominal, market rate of interest at time t. The slope of the money demand function is equal to $dm_t^d/di_t^n = -(1/\rho\sigma_i^2)$. Greater interest rate volatility leads to a reduction in the responsiveness of money demand to changes in the market rate of interest.

One of the major arguments in favor of the shift from an interest rate oriented operating procedure to a reserve aggregates one was that it would allow greater movements in interest rates. Since the resulting greater volatility of market interest rates increases the risk associated with holding interest earning assets, equation (29) predicts that the change in operating procedures should have produced a structural shift in the money demand equation. By affecting the risk characteristics of financial assets, a change in the monetary authority's behavior will result in private sector responses such that asset demand equations estimated under one policy regime will no longer reflect the behavior

33. Boonekamp's analysis is carried out under less restrictive assumptions.
34. This is derived in Walsh (1982b). If money also yields a return in the form of transaction services which are related to the volume of transactions,(29) would include a term such as income to proxy for transactions. For simplicity, income effects are ignored although they could easily be included as is done in Walsh (1982a).

of asset holders under the new policy regime. The parameters of the money demand equation should not be assumed to be policy invariant for the purpose of evaluating alternative operating procedures.

In terms of a standard graph of money demand on the horizontal axis and the interest rate on the vertical axis, a shift from a policy which stabilizes interest rates to one which allows greater fluctuations in interest rates is likely to produce a money demand curve which is steeper than that observed under the old policy. This, in turn, has implications for the degree of interest rate volatility which is likely to occur under a reserve targeting procedure.

In order to keep the money supply equal to its targeted path, interest rates must move in response to money demand shifts. If the demand for money appears unusually strong, interest rates must rise to keep money demand equal to the targeted money supply. This can be accomplished either by direct control over short-term interest rates or by exercising indirect control through nonborrowed reserves. This is illustrated in Figure 1 in which m^* is the money supply target, m^d is the initial money demand curve, and the dashed line represents money demand if there has been a random shock which has increased the demand for money. To keep the money supply on target, the interest rate must rise from r_0 to r,.

The line labeled Pre-1979 represents the interest rate-money stock co-movements which would have been tolerated under the old operating procedures. This policy response function, derivable from the reserve market equilibrium, was relatively flat as the Federal Reserve acted to stabilize interest rates. As a result of the positive shock to money demand, the interest rate rises only to r_2. As a consequence, the money stock rises above the target to m,.

The new operating procedures can be represented by a steeper policy response-reserve market equilibrium relation such as the line labeled Post-1979 in Figure 2. If there has been no change in the underlying money demand function m^d, the same positive shock as illustrated in Figure 1 now would lead to a rise in the interest rate to r,. Money again diverges from its target, but the discrepancy, $m_2 - m^*$, is smaller than under the old operating procedures.

If individuals correctly perceived that the Federal Reserve would tolerate wider interest rate movements under the new operating procedures, the money demand curve would not remain unchanged but would become steeper as the interest elasticity of money demand declined. The new money demand curve is drawn as m_d' in Figure 3. The same,[35] positive random shock to demand that could formerly have been offset by a rise in the interest rate tor, now requires that r rise further, to r,, to keep the money stock equal to m*. Under the new procedures, the interest rate increases to r_4 and the money supply equals m_3. The interest rate rises further and the money supply diverges from target further (i.e., $r_4>r_3$ and $m_3-m^*>m_2-m^*$) than they would have if the money demand function had not become steeper. If money demand becomes less sensitive to interest rate movements, larger movements in market interest rates will be necessary to maintain any given degree of control over the money supply.[36] The structural shift induced by the change in operating procedures implies that models estimated under an interest rate policy regime will underestimate the interest rate volatility which would be associated with the active use of nonborrowed reserves as the instrument of monetary policy. If this induced structural shift is ignored, the greater interest rate volatility required to control the money supply could be incorrectly interpreted as evidence that the demand for money has become more unstable and is now subject to larger shocks.[37].

In the period since October 1979, there has been a pronounced rise in interest rate volatility.[38] The analysis of this section suggests that some of this rise may be due to structural shifts induced by the change in the Federal Reserve's operating procedures. These structural shifts in asset demand equations are likely to have occurred because the policy change altered the joint distribution of asset returns and therefore affected the risk characteristics of financial assets. The analysis also suggests that, in choosing between an interest rate and a reserve aggregate instrument, the possibility that the structural relationships describing the economy may not be the same under both policies needs to be recognized.

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35. The shock is the same as measured by the horizontal displacement of the money demand curve.

36. Control over the money supply might be measured here by $E(m-m^*)^2$.

37. See Tinsley and others (1981) who concluded that the year after the introduction of the new operating procedures was atypical, subject to larger than normal shocks.

38. See Johnson and others (1981) and Tinsley and others (1981).

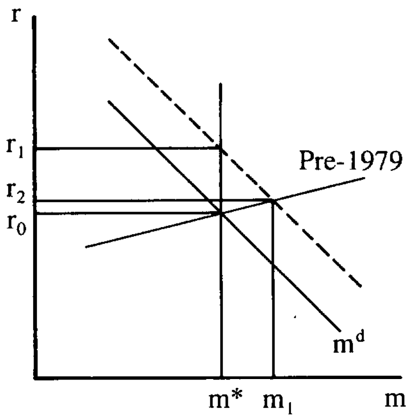

FIGURE I

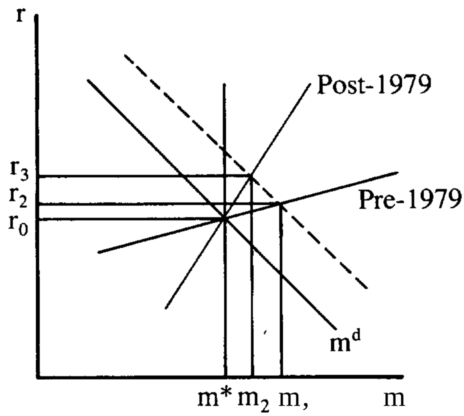

FIGURE 2

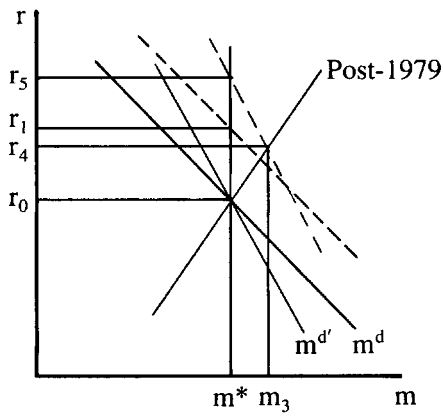

FIGURE 3

VI Implications for Monetary Policy

In this concluding section, some of the implications for monetary policy of the specific examples developed in the previous two sections are discussed. Some general observations on the relationship between policy and structural change will also be made.

The model of the previous section implied that a policy regime which tolerated greater fluctuations in interest rates would be accompanied by a money demand function that was relatively interest inelastic. To repeat one of the conclusions of that section, a policy which attempts to keep money on target will produce large swings in interest rates if the interest elasticity of the demand for money is small. Producing these large movements in interest rates would require aggressive use of the nonborrowed reserve instrument. This will be especially true if, as the analysis of Section IV suggests, the borrowings function exhibits greater interest elasticity when interest rate volatility rises.

The other implication of a low interest elasticity of the demand for money is that the automatic corrective response to deviations from the money target under a reserve aggregates policy is weakened. Under lagged reserve accounting, a positive shock to money demand results in a rise two weeks later in total reserve demand. Given a fixed path for nonborrowed reserves, the rise in reserve demand leads to an increase in market interest rates which serves the role of an automatic stabilizer by reducing money demand and offsetting the positive deviation of money above its target path. However, an increase in the responsiveness of borrowing to the funds rate and a decline in the interest elasticity of money demand reduces the force of this automatic adjustment. The rise in borrowing produces a smaller rise in the funds rate and other market rates which in turn exercises a weaker restraining effect on money demand. The speed with which money returns to its target will therefore be slower than estimates obtained under an interest rate policy regime might suggest.

Policy-induced structural change is a factor that has been ignored in the academic literature on the relative merits of an interest rate and a reserve aggregates operating procedure.[39] The implications of the previous two sections for this choice can be illustrated with the use of Figure 3 in Section V. Inspection of that figure shows that, for a given policy response-reserve market equilibrium schedule such as the post-1979 line drawn, money demand shocks produce more interest rate volatility and greater deviations of money from its target the steeper is the money demand curve. This indicates that monetary control will be worse in response to money demand shocks under a reserve aggregates policy than would be implied by empirical results obtained during an interest rate targeting regime.

Shocks to the market for reserves, on the other hand, may pose less of a problem than existing empirical models might imply. Such shocks cause the money stock to deviate from target by affecting interest rates

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39. This literature was initiated by Poole (1970). Other examples are Pierce and Thomson (1972), LeRoy (1979), and McCallum and Hoehn (1982).

and therefore money demand. Figure **3** suggests that random shifts in the policy response-reserve market equilibrium function will cause larger interest rate movements but smaller money stock deviations the steeper is the money demand function. The effects, therefore, of random shocks to borrowing or errors in predicting total reserves demand may be less than would be implied by pre-October 1979 empirical models. As discussed earlier, the resulting volatility of interest rates under a policy regime which controls the money supply through the use of nonborrowed reserves as the operational instrument will exceed the level implied by models estimated during a period of interest rate stability.

With lagged reserve accounting, McCallum and Hoehn (1982) have shown that an interest rate policy always produces better control over the money supply than does a reserve aggregates policy. This remains true when possible structural changes are considered, but the comparison becomes less unfavorable to a reserve aggregates policy; the decreased responsiveness of money demand to interest rates and the increased sensitivity of borrowing to the funds rate tend to moderate the impact of reserve market shocks on the money supply under a reserve aggregates policy.[40]

The reserve market equilibrium locus under a reserve aggregates policy depends upon the behavior of both the Federal Reserve and of the banking sector. Under an interest rate policy in which the federal funds rate is, over each week, fixed by the Federal Reserve, the reserve market equilibrium locus represents only the policy behavior of the Federal Reserve in setting interest rates. It is not a money supply function.[41] This plus the dependency of structural relationships on policy calls into question the reliability of any conclusions reached using money multiplier models. Money multipliers are claimed to be reduced-form parameters, and, as pointed out by Marschak (1953), knowledge of reduced-form parameters alone seldom constitutes sufficient information upon which to base policy choices. Money multipliers were, however, neither reduced-form parameters nor structural parameters in the pre-October 1979 period as both the money supply and reserve aggregates were endogenous variables. The ratio of two endogenous variables is unlikely to contain any casual information;

40. McCallum and Hoehn (1982) use a model in which income is also endogenous. An examination of their equation **23** (p. 16) shows that the general conclusions reached here are not affected when income shocks are incorporated into the model.

41. This is pointed out by McCallum and Hoehn (1982).

using pre-October 1979 multiplier models to carry out conterfactual policy experiments is illegitimate.[42] Using empirical results from models estimated prior to 1979 to draw inferences about the effects of imposing an arbitrary path for reserves, as is done by Johannes and Rasche (1981), may tell one little about the likely effects of such a policy.[43]

Suppose, however, that the Federal Reserve reinstituted contemporaneous reserve accounting and made total reserves (or any other choice of reserve aggregate) a truly exogenous variable. For simplicity, assume that the time series behavior of total reserves could be modeled as a moving average process, $R_t = R_0 + A(L)\epsilon_t$ where $A(L)$ is a polynomial in the lag operator L and ϵ is a white noise random variable. Under such a policy regime one could estimate a multiplier relationship for some monetary aggregate, M. If $\bar{m}$ is the money multiplier, on average, $M_t = \bar{m}R_t = \bar{m}(R_0+A(L)\epsilon_t)$.

Consider a change in policy, as represented by a change in $A(L)$ to $A'(L)$. It is highly unlikely that the monetary aggregate M would now be given by $M_t = \bar{m}(R_0+A'(L)\epsilon_t)$. As long as banks and the public have nontrivial portfolio choices to make, those choices will be affected by changes in the stochastic processes generating the exogenous variables which define the environment in which decisions are made. Since $\bar{m}$ is a reduced form parameter, it will be affected by changes in the underlying behavioral relationships which define the model structure.

The need to confront the possibility of policy induced structural change complicates the problem of evaluating any policy shift such as the October 1979 change in operating procedures. In the previous section it was noted that a change in the slope of the money demand curve could be misinterpreted as a more unstable money demand function. Distinguishing between a series of atypical shocks or a structural change as the correct explanation for what appears to be unusual behavior would be difficult over short periods, but attempting to do so is important since the two alternative explanations have different policy implications.

If, as suggested by Tinsley and others (1981), the increased volatility

42. This argument is made by Hetzel (1982).

43. "In arriving at these conclusions it was assumed. . . that the Johannes-Rasche multiplier forecasting models would remain stable in a reserve aggregate control regime." (Johannes and Rasche, 1981, p. 311.) It is just this assumption which is unlikely to be true. The multiplier approach is critically discussed in Lindsey (1981) and Lindsey and others (1981).

of money and interest rates subsequent to the Federal Reserve's change in its operating procedures was the result of unusually large shocks, no need is indicated for a reevaluation of the operating procedures. Attributing the greater volatility to the structural change induced by the shift in operating procedures, on the other hand, might suggest the need to reevaluate current operating procedures.

The dependency of economic relationships on the policy of the Federal Reserve suggests that the use of empirical models for policy analysis may be limited. The examples examined in this paper certainly indicate the general applicability of the Lucas critique to the problem of evaluating alternative operating procedures. Basic economic and financial relationships are unlikely to be invariant with respect to changes in the behavior of the Federal Reserve. Adequate policy evaluation requires a move away from ad hoc empirical models specified at the level of demand and supply curves. Such curves will not remain stable in the face of changes in the economic environment in which economic agents operate.

It is important to keep in mind, however, that the existence of a structural change does not automatically imply its quantitative significance. The induced behavioral responses to the October 1979 change in operating procedures may only be minor factors in explaining the subsequent behavior of interest rates and monetary aggregates. It is important, therefore, to view the October 1979 action as a regime shift which provides economists with a rare controlled experiment with which to assess the empirical importance of the Lucas critique. A search should be made for evidence of any structural changes that may have been due to the shift in operating procedures. The impact of greater interest rate volatility on the risk structure of financial assets and on the informational content of interest rate and money supply movements might provide starting points for any search for structural change.

This paper has focused on the behavioral changes that might result under alternative policy rules and has ignored the equally important effects of financial markets on the innovations induced by policy actions. Because the current behavior of the nonbank public and the banking sector depends upon current and prospective monetary policy, any analysis of alternative operating procedures needs to consider the ways in which policy affects the informational content of interest rates and money supply announcements and the risk structure of financial assets. Because these effects depend upon public perceptions of Federal Reserve behavior, the predictability of private sector behavior is likely to depend on the predictability of the Federal Reserve's behavior. It is only the structural implications of alternative policy rules that are likely to be tractable.

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