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Interest Rate Volatility and Alternative Monetary Control Procedures

Robert H. Rasche*

This study examines the volatility of short-term interest rates during three sample periods each corresponding to the use of different operating guides for monetary policy: the 1970s, October 1979 through September 1982, and October 1982 through December 1984. Interest rate volatility was highest in the 1979–1982 period although the experience was not homogeneous. Since October 1982, short-run interest rate volatility has been the same as that experienced in the 1970s. Based on these data and a standard money demand/supply model, some comparisons are made of the various monetary policy operating regimes.

During the past decade, the Federal Open Market Committee has employed three different operating procedures to implement its stated policy of a gradual return to noninflationary growth rates for the monetary aggregates M1, M2, and M3. Prior to October 1979, monetary policy was conducted by setting short-run targets for the federal funds rate. During the period from October 1979 until the fall of 1982, the FOMC placed more emphasis on controlling the supply of nonborrowed reserves to the banking system. Since the fall of 1982, the FOMC has implemented monetary policy in terms of targets for borrowed reserves. The differences among these various procedures have been discussed extensively (including Wallich, 1984, Axilrod, 1985, and Gilbert, 1985).

Each of these operating procedures has different implications for interest rate volatility. A graphical analysis of these implications can be found in Gilbert (1985). It is a widely, if not universally, accepted proposition that the implication of a change to a reserve-oriented operating procedure—such as that implemented by the FOMC in October 1979—is an increase in the short-term variability of interest rates, particularly very short-term interest rates. The rationale for this proposition is that under the federal funds rate operating procedure in effect during the 1970s, the various stochastic shocks to financial markets originating in the private sector of the economy were not allowed to affect interest rates in the short-run because they were offset through appropriate open market operations. With a reserve aggregate operating procedure, however, the reserve aggregate is maintained at a constant value in the face of

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such shocks, and prices (interest rates) function as the market equilibrating mechanism in the short-run.

One of the traditional concerns raised in opposition to a reserve aggregate operating procedure is that the interest rate variability under such a regime would be so large that it would interfere with the efficient functioning of financial markets. Consequently, one of the pressing questions in any evaluation of the 1979–82 monetary experiment is the extent to which the nonborrowed reserves operating procedures imposed additional volatility upon market interest rates. An extensive study of interest rate behavior in the 1970s compared to interest rate behavior during 1979–80 is available in the work of Dana Johnson, *et al.* (1981).

One purpose of this paper is to reexamine Johnson's investigation in light of what we know from the structure of various money market models such as those constructed by the staffs of the Board of Governors of the Federal Reserve and the Federal Reserve Bank of San Francisco, and to extend the examination of interest rate volatility into the period since the fall of 1980.

The latter is important since there are at least two reasons to believe that the experience in 1979–80 may not represent interest rate variability under an established reserve control procedure. First, the 1979 switch to the nonborrowed reserves procedure was one without precedent in the history of the Federal Reserve System, and it may have prompted a considerable period of learning for market participants. Second, in March 1980, a significant external shock was imposed upon financial markets with the implementation of credit controls. The results presented below suggest that the increase in interest rate volatility experienced during 1979–80 was not sustained uniformly throughout the nonborrowed reserves operating experiment (1979–82) and that alternative, and more appropriate, measures of interest rate volatility show considerably smaller increases during the 1979–82 period relative to the previous experience than do the measures used by Johnson, *et al.*

A second purpose of this study is to compare the results of the federal funds rate operating procedure with the borrowings procedure employed since late 1982. Wallich indicates that the latter was introduced to avoid uncertainties associated with targeting nonborrowed reserves in a period of rapid financial innovation, and, at the same time, to allow interest rates more responsiveness (such as the federal funds rate to market forces) than existed under the pre-1979 procedures.

We show that the standard money demand-money supply framework used for analyzing monetary control problems indicates that increased volatility of interest rates does not imply a reduction in the short-term variability of money around a target value when switching from a federal funds rate control procedure to a borrowings control procedure. Furthermore, the interest rate volatility observed under either of these operating procedures is a measure of the lack of precision in short-run monetary control, given a stable money demand function and constant precision in forecasting the income variables in the money demand function.

Finally, we compare the volatility of interest rates and borrowings in the 1969–79 period with the respective measures for the sample from the fall of 1982 through January 1984. The data suggest that there has been little, if any, change in the volatility of either the federal funds rate or borrowings from the Federal Reserve under the two regimes. This suggests that the borrowing procedure in effect since the fall of 1982 shares the monetary control problems that were encountered during the 1970s with the federal funds rate control procedure.

In Section I, the question of an appropriate measure of interest rate volatility is discussed. In Section II, comparisons of interest rate volatility are presented in samples drawn from different operating procedures. In Section III, the behavior of interest rates and monetary aggregates under federal funds rate and borrowings targeting procedures are compared, and the similarity of behavior across the two regimes is documented. Conclusions are stated in Section IV.

I. Appropriate Measures of Interest Rate Volatility

Johnson, *et al.* focus on the standard deviation of levels and changes in various interest rates, including the federal funds rate and yields on various maturities of Treasury securities averaged over one-week periods.[1] They observe increases in volatility (standard deviation) of weekly average first differences of the federal funds rates of more than 250 percent comparing the October 1979 through September 1980 period with the period of January 1968 through September 1979.

They also attempt to remove the effect of large cyclical swings in the funds rate (presumably low frequency) movements by focusing on deviations from centered moving averages of various lengths. Using these measures, they find increases in federal funds rate volatility of 280 to 460 percent under the reserve aggregate operating procedures.

There is reason to believe that these measures overstate the increase in volatility that should be attributed to the change in operating procedures. There was a considerable change in the level of the funds rate from the earlier period to the 1979–80 period. During the 1969–79 period, the funds rate averaged 7.05 percent, while during 1979–80 it averaged 12.78 percent. Thus, any first difference in interest rates in the later period corresponds to a smaller percentage change. This means that the difference in the levels of interest rates between the two samples is a significant factor in biasing the comparison of the behavior of interest rates under the two operating procedures.

Consider the following model of the demand and supply for money:

$$\ln m_t^D = \gamma_0 + \gamma_1 \ln Y_t - \gamma_2 \ln r_t^f + \mu_1 \quad (1)$$

$$\ln m_t^s = \delta_0 + \delta_1 \ln RU_b + \delta_2 \ln r_t^f + \delta_3 \ln r_t^D + \mu_2 \quad (2)$$

$$\ln m_t^s = \ln m_t^D = \ln m_t \quad (3)$$

where

m_t^D = demand for money balances
Y_t = income measure
r_t^f = fed funds rate
m_t^s = supply of money balances
RU_t = nonborrowed reserves
r_t^D = discount rate
μ_1, μ_2 = stochastic disturbances.

This model is borrowed from Pierce and Thomson (1972), but respecified in log-linear terms. The respecification is broadly consistent with the observed structure of econometric money market models (Tinsley, *et al.*, 1982; Judd and Scadding, 1981; Anderson and Rasche, 1982) that are very close to log-linear over a broad range of shocks. Questions of speed of adjustment to equilibrium are not important for the question being addressed here, so the model in equations 1–3 has been specified in equilibrium form for simplicity.

Consider the reduced form equation for the federal funds rate derived from this model under a nonborrowed reserves operating procedure (RU exogenous):

$$\ln r_t^f = \phi_0 + \phi_1 \ln Y_t + \phi_2 \ln r_t^D - \phi_3 \ln RU_t + \eta_t \quad (4)$$

where

$$\phi_0 = \frac{\gamma_0 - \delta_0}{\gamma_2 + \gamma_2};\ \phi_1 = \frac{\gamma_1}{\gamma_2 + \delta_2};$$

$$\phi_2 = \frac{\delta_3}{\gamma_2 + \delta_2};\ \eta_t = \frac{\mu_1 - \mu_2}{\gamma_2 + \delta_2};\ \sigma_3 = \frac{\delta_1}{\gamma_2 + \delta_2}$$

Now consider percentage changes of the federal funds rate over very short periods of time during which the income variable can be assumed unchanged, the discount rate is kept constant, and the nonborrowed reserves target is not changed. Under these circumstances:

$$\ln r_t^f - \ln r_{t-1}^f = (\eta_t - \eta_{t-1})$$

Thus, the implication of such a model is that over very short intervals, the *percentage change* in the federal funds rate under a reserve aggregate control procedure should have a constant variance (that is, be homoskedastic). This conclusion suggests that if volatility of the first difference of the federal funds rate with a reserve aggregate control procedure when the level of the funds rate is relatively low is compared with its volatility under the same operating procedure when the level of the funds rate is relatively high, then the latter regime would exhibit greater volatility by this measure than the former even though the variances of the structural disturbances are the same in the two situations. Since the available econometric evidence suggests that log-linearity is a better approximation to the structure of U.S. financial markets than linearity, the comparisons presented in Johnson, *et al.* may have inadvertently been biased.

The argument presented above concerns the appropriate interpretation of observed interest rate behavior in a macroeconomic context. But the fundamental concern with interest rate volatility is motivated by microeconomic questions, namely that interest rate changes cause capital gains or losses for bond holders. There are reasons to believe that arithmetic changes in interest rates do not provide a good measure of capital gains or losses accruing to bondholders, and that percentage changes in interest rates may be a preferable measure of the magnitude of the wealth effects that will occur as a result of monetary policy actions.

Consider the impact of equal arithmetic changes in interest rates from a low initial level of rates compared with a high initial level of rates. It is well known that bond prices move inversely with yields to maturity (the first partial derivative of prices with respect to yields is negative) and that the size of the price change increases for a given change in yield as the maturity of the bond increases.

It is also true that for a given maturity, the size of the price change for a given arithmetic change in yield varies with the base from which the yield changes. In particular, the higher the initial level of the yield to maturity, the *smaller* will be the absolute value of the bond price change for a given arithmetic change in the yield (Malkiel, 1966, Theorem 4, p. 55).[2]

Hence if the major cause for concern about interest rate changes is the dollar value of the capital gain or loss accruing to bondholders, the arithmetic change does not give a good measure of the relative size of the problem when the level of yields is different.

In contrast, percentage changes in interest rates may give a good measure of relative capital gains or losses to bondholders, particularly if we are concerned with such gains or losses in percentage terms. The general formula is complicated, and it is easier to see the rationale for this conclusion by focusing on securities at opposite ends of the maturity spectrum, as shown in Table 1.

TABLE 1
Measuring Gains and Losses to Bondholders
Percentage Change in Interest Rates

One period discount bond	One period coupon bond	Consol
$P = (1 - r)F$	$P = \frac{(1 + C)F}{(1 + i)}$	$\frac{CF}{i}$
$\frac{\partial \ln p}{\partial \ln r} = \frac{-r}{(1 - r)}$	$\frac{\partial \ln P}{\partial \ln i} = \frac{-i}{1 + i}$	-1
$\frac{\partial^2 \ln P}{\partial \ln r^2} = \frac{-r}{(1 - r)^2}$	$\frac{\partial^2 \ln P}{\partial \ln i^2} = \frac{-i}{(1 + i)^2}$	0

P = bond price
i = yield to maturity
C = coupon rate
F = face value
r = discount rate

At the very longest maturity, the elasticity of bond prices with respect to yield to maturity is constant. At the short end of the maturity spectrum—one period bonds or discount securities (bills), the elasticity of security prices with respect to the yield to maturity varies considerably relative to its own magnitude, but the elasticity is so small that the implied capital gains or losses are not very large. For example, for three-month bills with discounts at annual rates in the range of four to ten percent, the elasticity of bill prices with respect to the discount is in the range of .01 to .025.

II. Volatility of Rates Under Different Operating Procedures

The basic tests in Tables 4–9 of the Johnson, *et al.* study have been reconstructed in Table 2, but using logs of the various interest rates instead of levels.[3] The only significant difference in the data is that the sample from January 1968 through September 1979 used by Johnson, *et al.* has been truncated to January 1969 through September 1979 because the 1968 data were not readily available. The omission of 1968 is also preferable since the original change from contemporaneous to lagged reserve accounting occurred during that year. We recalculated all of the standard deviations reported in the original study and were able to replicate the reported numbers to within one or two basis points. These comparisons are available in Appendix B.

The results in Table 2 are quite remarkable.[4] The comparison of the 1969–79 period with the sample for October 1979 through September 1980 differs considerably when measured in percentage changes. The standard deviation of the week-to-week percentage changes in the latter sample is from 1.8 to 2.2 times as large as the corresponding standard deviation in the former sample, depending on the rate being compared. The larger increases in the standard deviations tend to be at the *longer* end of the maturity spectrum. The corresponding ratios of standard deviations measured in terms of arithmetic changes is 2.6 to 3.5. Thus, the choice of units of measurement for interest rate volatility is a substantial factor in assessing how much of an increase actually occurred in 1969–79. However, the use of percentage changes *does not* alter the conclusion that interest rate volatility increased during the 1979–80 period over what had been previously experienced.

The interesting experiment is to extend the analysis beyond the fall of 1980. Four separate

TABLE 2

Standard Deviations of Percentage Change of Various Interest Rates (Weekly Data)

Sample	Fed Funds Rate Regime	Nonborrowed Reserves Regime				Borrowed Reserves Regime		
	Jan. 69– Sept. 79	Oct. 79– Sept. 80	Oct. 80– Sept. 81	Oct. 81– Sept. 82	Oct. 79– Sept. 82	Oct. 82– Jan. 84	Feb. 84– Dec. 84	Oct. 82– Dec. 84
Fed funds rate	.039	.071	.053	.049	.059	.046	.038	.042
3-Mo. Bill	.033	.059	.047	.052	.054	.022	.019	.021
6-Mo. Bill	.028	.053	.041	.041	.046	.025	.017	.022
52 Wk. Bill	.026	.047	.033	.036	.040	.023	.016	.021
3-Year Note	.021	.042	.028	.028	.034	.021	.015	.019
5-Year Note	.017	.037	.032	.025	.032	.019	.015	.017
10-Year Note	.013	.029	.023	.025	.026	.018	.014	.016
20-Year Note	.012	.025	.022	.023	.024	.017	.013	.015

samples are identified for this purpose: October 1980 through September 1981, October 1981 through September 1982, October 1982 through January 1984, and February 1984 through December 1984. The first two of these samples are drawn from the era of nonborrowed reserve control procedure and allow observation of changes in interest rate behavior as the period progressed and markets gained experience with the new regime (they also avoid the contamination of the experiment with credit controls). The third sample covers the period from the abandonment of nonborrowed reserves control in favor of borrowed reserves targets (Wallich 1984, Axilrod 1985, Gilbert 1985) to the end of lagged reserve requirements; and the fourth sample covers the period of contemporaneous reserve requirements with borrowed reserves targets.

The volatility of interest rates remains higher, relative to the experience of 1969–79, throughout the three years of the nonborrowed reserve operating procedure experiment. However, interest rate volatility over this three-year period is not constant. There is a reduction in volatility of interest rates uniformly across the maturity spectrum from the 1979–80 period to the 1980–81 period measured as the standard deviation of week-to-week percentage changes. During the latter period, the volatility measure was from 1.2 to 1.9 times the corresponding measure in the 1969–79 base period.

Across the maturity spectrum, the volatility dropped by 15 to 33 percent of the observation for 1979–80. The observed volatility in the 1980–81 sample appears to be repeated in the 1981–82 sample. In some cases, the computed volatility in the 1981–82 sample is slightly higher than in the 1980–81 sample; in other cases, exactly the reverse is observed. The changes appear to be quite random across the maturity spectrum, suggesting a constant variance (homoskedasticity) during the two-year period.

The introduction of borrowed reserves targets appears to have altered rate volatility once again. The standard deviations of the week-to-week percentage change in rates decline uniformly after September 1982. In the case of short- and intermediate-term rates, the volatility measure returns to the pre-1979 level, although the 10- and 20-year maturities continue to exhibit volatility on the order of 1.5 times the pre-1979 observations in the 1982–84 period. After the return to contemporaneous reserve accounting in February 1984, interest rate volatility across the maturity spectrum is no greater than that observed prior to 1979, and, in the case of three- and six-month Treasury

TABLE 3
F-Statistics for Equality of Variance Compared to 1969–79 Sample

Interest Rates	Sample Periods				
	1979–80	1980–81	1981–82	1982–84	1984
Federal Funds	3.35*	1.86*	1.54*	1.35	.94
3-Month T. Bills	3.38*	2.18*	2.62*	.46	.33
6-Month T. Bills	3.54*	2.17*	2.15*	.77	.37
52-Week T. Bills	3.31*	1.63*	1.90*	.78	.39
3-Year T. Note	4.29*	1.88*	1.93*	1.00	.58
5-Year T. Note	4.73*	3.53*	2.74*	1.22	.73
10-Year T. Note	4.91*	3.30*	3.52*	1.82*	1.17
20-Year T. Bond	4.76*	3.66*	3.94*	1.99*	1.22
df(1969–79 = 559)	51	51	51	69	47
5% Critical F	1.38	1.38	1.38	1.34	1.39

*Significant at 5% level

bills, volatility seems to have declined sharply in the most recent period.

These observations suggest several hypotheses. First, it appears that in the 1980–82 period, interest rates were less volatile than during 1979–80, but, second, interest rates exhibited more volatility in that period than under the federal funds rate control regime. A third hypothesis is that, in terms of interest rate volatility, the borrowings control procedure pursued since the fall of 1982 is no different than the pre-1979 control regime. These hypotheses will be tested below.

One very simple procedure to test these hypotheses is to test the idea that the variance of the various percentage changes in interest rates is constant among different sample periods. The 1969–79 sample is used as an initial base for such comparisons. The relevant F statistics are presented in Table 3. The results presented there indicate that, for the three samples drawn during the nonborrowed reserves control period, interest rate volatility increased significantly across the maturity spectrum. For the two samples subsequent to the "deemphasis" of M1, the statistics in Table 3 generally support the conclusion that interest rate volatility is not significantly greater than it was during the 1970s. The exceptions to this general statement are the very longest maturities in the sample period from 1982 to January 1984.

These results are consistent with the second and third hypotheses above. Since the standard deviations in the 1982–January 1984 sample are larger than those in the 1969–79 sample for all rates except the three-month, six-month and 52-week bill rates (although not generally significantly so), it is interesting to base the tests for equality of variance on the interest rate volatility observed after the nonborrowed reserves control experiment. This procedure determines whether there was a significant reduction in interest rate volatility after the fall of 1982. The F-statistics for these tests are presented in Table 4.

The results for the federal funds rate here are somewhat surprising. The test statistics suggest that the volatility of the federal funds rate in the 1980–82 period was not significantly greater than that observed from the fall of 1982 through January 1984. In spite of this conclusion, the evidence suggests that volatility at all other points on the maturity spectrum declined significantly after the end of the nonborrowed reserves control experiment.

Finally, a test of the first hypothesis that interest rate volatility in 1980–82 is significantly lower than that experienced in 1979–80 is re-

TABLE 4

F-Statistics for Equality of Variance Compared to 1982–January 1984 Sample

Interest Rate	Sample Periods			
	1979–80	1980–81	1981–82	Feb–Dec 1984
Federal Funds	2.48*	1.38	1.14	.69
3-Month T. Bills	7.42*	3.65*	3.61*	.73
6-Month T. Bills	4.58*	2.81*	2.78*	.47
52-Week T. Bills	4.22*	2.08*	2.49*	.50
3-Year T. Note	4.28*	1.88*	1.92*	.55
5-Year T. Note	3.88*	2.90*	1.83*	.60
10-Year T. Note	2.70*	1.82*	1.93*	.64
20-Year T. Bond	2.42*	1.86*	2.01*	.62
df(1982–84 = 69)	51	51	51	47

*Significant at 5% Level

ported in Table 5. The results of this test support the hypothesis that a significant reduction in the volatility of short-term and intermediate-term rates occurred between 1979–80 and 1980–82.

Several conclusions appear to be warranted from this analysis. First, the period of reserve aggregate operating guides was accompanied by an increase in volatility that was not as large as has been previously measured because of differences in the level of interest rates before and after October 1979, and because the twelve months subsequent to 1979 appear to be influenced by special factors.

Nevertheless, it is not appropriate to use the volatility observed in 1980–82 as a measure of the increased interest rate volatility that would be observed under a pure reserve aggregate control regime. On the one hand, these observations are probably biased downward since the 1979–81 operation procedure was not a regime in which fixed reserve paths were maintained but one in which gradual adjustment was made back to such paths when deviations occurred. On the other hand, the interest rate volatility observed during this period may be biased upward compared to what could be achieved under a fixed reserve path operating guide because lagged reserve accounting was in effect throughout the period.

A third conclusion is that it is probably inappropriate to regard changes in the volatility of very short-term rates as necessarily affecting the volatility of longer term rates. Certainly volatility increased uniformly across the maturity spectrum in 1979. However, when the volatility of the funds rate dropped dramatically starting in late 1980, longer term rate volatility did not immediately follow. Furthermore, in the period since February 1984, it appears that the volatility of Treasury bill rates of various maturities has been reduced significantly below the volatility of the same rates prior to October 1979, even though the volatility of the federal funds rate in the two sample periods is unchanged.

TABLE 5
F-Statistics for Equality of Variance
Compared to 1980–82 Sample

Interest Rates	Sample Period
	1979–80
Federal Funds	1.95*
3-Month T. Bills	1.38
6-Month T. Bills	1.61*
52-Week T. Bills	1.84*
3-Year T. Note	2.19*
5-Year T. Note	1.61*
10-Year T. Note	1.40
20-Year T. Note	1.22
df(1980–82 = 103)	51

*Significant at 5% Level

III. Are the New Operating Procedures Different From Those of the 1970s?

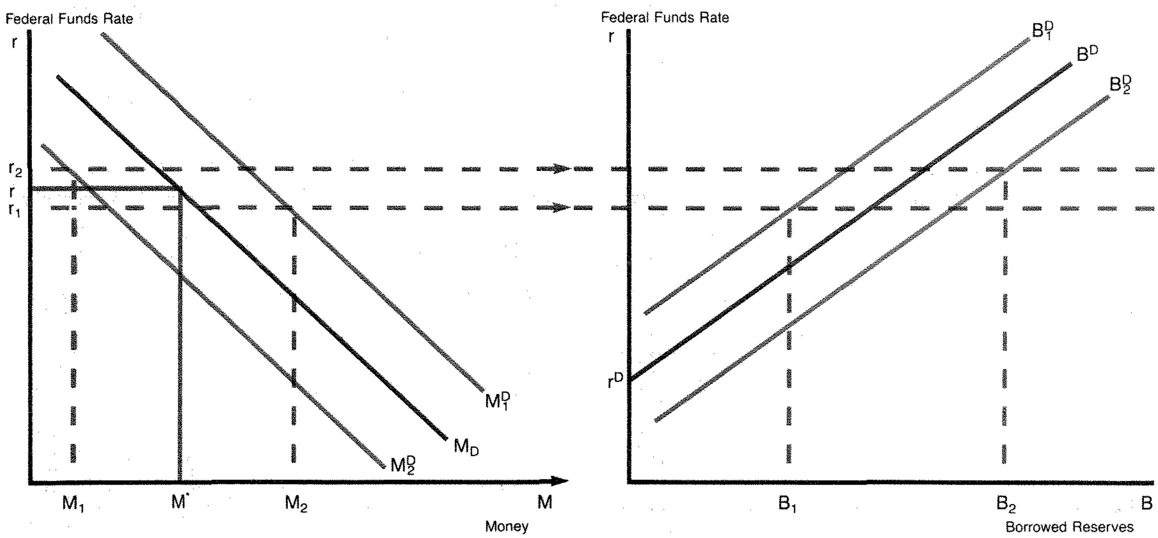
The information presented in Tables 2–5 suggests that there is considerable similarity between the volatility of interest rates across the maturity spectrum during the 1970s and in the period since the fall of 1982. Federal Reserve officials are on record as indicating that the present procedures are not a return to the techniques of the 1970s:

> Since the fall of 1982, the nonborrowed-reserves strategy and its automaticity have given way to a technique that allows the funds rate to be determined by the market, through the targetting of discount window borrowing from one reserve maintenance period to the next, implemented by allowing a flexible nonborrowed-reserves path. ...The relation of the borrowing level to the funds rate, which has been one of the most familiar features of the money market, always has been relatively loose. Since a chosen level of borrowings is consistent with any of a range of values of the funds rate, current operating procedures cannot be regarded as a form of rate-pegging (Wallich, 1984, p. 26).

In spite of assertions such as this, short-run interest rate pegging and borrowings targeting are fundamentally similar monetary control procedures. This can be seen from Figures 1 and 2 which illustrate a federal funds rate target procedure (the practice of the 1970s) and a borrowed reserves target procedure (the practice since fall 1982), respectively.[5] The curve labeled M^D in the left hand side of the figure represents a short-run money demand function, while the curve labeled B^D in the right hand side of the figure represents the demand for borrowed reserves by depository institutions. Both are drawn as functions of the federal funds rate (r), and it is assumed that the demand for borrowed reserves is zero when the federal funds rate is less than the discount rate (r^D). These are simplifying assumptions for purposes of illustration.

The exact positions of both the money demand curve and the demand for borrowed reserves curve are not known with certainty by the monetary authorities, nor are they constant. Rather, both fluctuate randomly over time.[6] It is assumed that those fluctuations occur within the ranges defined by the dotted

Figure 1
Federal Funds Rate Target Procedure



curves M_1^D and M_2^D and by B_1^D and B_2^D. These ranges of fluctuation are assumed the same for both operating procedures.

With a federal funds rate operating procedure, the monetary authorities, in principle, keep the federal funds rate within a small interval around the rate (F) that they believe is consistent with their monetary objective (M*). This range is represented by r_1 and r_2.[7] With the federal funds rate constrained to the range r_1–r_2, the money stock will be observed to fluctuate in the range M_1 to M_2 in the short-run, and borrowed reserves will be observed fluctuating in the range B_1 to B_2, with the specific outcomes dependent upon the size of the random fluctuations to M^D and B^D.[8] Movements of the federal funds rate outside the range r_1–r_2 are prevented by the monetary authorities through injections or withdrawals using open market operations of whatever nonborrowed reserves are required to keep the funds rate within the specified range.

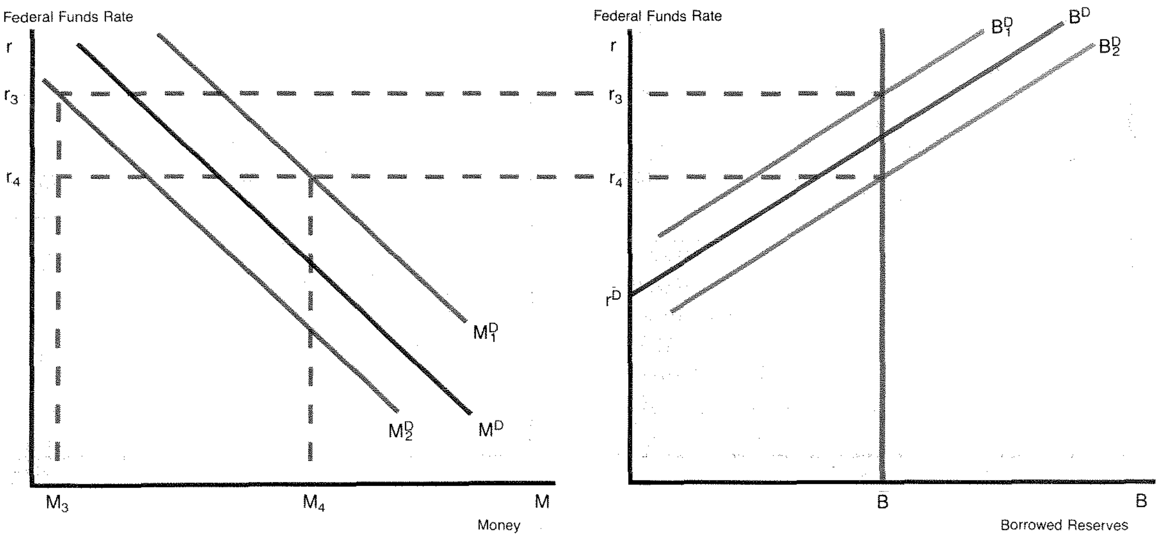
When a target is established for borrowed reserves, the operating procedure works in fundamentally the same fashion, except in this case the range of funds rate fluctuation is implicitly determined by the random fluctuations in the demand for borrowings rather than being explicitly stated in the operating procedure.

Assume that the monetary authorities establish and exactly achieve a target for borrowed reserves $\bar{B}$ (Figure 2). With this fixed supply of borrowed reserves to depository institutions, the federal funds rate will be observed to fluctuate in the range r_3–r_4 with the particular outcome dependent only upon the size of the random fluctuation in the demand for borrowed reserves.

The observed interest rate within the (r_3–r_4) range is not affected by random fluctuations in the demand for money under this operating procedure. The observed outcome in terms of money stock, M, will be in the range M_3–M_4 depending on the particular random fluctuations to the demand for borrowed reserves and the demand for money. Under the assumption of exact control of the amount of aggregate borrowed reserves available to depository institutions, the funds rate can fluctuate outside the range r_3–r_4 only by a deviation of borrowed reserves from $\bar{B}$. If borrowed reserves were to deviate from $\bar{B}$, the monetary authorities would inject or withdraw nonborrowed reserves to maintain borrowings at $\bar{B}$, and, implicitly, to maintain the federal funds rate in the range r_3–r_4.

In practice the monetary authorities probably cannot achieve the borrowed reserve target exactly, but can keep the supply of borrowed re-

Figure 2
Borrowed Reserves Target Procedure



serves within a small range around $\bar{B}$. The addition of such "noise" to the operating procedure does not affect the conclusion drawn from Figure 2 in any fundamental way. For given random shocks to the demand for borrowed reserves (B^D_1–B^D_2), the implied range of interest rate fluctuations (r_3–r_4) will be larger the larger the "noise" around the borrowed reserves target.[9] Nevertheless, the establishment of a borrowed reserves target implies the establishment of a permissible range of fluctuation for the funds rate, and that range is maintained by the automatic provision or withdrawal of nonborrowed reserves through open market operations whenever market forces attempt to drive the rate outside the implicit range.[10]

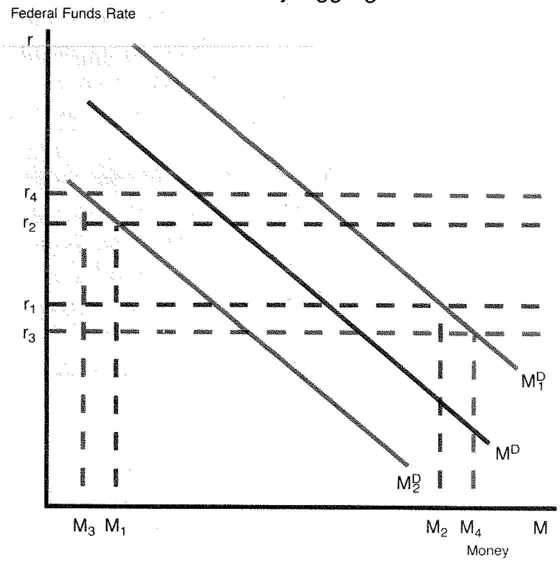
The ranges of federal funds rate fluctuation in Figures 1 and 2 represent the degree of funds rate volatility that will be observed under the two operating procedures. The size of this range is explicitly set as part of the federal funds rate operating procedures.[11] With a borrowed reserves operating procedure, the size of this range can be influenced, above some minimal amount determined by random shocks to the demand for borrowed reserves, by the amount of random fluctuation in borrowed reserves that is permitted around the target value.[12] The implication of the volatility measures computed in Section II is that the volatility of the funds rate implicit in the borrowed reserve operating procedure since the fall of 1982 has been basically the same as the volatility of the federal funds rate explicitly permitted under the 1970s operating procedure.

What are the implications of this conclusion for the short-run volatility of the monetary aggregates? Figure 3 examines the implications for the volatility of monetary aggregates of operating procedures that establish ranges of fluctuation for the funds rate, whether explicit or implicit (as with a borrowed reserves target).

First, consider the implication of widening the permissible range of funds rate fluctuation from r_1–r_2 to r_3–r_4, as indicated in Figure 3. With an unchanged range of fluctuation of the short-run money demand function (M^D_1 to M^D_2), more short-run volatility would be observed in

Figure 3

The Short-Run Relation of Funds Rate Volatility to the Monetary Aggregates



the monetary aggregates the wider the range of funds rate fluctuation. In Figure 3, the wider range of funds rate fluctuation (r_3–r_4) implies fluctuations of the money stock in the range M_3 to M_4 compared with fluctuations in the range M_1 to M_2 with the funds rate restricted to the narrower range (r_1–r_2). Thus, if the borrowed reserves control procedure had introduced more volatility into the funds rate, it could have been expected to introduce more short-run volatility into the monetary aggregates.[13]

This comparison of funds rates and borrowed reserves operating procedures stands in contrast to the results obtained from a comparison of a funds rate and nonborrowed reserves operating procedure. In the latter case, the monetary authorities would allow more interest rate volatility by not automatically conducting open market operations to change the stock of nonborrowed reserves. In the extreme, nonborrowed reserves would be fixed regardless of observed fluctuations in interest rates.

Generally, as operating procedures move towards a smaller response of the supply of nonborrowed reserves to interest rate fluctuations, rate stability decreases (volatility increases) and the precision of short-run monetary control increases. Thus, in moving from a federal funds rate operating procedure toward a pure non-borrowed reserves operating procedure, a trade-off exists between interest rate volatility and the precision of short-run monetary control.[14] This trade-off does not exist when comparing federal funds rate operating procedures with borrowed reserves operating procedures because both of those operating procedures allow the *automatic* changes in the supply of non-borrowed reserves to depository institutions in response to any shock that pushes the target variable to an extreme of the predetermined range of fluctuation.

Inertia in Adjusting Policy Guides

Although federal funds rate operating procedures as implemented in the 1970s and borrowed reserves operating procedures as implemented since fall 1982 may appear virtually the same from the perspective of their effects on short-run interest rate volatility and the short-run precision of monetary control, it is possible that the longer run precision of monetary control could improve from the switch. It could improve if there were less inertia in adjusting the operating guide under the borrowed reserves control procedure than under the federal funds rate control procedure.

The presence of inertia in adjusting the operating guides, whether interest rate or borrowings, introduces positive serial correlation into deviations of the money stock from its target value.[15] This positive serial correlation is stronger the more infrequent the adjustment of the target value for the operating guide and, conversely, weaker the more frequent the adjustment of the target value for the operating guide. Consequently, a change in operating procedure that did not affect the precision of short-run monetary control but that reduced the serial correlation in the deviations of the money stock from its target value would reduce the longer run variation of average money stock measures around the longer run average target value.

The inertia in adjusting the target value of the operating guide is the source of the fundamental criticism of the historical interest rate and free reserves (borrowings) targeting regimes: unless the monetary authorities are prepared to adjust the target variables quickly and correctly in response to new information, deviations from the desired path of the monetary aggregates are likely to persist.

The results discussed above suggest that a simple indicator of the short-run precision of monetary control with either an interest rate operating guide or a borrowed reserves operating guide is the short-run volatility of interest rates. With the same money demand function for the two control procedures, the larger the variability of interest rates, the worse the precision of short-run monetary control. The data on federal funds rate volatility during the periods 1969–79 and 1982–84 suggest that short-run monetary control is unlikely to improve under the procedures used by the FOMC since the fall of 1982 compared to the experience of the 1970s. If the proposition that the stability of the short-run money demand function has deteriorated in the 1980s were correct, then a strong case could be made that the operating procedure in effect since fall 1982 will produce less precise short-run monetary control than did the procedures implemented in the 1970s.

If it is assumed that the random shocks to the demand for borrowings are uncorrelated with the random errors in interest rates under the interest rate operating procedure, and that they are also uncorrelated with the random errors in the supply of borrowings under the borrowings control procedure, then the volatility of observed borrowings gives an equivalent measure of the precision of monetary control. Under these assumptions, and with a stable demand function for borrowed reserves under the two procedures, equal volatility of interest rates implies equal volatility of borrowings.

This conclusion appears to be supported by the data. The standard deviation of week to week percentage changes in adjustment borrowings (seasonal plus adjustment borrowings) for those weeks when the federal funds rate exceeded the discount rate is .513 (.493) in 1969–79 and .664 (.556) in October 1982–January 1984.

It is possible, despite the experience with the post-1982 borrowed reserves operating procedure which suggests no improvement for short-run monetary control over that experienced under the federal funds rate control procedure of the 1970s, that intermediate-run or longer run monetary control is improved by a reduction in the inertia in adjusting the operating guide. Changes in the precision of intermediate-run monetary control (one- to six-months) should be evidenced by distinctly different patterns in the time series properties of interest rates. A crude test of this hypothesis can be performed by estimating ARIMA models for the federal funds rate for the 1969–79 sample period and for the sample since October 1982. The resulting models are:

January 1969–September 1979[16]

$$\ln FF_t - \ln FF_{t-1} = a_t - \underset{(.0409)}{.1460}a_{t-1} + \underset{(.0405)}{.2268}a_{t-4} + \underset{(.0415)}{.1321}a_{t-9} + \underset{(.0408)}{.1040}a_{t-11} + \underset{(.0419)}{.1008}a_{t-13}$$

$$\text{s.e.} = .0371 \qquad \chi^2_{(df=37)} = 44.48 \qquad \chi^2(.05)_{(df=37)} \simeq 52.2$$

October 1982–January 1984

$$\ln FF_t - \ln FF_{t-1} + \underset{(.1117)}{.3941}\ (\ln FF_{t-1} - \ln FF_{t-2}) = a_t + \underset{(.1033)}{.7199}a_{t-12}$$

$$\text{s.e.} = .0317 \qquad \chi^2_{(df=22)} = 18.42 \qquad \chi^2(.05)_{(df=22)} = 33.92$$

February 1984–December 1984

$$\ln FF_t - \ln FF_{t-1} = a_t + \underset{(.1416)}{.4192}a_{t-2}$$

$$\text{s.e.} = .0348 \qquad \chi^2_{(df=23)} = 21.88 \qquad \chi^2(.05)_{(df=23)} = 35.17$$

At first glance, these estimates suggest that the time series properties of the federal funds rate are strikingly different among the sample periods discussed above, for which the variance of weekly changes is similar. There is clearly a distinct change associated with the introduction of contemporaneous reserve requirements, but the strong second order moving average term in the post-January 1984 sample appears consistent with the change to a two-week reserve averaging period.

The difference between the 1969–79 sample and the 1982–84 sample, however, is not as great as it appears. The latter sample exhibits more seasonality at approximately three-month intervals as indicated by the large twelfth order moving average factor. However, when the log of the federal funds rate is written in moving average form, the impact of innovations is remarkably similar for at least the first six weeks. The first terms of the moving average polynomials for the two sample periods for the log of the federal funds rate are:

January 1969–September 1979

$$\ln FF_t = a_t + .854\ (a_{t-1} + a_{t-2} + a_{t-3}) + 1.081(a_{t-4} + a_{t-5} + a_{t-6}) + \ldots$$

and expressed in the same form:

October 1982–January 1984

$$\ln FF_t = a_t + .69(.88a_{t-1} + 1.11a_{t-2} + 1.02a_{t-3}) + .72(1.01a_{t-4} + .99a_{t-5} + 1.00a_{t-6}) + \ldots$$

The only substantial difference between the effects of the first six lagged innovations in the two sample periods is that in the earlier sample lags 1–3 have the same weight as lags 4–6. It also appears that the three-week average of recent innovations (lags 1–3) has slightly less weight in the more recent period (.69 vs. 854), but no measure of the significance of the difference is available. Even though the statistical significance of these differences cannot be determined, it seems appropriate to conclude that there is no large difference in the intermediate-run time series behavior of the federal funds rate under the two control procedures. This evidence is consistent with the hypothesis that the inertia in the setting of the operating guide under current procedures, in terms of the speed with which interest rates (and hence the money stock) are allowed to adjust, is similar to the inertia in the 1970s under the federal funds rate operating guide.

IV. Conclusion

The available evidence suggests that interest rate volatility increased across the maturity spectrum with the introduction of the "new operating procedure." Subsequently, in 1980–82 the volatility of rates declined. It is not possible to discriminate whether this represents learning by market participants, contamination of the 1979–80 data by the credit control experience, or a revision of the implementation of the nonborrowed reserves operating procedure over time. By 1981–82, the volatility of the federal funds rate was not significantly greater than in 1969–79. Since the fall of 1982, volatility across the maturity spectrum has been the same as that experienced in the 1970s.

Since the volatility and time series of the federal funds rate under lagged reserve requirements and an operating procedure that targeted borrowings between the fall of 1982 and January 1984 replicates very closely the behavior of this rate under the fed funds rate operating procedure in effect prior to October 1979, it appears that the two operating procedures have similar implications for the short-run control of the growth of monetary aggregates.

Both operate through the money demand function and both share the common property that inertia in adjusting the target to new information will produce persistent drift in the monetary aggregate from its target value. However, if the stability of econometric money demand functions has deteriorated in the 1980s compared to the 1970s, as is frequently alleged, then a borrowings operating procedure that produces essentially the same funds rate volatility as the funds rate operating procedure, will not improve the precision of short-run monetary control.

The outlook for longer run monetary control under the two operating procedures is primarily determined by the degree of inertia in adjusting the operating targets. If it is more feasible for the FOMC to adjust a borrowed reserves target correctly in response to new information than it would be to adjust a federal funds rate target, then a borrowed reserves operating procedure could improve longer run monetary control even though short-run control could be less precise than under the funds rate operating procedure. Since the FOMC continues publicly to maintain the objective of gradually reducing the rate of monetary growth to non-inflationary levels, final judgment on the effectiveness of the current operating procedure must be deferred until the success or failure of current monetary policy is established.

Appendix A

Money Market and Monetary Control Implications of Alternative Operating Procedures

Some framework broad enough to evaluate the effects of the three alternative operating procedures on monetary aggregates and interest rates yet simple enough to produce useful conclusions is necessary. The vehicle used here is an extension of the money market model of equations 1 through 3 in the text.

The model is presented below.

(1) $\ln M = \gamma_0 + \gamma_1 \ln Y + \gamma_2 \ln r + \mu_1$

(2) $\ln M = p + \delta_1 \ln RR + \mu_2$

(3) $\ln BOR = \alpha_0 + \alpha_1 (\ln r - \ln r^d) + \mu_3$

(4) $\ln TR = w_1 \ln RU + (1 - w_1) \ln BOR + \mu_4$

(5) $\ln TR = \ln RR + \ln\left(1 + \frac{ER}{RR}\right) = \ln RR + \mu_5$

(6) $v_1 \ln r + v_2 \ln RU + v_3 \ln BOR = v_1 (\ln \bar{r} + \varepsilon_1) + v_2 (\ln \overline{RU} + \varepsilon_2) + v_3 (\ln \overline{BOR} + \varepsilon_3)$

for $v_1 = 1.0$; $v_2 = v_3 = 0.0$

or $v_2 = 1.0; v_1 = v_3 = 0.0$

or $v_3 = 1.0; v_1 = v_2 = 0.0$

Note: Greek letters can be polynomials in the lag operator B; i.e.

$\gamma_1 = \gamma_1(B) = \gamma_{10} + \gamma_{11} B + \gamma_{12} B^2$

and, $\gamma_1^* = \gamma_{11}B + \gamma_{12}B^2 + \cdots$ for any polynomial

Equation 1 is the money demand equation used above. Equation 2 is a reserve requirement that allows for stochastic fluctuations in reserve requirements ($p + \mu_1$) as a result of shifts in reserves among different types of banks and the possibility of lagged reserve accounting by changing the parameters of the polynomial δ.[17]

Equation 3 is a borrowings function that relates borrowings by financial institutions to the spread (in percentage terms) between market rates and the discount rate. Equation 4 is a Taylor series expansion of the log of total reserves in terms of the log of nonborrowed reserves and the log of borrowings with an approximation error (μ_4) to represent the higher order terms of the expansion. Equation 5 is a statement of the identity between total reserves, required reserves and excessive reserves, with an assumption that the excess reserve ratio can be approximated by a stochastic process (μ_5). Finally, equation 6 allows the interest rate (r), nonborrowed reserves (RU) or borrowings (BOR) to be set as an exogenous variable by suitable choice of the parameters, v_i.

Note that the control regimes are mutually exclusive: a nonzero value for one of the v_i requires that the other two v_j be set at zero.

The model has been specified to capture the relevant properties of empirical money market models, yet to retain log-linearity so that explicit reduced form expressions can be derived for ln r, ln M, ln RU and ln BOR. The general reduced form equations (without regard to the control regime) are functions of the potential exogenous variables: income (γ), the discount rate ($\bar{r}$), nonborrowed reserves (RU) and borrowings (BOR). The stochastic terms in these reduced form equations are functions of the stochastic μs and εs in equations 1 through 6. Finally, the coefficients in the reduced forms are complicated functions of the structural parameters of the model and the control regime variables—v_1, v_2, and v_3.

The model is not complete without a specification of the "policy rule" that governs how the operating procedure is adjusted over time.[18] Two extreme cases are interesting. The first is complete adjustment each period to any new information in the attempt to keep the monetary aggregate on its target path. The second regime is one of inertia in which the control variable is adjusted infrequently.

A. Continual Adjustment of Control Variable: Interest Rate Operating Guides

In this situation, the reduced form equations for interest rates and the monetary aggregate are:

(7) $\ln r_t = \ln\bar{r}_t + \varepsilon_t$

(8) $\ln M_t = \gamma_0 + \mu_1 + \gamma_2\varepsilon_1 + \gamma_1 \ln Y_t + \gamma_2 \ln\bar{r}_t$

and the policy rule governing the adjustment of $\ln\bar{r}_t$ is:

(9) $E^f_{t-1} \ln M_t = \ln M^*$

where $E^f_{t-1} \ln M_t$ is the monetary authorities' forecast of $\ln M_t$ based on information available at $t - 1$ and $\ln M^*_t$ is the desired value of the monetary aggregate at t.

From (8):

(10) $E^f_{t-1} \ln M_t = \gamma_0 + \mu_1^* + \gamma_2^*\varepsilon_1 + \gamma_{10}E^f_{t-1} \ln Y_t + \gamma_1^* \ln Y_t + \gamma_{20}\ln\bar{r}_t + \gamma_2^* \ln r_t$

so

(11) $\ln\bar{r}_t = \frac{1}{\gamma_{20}}(\ln M^* - \gamma_0 - \mu_1^* - \gamma_2^*\varepsilon_1 - \gamma_{10} E^f_{t-1} \ln Y_t - \gamma_1^* \ln Y_t - \gamma_2^* \ln r_t)$

and

(12) $(\ln M_t - \ln M^*) = \mu_{1t} + \gamma_{20}\varepsilon_{1t} + \gamma_{10}(\ln Y_t - E^f_{t-1} \ln Y_t)$

This is the standard result (Thomson and Pierce, 1972) that under an interest rate control procedure with constant adjustment, deviations from monetary targets depend upon stochastic money demand fluctuations and errors in forecasting income. The additional term here is generated by the error in hitting the interest rate target, ε_{1t}. As long as the income forecast errors are not serially correlated, deviations of money growth from targets should not exhibit serial correlation.

B. Continual Adjustment of Control Variable: Borrowing Operating Guide

In this situation, the reduced form equations for borrowings and the monetary aggregate are:

(13) $\ln BOR_t = \varepsilon_{3t} + \ln \overline{BOR}_t$

(14) $$\ln M_t = \left[(\gamma_0 + \mu_{1t}) + \left(\frac{\gamma_2}{\alpha_1}\right)\varepsilon_{3t} - (\alpha_0 + \mu_{3t})\left(\frac{\gamma_2}{\alpha_1}\right)\right] + \gamma_1 \ln Y_t + \ln r_t^d + \left(\frac{\gamma_2}{\alpha_1}\right)\ln \overline{BOR}_t$$

and the policy rule covering the adjustment of $\ln \overline{BOR}_t$ is the same as in equation 9: We assume that the discount rate is set exactly by the monetary authority and is not changed.[19]

The resulting behavior of the monetary aggregate relative to the target value is described by:

(15) $$(\ln M_t - \ln M^*) = \mu_{1t} + \gamma_{10}(\ln Y_t - E^f_{t-1}\ln Y_t) + \gamma_{20}\left(\frac{\varepsilon_{3t} - \mu_{3t}}{\alpha_{10}}\right)$$

C. Infrequent Adjustment of the Control Variable To New Information: Interest Rate Operating Guide

The criticism levied against monetary control procedure in the 1970s and the free reserves procedures of the 1950s and 1960s was not directed against the regimes described above. Rather, as is now generally acknowledged, in those periods, targets were changed only infrequently, or only by small amounts, in spite of the availability of new information.

Consider a regime where $\ln \bar{r}_\tau$ is set at a value based on information available at time $t-n$ and maintained at that value for r subsequent periods, that is, set $\ln \bar{r}_\tau$ so that $E^f_{t-n}\ln M_\tau = \ln M^*$ for $\tau = t-n+1,.., t$.

then

(16) $$(\ln M_\tau - \ln M^*) = (\mu_{1\tau} - E^f_{t-n}\mu_{1\tau}) + \gamma_1(\ln Y_\tau - E^f_{t-n}\ln Y_\tau) + \gamma_2[\ln \bar{r}_\tau + \varepsilon_{1\tau} - E^f_{t-n}(\ln \bar{r}_\tau + \varepsilon_{1\tau})]$$

$$= \mu_{1\tau} + \sum_{i=t-n}^{\tau} \gamma_{1\tau-i}(\ln Y_\tau - E^f_{t-n}\ln Y_\tau) + \sum_{i=t-n}^{\tau} \gamma_{2\tau-i}\,\varepsilon_{1\tau}$$

for $\tau = t-n+1,\ldots,t$

In a regime where $\ln \overline{BOR}_t$ is set at a value based on information available at $t-n$ and maintained at that value for n subsequent periods, that is, set $\ln \overline{BOR}_\tau$ so that $E^f_{t-n}\ln M_\tau = \ln M^*$ for $\tau = t-n+1,.., t$

then:

(17) $$(\ln M_\tau - \ln M^*) = \mu_{1\tau} + \sum_{i=t-n}^{\tau} \gamma_{1\tau-i}(\ln Y_\tau - E^f_{t-n}\ln Y_\tau) + \sum_{i=t-n}^{\tau} \gamma_{2t-i}\left(\frac{\varepsilon_{3\tau} - \mu_{3\tau}}{\gamma_1}\right)$$

APPENDIX B

Standard Deviations of First Differences of Various Interest Rates (Weekly)

Sample	Fed Funds Rate Regime	Nonborrowed Reserves Regime			Borrowed Reserves Regime	
	Jan 69–Sept 79	Oct 79 Sept 80	Oct 80 Sept 81	Oct 81 Sept 82	Oct 82 Jan 84	Feb 84 Dec 84
Federal Funds Rate	.28	.95	.87	.63	.43	.39
3-Month Bill	.21	.64	.69	.56	.18	.17
6-Month Bill	.18	.57	.57	.48	.21	.16
52-Week Bill	.17	.51	.43	.43	.20	.16
3-Year Note	.14	.49	.39	.40	.22	.18
5-Year Note	.12	.43	.44	.36	.21	.18
10-Year Note	.09	.33	.31	.35	.20	.18
20-Year Bond	.08	.29	.29	.33	.19	.17

FOOTNOTES

1. The results reported in Johnson, *et al.* Tables 4–9 were reproduced with the data set employed in this study. The current data set replicates the previously reported results with a high degree of accuracy.

2. This point also appears in the bond duration literature where the *percentage* change in bond prices for a given *absolute* change in yield to maturity is shown to be proportional to the duration of the bond. Since for a given maturity and coupon rate, duration *decreases* with increases in yield to maturity, the percentage (and absolute) change in bond price for a given change in yield to maturity is lower the higher the initial yield (see Yawitz, 1977).

3. The discussion here focuses on week-to-week percentage changes in the various rates (measured as log first differences). Measures of interest rate volatility were also constructed using percentage deviations from various length centered moving geometric averages. These measures were compared with the measure reported in Johnson, *et al.* for deviations from centered moving arithmetic averages. The results of these comparisons are consistent with the comparisons reported here between arithmetic and percentage changes in rates.

In particular, the same pattern of significant increases in interest rate volatility in the 1979–80 period, and declining volatility in subsequent sample periods, is observed when the computations are performed relative to centered geometric moving averages.

4. Volatility measures were also tabulated for the 1969–70 and 1973–75 subsamples considered by Johnson, *et al.* Measurements of rate volatility in percentage changes for these subsamples share the homoskedasticity property that Johnson, *et al.* found in the arithmetic measures of volatility.

5. The figures presented here are graphical representations of the short-run money demand and money supply model in Appendix A.

6. The random variation in the money demand function is represented by μ_1 in the model in Appendix A; the random fluctuation in the demand for borrowed reserves by μ_3.

7. In Appendix A, the fluctuation of the federal funds rate under a funds rate operating procedure is represented by ε_1.

8. In Figures 1A and 1B we assume that the fluctuations of the federal funds rate in the range r_1–r_2 are independent of shocks to the money demand function. In practice, during the 1970s, the Fed's Trading Desk was given the authority to move the federal funds rate systematically toward an extreme of the range established by the FOMC when the growth of money stock was observed to deviate from the established short-run path. This procedure implies a nonzero covariance between money demand shocks and deviations of the funds rate from the midpoint of the r_1–r_2 range. The general expression for the variability of the money stock under this control procedure is given by equation 12 in Appendix A, which can accommodate nonzero covariance between ε_1, the funds rate fluctuation, and μ_1—the shock to money demand.

9. In terms of the model in Appendix A, the variability of the funds rate is determined by the expression:

$$\frac{\varepsilon_{3t} - \mu_{3t}}{\alpha_{10}}$$

which represented the effect of random disturbances to the demand for borrowed reserves (μ_{3t}) and the range of fluctuation in the supply of borrowed reserves (ε_{3t}). The interest rate fluctuations are amplified or attentuated by the interest elasticity of the demand for borrowed reserves, but are not affected by the parameters of or residual variance in the demand for money.

10. Recent directives give the Desk authority to change the degree of restraint on reserve positions systematically when the growth of the money stock is observed to deviate

from the paths established by the FOMC. This procedure implies a nonzero covariance between fluctuations in borrowed reserves supplied and shocks to money demand. In the discussion here, a zero covariance is assumed. The general expression that allows for nonzero covariances is given in equation 15 of Appendix A.

11. ε_{it} in the model of Appendix A.

12. $\frac{\mu_{3t} - \varepsilon_{3t}}{\alpha_{10}}$ in the model of Appendix A.

13. This can be seen by comparing either equations 12 and 15 or 16 and 17 in Appendix A. The only difference between 12 and 15 or 16 and 17 is the replacement of ε_{it} in 12 and 15 by

$$\frac{\varepsilon_{3t} - \mu_{3t}}{\alpha_{10}}$$

in 15 and 16. But those terms just represent the volatility of interest rates under the two operating procedures. Hence, if a funds rate operating procedure is compared with a borrowed reserves operating procedure under the assumption that the variance of the random component of money demand and the precision of forecasting income are unchanged, then the operating procedure with the larger volatility of interest rates will exhibit less precision in short-run monetary control.

14. Graphically, the movement from a federal funds operating procedure to a pure nonborrowed reserves operating procedure is a change from a horizontal "money supply function" to a vertical "money supply function." Intermediate cases, where the operating procedure allows for some response in the supply of nonborrowed reserves to interest rate fluctuations, are represented by positively sloped "money supply functions."

15. This serial correlation is introduced through the distributed lag terms in the estimated short-run money demand equation, and occurs even if the underlying random disturbances in the model (μ_{1t}, μ_{2t}, ε_{1t} and ε_{3t}) are not serially correlated.

16. a_t represents a shock to the federal funds rate. The χ^2 statistic measures the probability that the a's are not serially correlated. A tabulated χ^2 value below the critical value signifies that the probability of serial correlation in the a's is below conventionally accepted levels of statistical significance.

17. By suitable choice of the coefficients in the polynominal δ, the model can even handle different marginal and average reserve requirements such as proposed by Poole (1976). A potential criticism of this model is that it does not adequately account for the expectational behavior of either households and firms with respect to the demand for money or banks with respect to their demand for borrowed reserves from the Federal Reserve System.

An elegant analysis of short-run money market behavior has been constructed recently by Goodfried, *et al.* (1983). It attempts to incorporate rational expectations with respect to future interest rate behavior on the part of money demanders and banks, a sophisticated supply function for borrowed reserves that captures "administrative pressure" at the discount window, and a gradual adjustment rule for the supply of nonborrowed reserves. The dynamic properties of this model closely replicate the dynamic properties of a simple model such as that in Table 10. Therefore, conclusions drawn from a model such as that in Table 10 should be applicable over a broad range of potential models.

18. We assume that the monetary authorities have no time advantage with respect to current developments, so the setting of the policy variable ($\bar{r}$, $\overline{RU}$ or $\overline{BOR}$) for time = t is based solely on information available through time = t − 1.

19. In fact, the discount rate at the N.Y. Federal Reserve Bank changed on only three occasions in the period October 1982 through January 1984, and only twice during 1984, so discount rate changes are not a major consideration in current operating procedures.

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