MONETARY POLICY REGIMES, EXPECTED INFLATION, AND THE
RESPONSE OF INTEREST RATES TO MONEY ANNOUNCEMENTS

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ABSTRACT

This paper examines the response of the term structure of interest

rates to weekly money announcements. Estimated responses for both the

pre- and post-October 1979 periods are first presented. Then, two com-

peting hypotheses involving the policy anticipations and expected infla-

tion effects are formally specified and compared to the estimated responses.

Both hypotheses are found to be consistent with the responses, but they

have sharply different implications about the Federal Reserve's short-

run monetary policy. The expected inflation hypothesis implies that

weekly money surprises should have persistent effects on the level of the

money stock, reflecting shifts in the Federal Reserve's long-run target.

In contrast, the policy anticipations hypothesis implies that the effect

of money surprises should diminish over time, reflecting the Federal

Reserve's desire to offset deviations from target. Additional empirical

results reported in the paper support this latter description of the

money stock process.

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MONETARY POLICY REGIMES, EXPECTED INFLATION, AND THE RESPONSE OF INTEREST RATES TO MONEY ANNOUNCEMENTS

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Recent studies on the response of interest rates to weekly money announcements reveal several interesting empirical relationships. First, the empirical results of Berkman (1978), Grossman (1981), and Urich and Wachtel (1981) indicate that Treasury bill yields rise (fall) in response to an unanticipated increase (decrease) in the announced money stock.[1/] Second, Roley (1982, 1983) and Cornell (1983) find that the magnitude of the bill-yield response increased following the Federal Reserve's announced change in operating procedures on October 6, 1979. Third, Cornell (1983) estimates significant positive responses for long-term yields in both the pre- and post-October 1979 periods, with a significantly larger response in the post-October 1979 period.

These empirical results are of interest not only because of the magnitude of the interest-rate fluctuations associated with unanticipated announced changes in money, but also because the estimated responses potentially provide evidence on the short-run monetary policy rule describing Federal Reserve behavior. In particular, under rational expectations, the market's response depends importantly on the Federal Reserve's desire to offset deviations in money from its target. The empirical evidence, however, appears to be consistent with two different hypotheses about the Federal Reserve's desire to control money as well as the information content of weekly money announcements.

One hypothesis relies on studies by Fama (1975) and Nelson and Schwert (1977), among others, who estimate that changes in expected inflation account for most of the fluctuations in nominal interest rates.[2/] Under this hypothesis,

a positive surprise in a weekly money announcement that is not expected to be offset totally by the Federal Reserve leads to an increase in expected inflation. Thus, the increased interest-rate response following the change in operating procedures in October 1979 is interpreted as evidence that the Federal Reserve is less committed to monetary control. Moreover, the significant response of long-term interest rates in both the pre- and post-October 1979 periods is interpreted as reflecting changes only in expected inflation [e.g., Cornell (1983) and Hardouvelis (1982)].

The other hypothesis is based on a policy anticipations effect. Under this hypothesis, market participants are assumed not to revise their expectation about future inflation on the basis of any one-week's money surprise. Instead, the Federal Reserve is assumed to offset at least partially any deviation in money from its target. A positive money surprise would then imply a rise in expected future interest rates in anticipation of policy actions designed to bring the money stock back to target. This paradigm, therefore, suggests that real interest rates change in response to unanticipated announced changes in money. Thus, in contrast to the expected inflation hypothesis, the increased interest-rate response after October 1979 is consistent with a greater desire by the Federal Reserve to control money along with other possible effects related more closely to the change in operating procedures itself [e.g., Roley (1982, 1983) and Walsh (1983)]. Evidence supporting the policy anticipations hypothesis is presented by Cornell (1982) and Engel and Frankel (1982) who find, in the context of the foreign exchange market, that the dollar appreciates in response to a positive surprise in announced money.[3/] However, both Cornell

(1983) and Hardouvelis (1982) claim that the response of long-term interest rates is too large to be explained by this effect.

The purpose of this paper is to specify separate models consistent with the policy anticipations and expected inflation effects, respectively, and to compare their implications for interest rate responses over the entire term structure. The increased response of interest rates after October 1979 and the relatively large response of long-term rates are shown to be consistent with the policy anticipations effect. In particular, these phenomena can be explained by the Federal Reserve's change in operating procedures, the degree of short-run monetary control, and the persistence of money demand shocks. Other models of the policy anticipations effect do not include long-term interest rates, and they selectively ignore such important institutional features as the type of operating procedures used by the Federal Reserve, lagged reserve accounting, and the lag in money announcements [e.g., Urich (1982) and Nichols, Small, and Webster (1983)]. This institutional detail plays a key role in the models considered here.

In the first section of this paper, the response of the term structure of interest rates in the pre- and post-October 1979 periods is estimated. The policy anticipations and the expected inflation models are presented in the second and third sections, respectively. In the fourth section, the empirical results are reconciled with the predictions of both models, and additional empirical evidence on the relative merits of the two models is discussed. The main conclusions are summarized in the final section.

I. Estimated Response of Interest Rates

In this section, the response of the term structure of interest rates in the pre- and post-October 1979 periods is estimated. The empirical results

exhibit both the increase responsiveness since October 1979 and the relatively large response of long-term yields. These results are presented following brief discussions of the specification and data used in the estimation.

Specification

The usual efficient markets approach is adopted to estimate the response of interest rates to weekly money announcements. To conform with the theoretical models presented in subsequent sections, the consequences of the efficient markets hypothesis may be represented as

$$\Delta R_t = b_0 + b_1 \cdot (\ln M_t - \ln M_t^e) + e_t$$

where ΔR_t = change in the interest rate over a time interval including the money stock announcement in week t

M_t = announced level of the money stock in week t

M_t^e = market's rational expectation of the announced level of the money stock in week t

e_t = random error term uncorrelated with any information available to the public prior to the money announcement in week t

b_0, b_1 = estimated coefficients

While a constant term is always included in the empirical specifications, it should equal zero under the null hypothesis of market efficiency and in the absence of systematic measurement error.

Data

All of the data described below are weekly and span the period beginning on September 29, 1977 and ending on October 15, 1982. The last observation of the pre-October 1979 subsample falls on October 5, 1979. Observations were excluded if either discount rate changes or announcements of other relevant economic data were made within the time interval corresponding to the measured change in interest rates.[4/]

The money stock data consist of announced weekly levels of the narrowly defined money stock, in billions of dollars, as reported in the Federal Reserve's H.6 release. From the beginning of the sample through January 31, 1980, the data correspond to "old M1," and weekly announcements were made on Thursday. From February 8, 1980, through October 15, 1982, announcements were made on Friday. For this period, the data employed are those for M1-B, and more recently, M1, where the definition of this latter aggregate is equivalent to that of M1-B.[5/]

Data for the expected announced level of the money stock are based on the survey data compiled by Money Market Services, Inc. The survey data represent the market's expected announced change in the money stock. To construct expected levels, market participants are assumed to expect no revision in the previous week's announced level.[6/] The survey data begins on September 29, 1977. Prior to February 8, 1980, the median of the Thursday survey is used to represent the market's anticipated money announcement on each Thursday. For the remainder of the sample, the survey was conducted on Tuesday for the Friday announcement. Because of this misalignment, a revised expectation reflecting the availability of new information from Tuesday to Friday is used.[7/]

The yield data are taken from the H.15 release, published by the Federal Reserve. All data are in terms of coupon-equivalent yields, in percent, and quoted bids are used. The change in interest rates is measured from 3:30 p.m. on the day of a money announcement to 3:30 p.m. on the following business day. Thus, any effect of money announcements—which are made at 4:10 p.m.—should be reflected in the measured change in yields.[8/]

Empirical Results

Estimation results of the efficient markets model (1) over the pre-
and post-October 1979 subsamples are presented in Table 1.[9/] Within each
subsample, the estimated response of Treasury security yields declines, with
one exception, as maturity increases. In the pre-October 1979 subsample, for
example, the 3-month Treasury bill yield is estimated to increase by about
6 1/2 basis points for a 1 percent announced money surprise, while the 20-year yield
increases by about 1 basis point. Similarly, in the post-October 1979 subsample,
the 3-month yield's response is over 2 1/2 times greater than that of the
20-year yield. Despite the lower estimated response of long-term yields,
Cornell (1983) and Hardouvelis (1982) suggest that the response is nevertheless
too large to be explained by the policy anticipations effect, especially in the
post-October 1979 period. Instead, the expected inflation effect is hypothesized
to account for the response of long-term yields.

The empirical results in Table 1 also indicate that the estimated response
for all maturities of Treasury securities is over five times larger in the post-
October 1979 period. In the last column, the equality of the response is
formally tested, and in each case the null hypothesis can be rejected at less
than the 1 percent level of significance.[10/] As mentioned earlier, these
results are apparently consistent with two competing hypotheses. First, the
response may have increased because of the change in Federal Reserve operating
procedures and perhaps a somewhat greater commitment to monetary control
[Roley (1982, 1983) and Walsh (1983)]. Second, the larger response may reflect
less desire to control money, implying larger changes in expected inflation for
a given money surprise [Cornell (1983) and Hardouvelis (1982)]. These empirical
results are discussed further in the fourth section in the context of the two
competing hypotheses.

Table 1
RESPONSE OF INTEREST RATES TO
MONEY ANNOUNCEMENT SURPRISES

$$\Delta R_t = b_0 + b_1 \cdot UM_t + e_t$$

| Yield[‡] | Pre-October 1979[†] | | | | Post-October 1979[†] | | | | $H_0: b_1 = b_1{'}$ |
	b_0	b_1	$\overline{R}^2$	SE	$b_0{'}$	$b_1{'}$	$\overline{R}^2$	SE	$F(1,194)$[§]
RFF	.0036 (.0128)	.4216 (2.890)	−.02	.1009	.0516 (.0570)	43.31* (10.37)	.11	.6605	15.86
R1W	.0501* (.0222)	4.686 (5.017)	−.00	.1752	.2146* (.0509)	36.72* (9.253)	.10	.5891	9.26
R3M	.0121 (.0136)	6.478* (3.065)	.05	.1070	.0567 (.0332)	36.40* (6.046)	.21	.3847	19.48
R1Y	.0087 (.0079)	5.199* (1.789)	.11	.0625	.0279 (.0259)	35.54* (4.719)	.29	.3005	36.14
R5Y	.0031 (.0041)	2.574* (.9322)	.10	.0326	.0397* (.0179)	21.23* (3.257)	.24	.2074	30.34
R10Y	.0067 (.0042)	.9197 (.9495)	−.00	.0332	.0381* (.0156)	16.08* (2.834)	.19	.1804	25.74
R20Y	.0036 (.0030)	1.161 (.6809)	.03	.0238	.0367* (.0157)	14.41* (2.847)	.16	.1812	20.50

*Significant at 5 percent level.

[†]The pre-October 1979 subsample begins on September 29, 1977 and ends on October 5, 1979. The post-October 1979 subsample begins on October 8, 1979 and ends on October 15, 1982. Standard errors of estimated coefficients are in parentheses.

[‡]Treasury security yield data correspond to changes in bid quotations from 3:30 p.m. on the announcement day to 3:30 p.m. on the following business day. Federal funds rate data are daily averaged yields. (Source: Board of Governors of the Federal Reserve System, H.15.)

[§]In each test, the null hypothesis can be rejected at less than 1 percent level of significance.

RFF = federal funds rate
R1W = 1-week Treasury bill yield
R3M = 3-month Treasury bill yield
R1Y = 1-year constant maturity yield on Treasury securities
R5Y = 5-year constant maturity yield on Treasury securities
R10Y = 10-year constant maturity yield on Treasury securities
R20Y = 20-year constant maturity yield on Treasury securities
UM = $\ln M - \ln M^e$, where M and M^e are the actual and expected announced levels of the money stock, in billions of dollars (Source: Board of Governors of the Federal Reserve System, H.6; and Money Market Services, Inc.)
e_t = random error term
$\overline{R}^2$ = multiple correlation coefficient corrected for degrees of freedom
SE = standard error

II. Policy Anticipations Model

In this section, a model of the response of interest rates to money announcements is developed which focuses exclusively on the policy anticipations effect. By ignoring the role of expected inflation, it will be possible to determine whether the policy anticipations explanation is, in isolation, consistent with the empirical results reported in Table 1. Of particular interest is the ability of the model to explain the response of long-term interest rates as well as the increased response of all rates in the post-October 1979 period. Because institutional features are important for a complete understanding of the policy anticipations effect, it will be useful to begin with an overview of the Federal Reserve's policy procedures before turning to the formal model.

The money stock figure released at 4:10 p.m. on Fridays is the Federal Reserve's current estimate of the money stock during the settlement week ending nine days previously. This has two important implications. First, because of lagged reserve accounting, the Friday announcement provides market participants with an estimate of the deposit levels against which required reserves for the current settlement week are levied. Second, because money demand shifts cause week to week movements in the quantity of money, the announcement provides information on any money demand shift which may have occurred two weeks previously.[11/]

In estimating the money stock prior to the Friday announcement, the Federal Reserve may adjust its target path for the monetary aggregates in light of any deviation of actual money from target. Under lagged reserve accounting, monetary policy is implemented by using a policy instrument—

the federal funds rate in the pre-October 1979 period and nonborrowed reserves in the post-October 1979 period—in an attempt to make money demand equal to the targeted quantity of money. While the direct effects of Federal Reserve actions are to influence the federal funds rate, this is not the interest rate most relevant for the demand for money. The Federal Reserve must, therefore, estimate what change in the funds rate will lead to changes in other short-term rates which, in turn, will produce the desired effect on the demand for money. Any model of the policy anticipations effect needs, therefore, to specify: 1) the informational content of the money announcement and how it depends on the operating procedures of the Federal Reserve; 2) the determinants of the demand for money; 3) the linkages between variables influencing money demand and the Federal Reserve's policy instruments; 4) the operating procedures followed by the Federal Reserve in attempting to achieve its monetary targets; and 5) the manner in which the target path for money is adjusted in light of deviations between the actual quantity of money and the target path.

Within this conceptual framework, consider the actions of the Federal Reserve at the beginning of settlement week t. Assume, for simplicity, that in setting its policy instrument for week t, the Federal Reserve, but not yet the public, knows m_{t-2}, the (log) money supply during week t-2. This is the number which will be announced on Friday of week t. The Federal Reserve cannot yet observe m_{t-1}, but on the basis of m_{t-2} (and perhaps other information), an estimate of week t-1's deviation from target, $E(m_{t-1}|\Omega_t) - m_{t-1}^T(\Omega_{t-1})$, is formed, where Ω_t denotes the Federal Reserve's information set at the start of week t, $E(m_{t-1}|\Omega_t)$ is the expectation of m_{t-1} conditional on Ω_t, and

$m_{t-1}^T(\Omega_{t-1})$ is the target value for m_{t-1} which had been set at the start of week t-1 based on Ω_{t-1}. The estimate of this deviation is used to revise the target path. The policy rule is assumed to be,

$$m_{t+j}^T(\Omega_t) - m_{t+j}^T(\Omega_{t-1}) = [\delta_1 + (1-\lambda)^{j+1}(1-\delta_1)]$$

$$\cdot [E(m_{t-1}|\Omega_t) - m_{t-1}^T(\Omega_{t-1})]; \quad j = 0,1,\ldots \quad (2)$$

According to (2), a deviation from target during week t-1 leads to a revised target path for money for all future weeks. Equation (2) implies that the Federal Reserve plans to offset eventually a fraction $(1-\delta_1)$ of the week t-1 deviation from target. It does so only gradually, however, at the rate $(1-\lambda)$ per week. The remaining fraction of the deviation, δ_1, is not offset.[12/] If $\delta_1 = 0$, the new path $[m_{t+j}^T(\Omega_t)]$ returns to the old path $[m_{t+j}^T(\Omega_{t-1})]$ as $j\to\infty$. Because this section treats expected inflation as constant in order to emphasize the policy anticipations effect, equation (2) implicitly assumes that the Federal Reserve does not revise its targeted long-run growth rate for the money supply.

The Federal Reserve has two potential policy instruments: the weekly average federal funds rate, i_t, or the weekly average path of (log) nonborrowed reserves, $\ln NBR_t$.[13/] Dealing first with the pre-October 6, 1979 period, i_t will initially be treated as the tool used to implement policy.

Pre-October 1979 Operating Procedures

Prior to October 1979, the Federal Reserve used i_t in trying to equate money demand to the targeted quantity of money. It is assumed that money demand is given by

$$m_t - p_t = \alpha_0 - \alpha r_t + u_t \quad (3)$$

where p_t is the log of the price level and r_t is the rate on an n-week

security, such as a 13-week Treasury bill. The appearance of r_t in (3)

captures the notion that the demand for money does not depend on the federal

funds rate, but on a longer term interest rate. Income is treated as a

constant for this analysis and is not explicitly included in (3). Since, in

this section, p_t will be treated as a constant, it will be covenient to define

$\alpha_0' = \alpha_0 + p_t$ and write

$$m_t = \alpha_0' - \alpha_1 r_t + u_t \tag{3'}$$

As (3') is a weekly money demand equation, the random disturbance u_t

is likely to exhibit a high degree of serial correlation.[14] To model this

in a simple way, assume

$$u_t = \rho u_{t-1} + \varepsilon_t, \quad |\rho| < 1 \tag{4}$$

where ε_t is a white noise process.

An expectations model of the term structure of interest rates is used

to link i_t and r_t. If Φ_t is defined as the information set available to the

public,

$$r_t = (1/n) \sum_{j=0}^{n-1} E(i_{t+j} | \Phi_t). \tag{5}$$

Equation (5) reveals why current interest rates such as r_t will depend on

anticipated future policy since r_t is a function of expected future settings

of the policy variable i_t.

Using the money demand function (3'), the Federal Reserve can calculate

the path of r_t which is consistent with its target path for the money stock,

conditional on the information available at the beginning of week t. If

$r_{t+i}^T(\Omega_t)$ is this target path, suppose $i_{t+i}^T(\Omega_t)$ is the path for the federal funds

rate which satisfies:

$$r^T_{t+i}(\Omega_t) = (1/n) \sum_{j=0}^{n-1} i^T_{t+i+j}(\Omega_t); \quad i = 0,\ldots \qquad (6)$$

Because of idiosyncratic developments during week t, assume the funds rate actually set by the Federal Reserve is given by

$$i_t = i^T_t(\Omega_t) + \theta_t \qquad (7)$$

where θ_t is a mean zero, serially uncorrelated weekly policy deviation from the targeted value of the funds rate.

With a funds rate operating procedure, the Federal Reserve sets i_t according to (7) at the beginning of the settlement week. Because $i^T_t(\Omega_t)$ is based on Ω_t which includes information not available to the public prior to the Friday announcement, the public cannot distinguish the component parts in (7). Using the term structure equation (5), the appendix shows that r_t can be written as

$$r_t = (1/n)i_t - \alpha^{-1} \sum_{j=0}^{\infty} E(m^T_{t+jn+1} - m^T_{t+jn+n}|\Phi_t)$$

$$+ \alpha^{-1} \sum_{j=0}^{\infty} E(u_{t+jn+1} - u_{t+jn+n}|\Phi_t) + \frac{n-1}{n} E(r^T_{t+\infty}|\Phi_t) \qquad (8)$$

Equation (8) shows explicitly how r_t depends on the public's expectations about the target path for the money supply.

In order to analyze the effects of the money announcement, it will be necessary to define more specifically the public's information set Φ_t and relate it to the Federal Reserve's information set Ω_t. Let Φ^b_t denote the public's information prior to the money announcement. Let r^b_t be the equilibrium value of r_t, just _prior_ to the announcement, obtained by substituting Φ^b_t for Φ_t in (8). Similarly, define $\Phi^a_t = \{m_{t-2}, \Phi^b_t\}$ as the public's information set after

m_{t-2} is announced. The interest rate after the announcement is r_t^a. Since the only new information analyzed here is the announcement of m_{t-2}, it follows that $\phi_t^b = \Omega_{t-1} \subset \Omega_t = \phi_t^a$.

From (3´), $m_{t-2} = \alpha_0' - \alpha r_{t-2} + u_{t-2}$ so that prior to the announcement, $E(m_{t-2}|\phi_t^b) = \alpha_0' - \alpha r_{t-2} + \rho u_{t-3}$. The new information contained in the announcement of m_{t-2} is then equal to

$$m_{t-2} - E(m_{t-2}|\phi_t^b) = u_{t-2} - \rho u_{t-3} = \varepsilon_{t-2}. \tag{9}$$

The money "surprise", the difference between the announcement on Friday and the public's expectation of m_{t-2}, is just the week $t-2$ innovation in the money demand disturbance.

Making use of the policy rule (2), together with (8), it is possible to derive the adjustment in r_t which occurs in response to the announcement (details can be found in the appendix):

$$r_t^a - r_t^b = \alpha^{-1}\left[\frac{\rho(1-\lambda)^2(1-\delta_1)[(1-\lambda)^{n-1}-1]}{1-(1-\lambda)^n} + \frac{(1-\rho^{n-1})}{1-\rho^n}\rho^3 - \frac{(n-1)\delta_1\rho}{n}\right]\varepsilon_{t-2}. \tag{10}$$

Although the money surprise, ε_{t-2}, is itself direct information only on the week $t-2$ money demand innovation, its effect on r_t can be seen from (10) to consist of three components. The last term, $\alpha^{-1}(1-n)\delta_1\rho/n < 0$ is a Keynesian liquidity effect. To the extent that a positive deviation above target, for example, is partially accommodated ($0 < \delta_1 < 1$), the money supply will be permanently higher. Since the interest elasticity of the demand for money is negative, interest rates must fall.

The middle term in (10) is positive and represents the effect on r_t of the public's revised expectations about future money demand. If $\varepsilon_{t-2} > 0$,

individuals revise upwards their estimates of future u_{t+i}'s. Higher estimates of future money demand lead to expectations of higher future interest rates for a given target path.

The first term in (10) is negative since $(1-\lambda)^{n-1} < 1$. The upward pressure on interest rates produced by a positive surprise is moderated to the extent that the Federal Reserve is expected to return m to the target path only gradually.[15]

The effect of the money announcement in this policy anticipations model on interest rates of longer maturity than r_t can also easily be derived using the expectations model of the term structure. Let R_t be the rate on a security with m·n weeks to maturity. Then

$$R_t = (1/m) \sum_{k=0}^{m-1} E(r_{t+kn}|\Phi_t).$$

(11)

Making use of some earlier results, it can be shown that

$$R_t^a - R_t^b = (1/m)(r_t^a - r_t^b) + (1/m)\alpha^{-1} \sum_{k=1}^{m-1} [(1-\lambda)^{kn+1}(1-\delta_1) + \rho^{kn+1}]\rho\varepsilon_{t-2}$$

$$+ [(1-m)/m] \alpha^{-1}\delta_1\rho\varepsilon_{t-2}.$$

(12)

The first and second terms on the RHS of (12) are both positive if $\varepsilon_{t-2} > 0$. The final term is negative, and it represents the money surprise that is permanently accommodated and which, therefore, through a Keynesian liquidity effect, tends to reduce future interest rates. If the Federal Reserve always attempts to return to target, $\delta_1 = 0$ and $|R_t^a - R_t^b| > (1/m) \cdot |(r_t^a - r_t^b)|$.

Post-October 1979 Operating Procedures

Equations (10) and (12) give the response to the money announcement of both short- and long-term interest rates under a federal funds rate operating

procedure. On October 6, 1979, however, the Federal Reserve shifted to a nonborrowed reserves operating procedure. Such a procedure involves setting a path for nonborrowed reserves which is consistent with achieving the targeted path for money. To analyze the interest rate response to a money announcement during the post-October 1979 period it is necessary to note that the current week's funds rate, i_t, is no longer fixed. A positive money surprise indicates to market participants that the level of required reserves for the current settlement week will be higher than expected. This should lead to a higher funds rate in the remainder of the current week, which through the term structure equation (5), leads to a higher r_t. To explicitly model this additional effect, it is necessary to incorporate into the model a specification of the market for reserves.

Under lagged reserve accounting, the log of required reserves is given by

$$\ln RR_t = k + m_{t-2} \tag{13}$$

where k is the log of the required reserve ratio. For simplicity, it is assumed that all deposits are subject to the same reserve ratio and that the deposit to money ratio is constant. Assuming excess reserves are zero, equation (13) gives the demand for reserves.

The supply of reserves consists of nonborrowed reserves—taken to be the policy variable in the post-October 1979 period—and borrowed reserves. A rise in the funds rate relative to the discount rate leads to a rise in bank borrowings and a fall in nonborrowed reserves as a fraction of total reserves. This relationship is specified as

$$\ln \frac{NBR_t}{RR_t} = \beta_0 - \beta(i_t - i_t^{dis}) + v_t \qquad (14)$$

where i_t^{dis} is the discount rate, and v_t is a mean zero, serially uncorrelated disturbance term.

To represent the determination of the policy variable in week t, assume

$$\ln NBR_t = \ln NBR_t^T + \psi_t \qquad (7´)$$

where $\ln NBR_t^T$ is the (log) value of nonborrowed reserves consistent with achieving the target path for the money supply and ψ_t is a transitory policy deviation from the target. Equation (7´) replaces (7) in an analysis of the post-October 1979 period. Parallel with the treatment of the pre-October 1979 period, assume that at the beginning of week t, the public knows $\ln NBR_t$ but not its decomposition into $\ln NBR_t^T$ and ψ_t.

Under this operating procedure, the federal funds rate adjusts to equilibrate the reserve market. Equating the demand for reserves to the supply and solving for i_t yields

$$i_t = i_t^{dis} + \beta^{-1}[k + \beta_0 + m_{t-2} - \ln NBR_t^T + v_t - \psi_t]. \qquad (15)$$

The response of the funds rate to the announcement can be shown to equal

$$E(i_t|\Phi_t^a) - E(i_t|\Phi_t^b) = \beta^{-1}(m_{t-2} - E(m_{t-2}|\Phi_t^b)) = \beta^{-1}\varepsilon_{t-2}. \qquad (16)$$

A positive surprise ($\varepsilon_{t-2} > 0$) causes an upward revision in expected reserve demand over the remainder of the settlement week, leading to a rise in the funds rate.

To determine the impact under a reserves operating procedure of the announcement, equation (5) can be utilized, along with (16) to derive the response of the short-term interest rate:

$$r_t^a - r_t^b = \left[\frac{1}{\beta n} - \frac{\alpha^{-1}\rho(1-\lambda)^2(1-\delta_1)[(1-\lambda)^{n-1} - 1]}{1 - (1-\lambda)^n} \right.$$

$$\left. + \frac{\alpha^{-1}(1-\rho^{n-1})\rho^3}{1-\rho^n} - \frac{\alpha^{-1}(n-1)\delta_1\rho}{n} \right] \varepsilon_{t-2} \qquad (17)$$

One result is immediate from a comparison of (10), the pre-October 1979 effect, and (17), the post-October 1979 effect. For given values of α, ρ, λ, and δ_1, the change in operating procedures introduces a new term, $1/\beta n > 0$, into the response coefficient. A given money surprise has a larger effect on short-term interest rates under a nonborrowed reserves operating procedure than under a funds rate operating procedure. This is consistent with the increased response after October 1979 documented in Table 1. From (12) and (17), however, it may be shown that the response of longer term (m-quarter) yields increases by only $1/m \cdot 1/\beta n$. Thus, some other factors in the model must contribute to the increased response of long-term yields.

One possibility is that the change in operating procedures was viewed by the public as accompanied by a shift in the policy adjustment rule followed by the Federal Reserve. If the use of nonborrowed reserves rather than the funds rate was interpreted as signaling a greater determination on the part of the Federal Reserve to keep money on target, either λ or δ_1 (or both) may have changed. A fall in δ_1 would indicate that less of any deviation from target would be accommodated, while a rise in λ would indicate a faster elimination of any deviations. Either such change tends to increase the response to the money surprise in (17) and (12).

Another result of the change in operating procedures was a large increase in the volatility generally of interest rates. In Walsh (1982, 1983), it is

shown that a rise in the volatility of interest rates may lead to a fall in the interest elasticity of the demand for money which is proportional to the rise in volatility. Such a decline in α as a consequence of the shift to a nonborrowed reserves operating procedure would also tend to increase the response of both short- and long-term yields to a given money surprise. The effects of changes in these various parameters are examined further using numerical examples in the fourth section.

III. Expected Inflation Model

The model in the previous section, in order to focus on the policy anticipations effect, assumed that the expected rate of inflation remained constant in the face of the money announcement. This implies that the interest rate adjustments were adjustments in real interest rates. An alternative view of interest rate determination argues that real interest rates are independent of monetary influences so that any response of interest rates to a money announcement must be due to changes in the expected inflation premium incorporated in market rates. The present section develops a model of interest rate responses which attributes all changes in rates to changes in expected inflation.

If μ is the constant ex ante real rate of interest and r_t is, as before, the rate on an n-week security, then

$$r_t = \mu + \frac{\gamma}{n} \quad [E(p_{t+n}|\Phi_t) - p_t] + \eta_t \tag{18}$$

where $\gamma = 5200$[16]/ and η_t is a mean zero disturbance term assumed to be serially uncorrelated.

In the model of section II, any deviation of the money stock from its target value leads to an adjustment in target levels but no change in the targeted long-run growth rate. This assumption needs to be modified to allow for the possibility that a value of m_{t-2} above target leads the Federal Reserve to revise

upwards its targeted growth rate. If this occurred, the public, in the face of a positive money surprise, might infer faster money growth and higher inflation in the future. This possibility can be captured by rewriting the policy reaction rule in the form

$$m_{t+j}^T(\Omega_t) - m_{t+j}^T(\Omega_{t-1}) = [(j+1)\delta_2 + \delta_1 + (1-\lambda)^{j+1}(1-\delta_1)]\rho\varepsilon_{t-2};$$

$$j = 0,1,\ldots \tag{2'}$$

where use has been made of the fact that $\rho\varepsilon_{t-2} = E(m_{t-1}|\Omega_t) - m_{t-1}^T(\Omega_{t-1})$. To understand the role of δ_2, suppose that the targeted growth rate is k and that $m_{t+j}^T = m_{t-2}^T + (j+2)k$. The actual growth rate from t-2 to t-1 is estimated, at time t, to be $k + \rho\varepsilon_{t-2}$. If this growth rate were to be maintained, the new target for m_{t+j} would be $m_{t+j}^T = E(m_{t-1}|\Omega_t) + (j+1)k + (j+1)\rho\varepsilon_{t-2}$ (ignoring λ and δ_1 for simplicity). If the deviation has no effect on the targeted growth rate, $m_{t+j}^T = E(m_{t-1}|\Omega_t) + (j+1)k$, which is the case considered in the previous section. Equation (2') allows a fraction δ_2 of the growth-rate deviation to have a permanent effect on the Federal Reserve's growth-rate target.

To determine the expected rate of inflation as a function of the underlying parameters of the model, it is first necessary to find the equilibrium solution for the log of the price level. From the money demand equation (3) and the Fisher equation (18):

$$m_t - p_t = \alpha_0 - \alpha[\mu + (\gamma/n)(E(p_{t+n}|\Phi_t) - p_t)] + u_t. \tag{19}$$

Solving for p_t, equation (19) implies

$$p_t = (n+\gamma\alpha)^{-1}[nm_t + n(\alpha\mu - \alpha_0) + \gamma\alpha E(p_{t+n}|\Phi_t) - nu_t]. \tag{20}$$

Since $\gamma\alpha/(n+\gamma\alpha) < 1$, equation (20) can be solved forward under the assumption of rational expectations. This yields

$$P_t = \alpha\mu - \alpha_0 + \frac{n}{n+\gamma\alpha}(m_t - u_t) + \frac{n}{n+\gamma\alpha}\sum_{j=1}^{\infty}\left(\frac{\gamma\alpha}{n+\gamma\alpha}\right)^j E(m_{t+jn}^T|\Phi_t)$$

$$- \frac{n}{n+\gamma\alpha}\sum_{j=1}^{\infty}\left(\frac{\gamma\alpha}{n+\gamma\alpha}\right)^j E(u_{t+jn}|\Phi_t). \tag{21}$$

In response to the Friday announcement, r_t adjusts to the extent that $(\gamma/n)[E(p_{t+n}|\Phi_t) - p_t]$ is affected. Using (21) to evaluate the change in $[E(p_{t+n}|\Phi_t) - p_t]$, the appendix shows that under the policy rule (2´),

$$r_t^a - r_t^b = \gamma\left[\frac{(1-\lambda)^{n+1}(1-\delta_1)}{n+\gamma\alpha[1-(1-\lambda)^n]} - \frac{\rho^{n+1}}{n+\gamma\alpha(1-\rho^n)} + \frac{n+\gamma\alpha}{n}\delta_2\right.$$

$$\left. + \frac{1}{n}(\delta_1 + \delta_2)\right]\rho\varepsilon_{t-2} \tag{22}$$

The corresponding expression for a longer term (m quarter) security is given by

$$R_t^a - R_t^b = (1/m)(r_t^a - r_t^b) + \gamma\left[\frac{m-1}{m}\delta_2\right.$$

$$+ (1/m)\frac{(1-\lambda)^{n+1}(1-\delta_1)[1-(1-\lambda)^{-n}]}{n+\gamma\alpha[1-(1-\lambda)^n]}\sum_{i=1}^{m-1}(1-\lambda)^{in}$$

$$\left. - (1/m)\frac{\rho(\rho^n-1)}{n+\gamma\alpha(1-\rho^n)}\sum_{i=1}^{m-1}\rho^{in}\right]\rho\varepsilon_{t-2}. \tag{23}$$

Letting m go to infinity, equation (23) implies that $\lim_{m\to\infty}(R_t^a - R_t^b) = \gamma\delta_2\rho\varepsilon_{t-2}$; any permanent change in the annual growth rate of money leads to a one-for-one rise in long-term interest rates.

Because interest rates in this model adjust only in response to changes in the expected rate of inflation, it is possible to solve for the adjustment responses in (22) and (23) without any reference to the Federal Reserve's operating procedure. The expected inflation model predicts that the interest

rate response to a money announcement is independent of the particular proce-
dure used by the Federal Reserve to implement monetary policy. To explain
the large increases in the response coefficients reported in Table 1 within
the context of the inflation expectations model, it is necessary to assume
that there were shifts in the basic model parameters at the time of the change
in operating procedures. For example, a rise in δ_2, the fraction of the week
t-2 to t-1 growth rate deviation which the Federal Reserve accommodates, would
increase the response coefficients. Using numerical examples, the model is
also compared to the estimated responses in the next section.

IV. Evaluation of the Models

In this section, the stylized models of the policy anticipations and
the expected inflation effects are examined in terms of their consistency
with the empirical results reported in Table 1. While the models are specified
under a variety of simplifying assumptions, they nevertheless embody the impor-
tant features of the underlying hypotheses. Following the evaluation of the
models, additional empirical evidence is presented on the persistence of
announced money surprises.

In examining the consistency of the models with the estimated responses
in Table 1, iterative grid searches are performed over the models' parameters
in both the pre- and post-October 1979 periods. In addition, the searches
are implemented simultaneously for the 3-month (n=13), 1-year (m=4), 5-year
(m=20), 10-year (m=40), and the 20-year (m=80) yields. For the policy
anticipations model, the response of the 3-month yield is represented by (10) and
(17) for the pre- and post-October 1979 periods, respectively. For longer
term yields (m=4, 20, 40, 80), the response under both policy regimes is

given by (12). For the expected inflation model, the response of the
3-month yield is represented by (22), and the response of longer term yields
is given by (23). In each case, all parameters of the models--λ, δ_1, α, ρ,
and δ_2 (when relevant)--are subjected to the grid search. The criterion
used in the search is to minimize the sum of the absolute percentage
differences from the point estimates in Table 1 across the five yields.[17/]

Is the Policy Anticipations Model Consistent with the Estimated Responses?

The response of the term structure of interest rates under the policy
anticipations hypothesis is computed for selected parameter values in Table 2.
The reported values for the responses consist of both those conforming to the
estimated responses in Table 1--given the criterion described above--as well
as examples exhibiting the effects of changes in parameter values. As is
apparent in the table, sets of parameters are calculated separately for the
pre- and post-October 1979 periods.

For the pre-October 1979 period, the policy anticipations model is
capable of yielding responses fairly close to those in Table 1 when the
parameters take values of $\rho = .986$, $\alpha = .143$, $\lambda = .687$, and $\delta_1 = .000$.
The response of the 3-month yield, for example, is calculated as 6.48, which
is identical to its estimated value in Table 1. Moreover, the responses of
longer term interest rates are all positive and fairly close to the
corresponding estimated values.

The reported parameter values implied by the responses for the pre-
October 1979 period suggest that weekly money demand disturbances are highly
serially correlated ($\rho = .986$), and that they are eventually offset
completely ($\delta_1 = 0$). The speed at which a money demand shock is offset,

however, is implausibly high. In particular, the value in Table 2 (λ = .687) implies that approximately 68 percent ($\lambda \cdot \rho \cdot \varepsilon_{t-2}$) of a surprise in announced money is offset during the week of the announcement. The responses are nevertheless quite insensitive to changes in the rate at which surprises are offset, as indicated by the third and fourth rows in Table 2. In contrast, the fraction of the surprise accommodated has a larger impact on the responses, as indicated in the second row, where δ_1 is increased to .100.

In the lower panel of Table 2, sets of parameter values for the post-October 1979 period are reported. The first row again corresponds to the parameters obtained from the grid search. The next three rows report values for selected changes in the policy parameters, as before. The results for the post-October 1979 period suggest that money surprises are somewhat more highly serially correlated (ρ = .996), and that the interest-rate responsiveness of money demand is over five times smaller than that in the pre-October 1979 period.[18] Because of the persistence of money demand shocks and the much lower interest-rate responsiveness of money demand, short-term rates must remain above their original levels for an extended period of time if the original long-run target path for money is maintained (δ_1 = 0). The combination of these factors is sufficient to explain the relatively large response of long-term interest rates. By comparing the first and fifth rows in each panel, note that changes in policy parameters across periods have negligible effects on the responses.

Is the Expected Inflation Model Consistent with the Estimated Responses?

Analogous to Table 2, the response of the term structure of interest rates under the expected inflation hypothesis is solved for selected parameter

Table 2
SELECTED PARAMETER VALUES FOR
THE POLICY ANTICIPATIONS MODEL*

Policy Parameters		Interest Rate Response: Pre-October 1979 (ρ=.986, α=.143)				
λ	δ_1	R3M	R1Y	R5Y	R10Y	R20Y
.687	.000	6.48	5.19	1.96	1.006	.503
.687	.100	5.86	4.52	1.28	.318	-.185
.587	.000	5.98	5.07	1.94	.994	.497
.787	.000	6.84	5.28	1.98	1.015	.508
.779	.000	6.82	5.28	1.98	1.015	.508
estimate‡		6.48	5.20	2.57	.920	1.16

		Interest Rate Response: Post-October 1979 (ρ=.996, α=.0265)[†]				
.779	.000	36.4	34.4	23.8	16.1	9.06
.779	.100	32.8	30.7	20.1	12.4	5.30
.679	.000	34.4	33.9	23.7	16.1	9.04
.879	.000	37.7	34.7	23.9	16.1	9.08
.687	.000	34.6	34.0	23.7	16.1	9.04
estimate‡		36.4	35.5	21.2	16.1	14.4

*See the notes in Table 1 for variable definitions. Parameters are defined in the text.

†The post-October 1979 responses are calculated under the assumption that the one-week bill yield's response equals its estimated value in Table 1 of 36.72. This estimate implies β=.027.

‡From Table 1.

Policy Parameters			Interest Rate Response: Pre-October 1979 (ρ=.931, α=.0418)				
λ	δ_1	δ_2	R3M	R1Y	R5Y	R10Y	R20Y
.438	.006	.000192	6.47	5.20	1.82	1.38	1.15
.438	.000	.000192	4.24	4.64	1.71	1.32	1.12
.438	.106	.000192	43.7	14.5	3.68	2.31	1.62
.338	.006	.000192	6.53	5.20	1.82	1.38	1.15
.538	.006	.000192	6.47	5.20	1.82	1.38	1.15
.438	.006	.000092	−2.14	2.69	.931	.688	.567
.438	.006	.000292	15.1	7.72	2.71	2.06	1.74
.438	.021	.00256	216	66.2	23.2	17.8	15.1
estimate†			6.48	5.20	2.57	.920	1.16

			Interest Rate Response: Post-October 1979 (ρ=.980, α=.0216)				
.438	.021	.00256	36.4	32.3	19.1	16.1	14.6
.438	.000	.00256	28.2	30.2	18.7	15.9	14.5
.438	.121	.00256	75.6	42.1	21.1	17.1	15.1
.338	.021	.00256	36.5	32.3	19.1	16.1	14.6
.538	.021	.00256	36.4	32.3	19.1	16.1	14.6
.438	.021	.00156	−13.1	16.1	11.8	9.89	8.92
.438	.021	.00356	85.9	48.5	26.4	22.3	20.2
.438	.006	.000192	−86.7	−7.51	1.49	1.25	1.11
estimate†			36.4	35.5	21.2	16.1	14.4

*See the notes in Table 1 for variable definitions. Parameters are defined in the text.

†From Table 1.

values in Table 3. As before, parameter values may be obtained which are consistent with the estimated responses in Table 1. In the pre-October 1979 period, the value for the serial correlation of money demand shocks is again quite high, but the interest-rate responsiveness of money demand is lower than that computed under the policy anticipations hypothesis. The policy parameters also differ substantially. In particular, the rate at which money surprises are offset (λ) is .438, although the reported responses are fairly insensitive to this parameter, as indicated in the fourth and fifth rows in the table. In addition, the results suggest that a portion of the shock is accommodated by changing the level of money's target path ($\delta_1 = .006$), and that the Federal Reserve permanently raises its target growth rate in response to a positive shock ($\delta_2 = .000192$). For a positive 1 percent shock, for example, the target annualized growth rate is increased by almost .01 percentage points ($52 \cdot \delta_2$). As indicated in the table, the 20-year yield's response of about 1 basis point predominately reflects this revision in the target growth rate. This sensitivity is also apparent in the sixth and seventh rows in the table, where the responses are calculated with different values of δ_2. The response of short-term yields also depends importantly on the initial accommodation in the current level of money (δ_1), as may be seen in the second and third rows.

For the post-October 1979 period, the two main changes in the parameters are that δ_2 increases to .00256 and the interest-rate responsiveness of money demand is about one-half its previous value. As suggested by Cornell (1983) and Hardouvelis (1982), the increase in δ_2 indicates greater accommodation of money surprises by the Federal Reserve through revisions in its target growth rate. In this case, the calculated value of δ_2 indicates that a 1 percent

money surprise leads to a revision in the target annualized money growth of
.13 percentage points. Again, the 20-year yield's response of 14.6 basis
points predominately reflects this accommodation. The eighth row in each panel
also indicates the key role of this parameter.

Persistence of Money Surprises

The previous two subsections indicate that different sets of parameter
values may be found that make both the policy anticipations and expected infla-
tion hypotheses consistent with the estimated responses in Table 1. Despite
this inability to distinguish between the hypotheses on the basis of their
consistency with the estimated responses, the implications of the models do
differ dramatically. In particular, under the policy anticipations hypothesis,
the parameter values indicate that money surprises are totally offset after
some period of time. In contrast, under the expected inflation hypothesis,
target growth rates are permanently changed in the direction of the surprise.

These different implications suggest one way in which the hypotheses
may be distinguished. In particular, under the policy anticipations hypothesis,
past surprises in the announced level of money would be expected to have
diminishing effects on the level of the money stock over time. Under the
expected inflation hypothesis, this should not be the case. Indeed, for
money surprises to affect expected inflation over the maturity of a long-
term security, surprises would be expected to persist over lengthy intervals.

The monetary policy rule specified previously (2´) may be used to
illustrate the possible relationship between past money surprises and the
level of the money stock. In particular, recursive substitution yields

$$m_t = m_t^T(\Omega_{t-k}) + \varepsilon_t + \rho\varepsilon_{t-1} + \sum_{j=0}^{k-1} [(j+1)\delta_2 + \delta_1 + (1-\lambda)^{j+1}(1-\delta_1)]\rho\varepsilon_{t-j-2} \quad (24)$$

where $m_t = m_t^T(\Omega_t) + \rho\epsilon_{t-1} + \epsilon_t$. Under the pure policy anticipations model, $\delta_2 = 0$ so that as j becomes large, the coefficients on the lagged money surprises decline, approaching $\delta_1\rho$ asymptotically. In contrast, the inflation expectations model requires $\delta_2 > 0$. In this case, equation (24) shows that as j becomes larger, the coefficients on the lagged money surprises must eventually start increasing with j. For the parameters reported in Table 3 for the post-October 1979 period, for example ($\lambda = .438$, $\delta_1 = .021$, $\delta_2 = .00256$), the coefficients are increasing for $j \overset{>}{=} 10$.

Equation (24), therefore, suggests a simple means of discriminating between the policy anticipations hypothesis and the inflation expectations hypothesis. To examine the persistence of money surprises, the following empirical analogue of equation (24) is estimated:

$$m_t = b_0 + b_1 \cdot trend_t + \sum_j c_j \epsilon_{t-j} \qquad (24')$$

where the trend variable is used to proxy $m_t^T(\Omega_{t-k})$.[19] If $\delta_2 > 0$, the c_j's should eventually increase with j; if $\delta_2 = 0$, they should decline towards a possibly nonzero constant. The estimation results for equation (24') for both the pre- and post-October 1979 periods are reported in Table 4. In each case, the equation is estimated without any constraints on the lag structure.[20]

The estimation results suggest that money surprises are offset within one year. In both periods, additional lag terms were included in the equations until the estimated coefficients appeared to remain around, or even below, zero.[21] In the pre-October 1979 period, the unconstrained estimates become negative after 33 weeks. Similarly, estimated lag coefficients for the post-October 1979 period become negative after 48 weeks. This empirical evidence, at least, casts strong doubt on the validity of the expected inflation hypothesis.

Table 4
PERSISTENCE OF MONEY SURPRISES

$$\ln M_t = b0 + b1 \cdot trend_t + \sum_i ci \cdot UM_{t+2-i} + e_t$$

	Pre-October 1979[†]		Post-October 1979[†]	
b0	5.828*	(.0026)	6.425*	(.0880)
b1	.0011*	(.0001)	-.0229*	(.0040)
c0	.9295*	(.1971)	.8443*	(.0688)
c1	.5852*	(.1996)	.6480*	(.0693)
c2	.4850*	(.2031)	.6362*	(.0695)
c3	.3853	(.2014)	.5532*	(.0705)
c4	.3747*	(.1803)	.4759*	(.0710)
c5	.1681	(.1699)	.4312*	(.0698)
c6	.2002	(.1705)	.5236*	(.0680)
c7	.2418	(.1719)	.4739*	(.0690)
c8	.2617	(.1707)	.5319*	(.0687)
c9	.1362	(.1653)	.4946*	(.0685)
c10	.1902	(.1654)	.4512*	(.0711)
c11	.2051	(.1622)	.5121*	(.0737)
c12	.1784	(.1611)	.4483*	(.0747)
c13	.3011	(.1610)	.6404*	(.0725)
c14	.2804	(.1594)	.6337*	(.0753)
c15	.2819	(.1600)	.5663*	(.0754)
c16	.3998*	(.1649)	.4610*	(.0797)
c17	.4098*	(.1622)	.4692*	(.0768)
c18	.4193*	(.1609)	.4846*	(.0787)
c19	.3889*	(.1609)	.4126*	(.0770)
c20	.4344*	(.1626)	.4500*	(.0782)
c21	.4143*	(.1621)	.4084*	(.0780)
c22	.4265*	(.1586)	.5655*	(.0781)
c23	.3270	(.1690)	.4868*	(.0786)
c24	.2866	(.1736)	.4136*	(.0777)
c25	.4550*	(.1746)	.3803*	(.0786)
c26	.3647*	(.1764)	.5154*	(.0767)
c27	.3965*	(.1797)	.4305*	(.0770)
c28	.3590*	(.1767)	.2646*	(.0796)
c29	.3869*	(.1846)	.3278*	(.0779)
c30	.2728	(.1825)	.2595*	(.0794)
c31	.1401	(.1903)	.2673*	(.0776)
c32	.1400	(.1912)	.1623*	(.0763)
c33	.0406	(.1980)	.1157	(.0634)
c34	-.1059	(.1916)	.1896*	(.0634)
c35	-.1093	(.1896)	.1935*	(.0640)
c36			.2186*	(.0631)
c37			.1757*	(.0627)
c38			.1513*	(.0633)
c39			.2837*	(.0624)
c40			.1664*	(.0619)
c41			.2525*	(.0618)
c42			.2273*	(.0622)
c43			.2436*	(.0619)
c44			.1398*	(.0620)
c45			.0874	(.0613)
c46			.1152	(.0610)
c47			.0506	(.0601)
c48			.0496	(.0607)
c49			-.0278	(.0599)
c50			-.0001	(.0592)
$\bar{R}^2$	.94		.99	
SE	.0005		.0003	
DW	0.33		1.14	

*Coefficient is more than twice its estimated standard error.

[†]See the notes in Table 1. Due to the lag lengths, the estimation
periods begin 36 and 51 weeks, respectively, after the starting dates
of the sample periods reported in Table 1. These reduced estimation
periods consist of 68 and 111 observations in the pre- and post-
October 1979 periods, respectively. The lags are estimated unconstrained.

$trend_t \cdot t + a_1 \cdot t^2 + a_2 \cdot t^3 + a_3 \cdot t^4$, where $t = 1,2,3,\ldots$, and the
degree of the polynomial in each period is determined by the statistical
significance of the final term. In the pre-October 1979 period, $a_1 = a_2 = a_3 = 0$. Also note that $UM_{t+2-i} = e_{t-i}$.

V. Summary of Conclusions

By constructing a model of interest rate responses to money announcements, it has been possible to examine explicitly the effect of the Federal Reserve's operating procedures and policy rule on the responses across the entire term structure of interest rates. Two main conclusions follow from this paper.

First, despite claims to the contrary, the policy anticipations hypothesis is capable of explaining the response of the entire term structure of interest rates to surprises in weekly money announcements. This hypothesis was shown to be consistent with the response in both the pre- and post-October 1979 periods. Two key elements of this explanation involve the persistence of money demand shocks along with the Federal Reserve's desire to eventually offset money surprises. Nevertheless, the expected inflation hypothesis was also shown to be consistent with the term structure's response. Under this hypothesis, it follows that the Federal Reserve increases both the level and growth rate of their monetary target in response to positive money surprises.

Second, in examining the effects of past money surprises on the level of the money stock, the empirical evidence suggested that their effects diminish to zero within one year. This result is inconsistent with the expected inflation hypothesis, which posits an increasing effect of money surprises on the level of the money stock. Further empirical work would, nevertheless, be useful in distinguishing between the competing hypotheses.

1. Initial research on this topic also includes unpublished studies by Sivesand (1978) and Conrad (1978).

2. Both of these studies are, of course, based on pre-October 1979 data. Using post-October 1979 data, Makin (1982) finds that movements in nominal interest rates have been influenced more by changes in expected real rates than by expected inflation.

3. However, Cornell (1982) does not attribute these results to the policy anticipations effect. Also, Urich and Wachtel (1982) and Roley and Troll (1983) examine the impact of unanticipated announced changes in the consumer (CPI) and producer (PPI) price indices on Treasury bill yields. Both studies find statistically insignificant responses in the pre-October 1979 period, and Urich and Wachtel (1982) estimate a response to PPI surprises which is significant at the 5 percent level in the October 1979-June 1981 period. By extending the sample to October 1982, however, Roley and Troll (1983) find that the estimated response is again insignificant at the 10 percent level.

4. The excluded observations correspond to announcements of the CPI, the PPI, the unemployment rate, and industrial production. In the pre-October 1979 sample, 43 observations were excluded, while 22 were excluded in the post-October 1979 sample.

5. Announced changes in M1-B are analyzed here because of the emphasis placed on M1-B by Federal Reserve policymakers and market participants. It should also be noted that the M1-B data for 1981 are not the shift-adjusted M1-B figures which reflect the introduction of nationwide NOW accounts. While the Federal Reserve's target range was in terms of shift-adjusted M1-B, weekly announced changes were not shift adjusted.

6. As reported by Roley (1983) in the context of the response of Treasury bill yields, specifying the surprise in terms of levels rather than changes has virtually no effect on the empirical results. For this paper, specifications were estimated with changes in the levels of interest rates, changes in the log of interest rates, and with money surprises in terms of announced changes, announced levels, and the log of announced levels. Again these alternative specifications yielded virtually the same results. We are indebted to Raul A. Nicho, vice president with Money Market Services, for making the survey data available for this project.

7. In forming the revised expectation, the change in the 3-month bill yield from Tuesday at 3:30 p.m. to Friday at 3:30 p.m. is taken as a proxy for the receipt of all new information from the time of the survey to just before the money announcement. Regressing the announced change in money on the survey measure and this change in the bill yield indicates that this proxy is statistically significant at the 5 percent level [see Roley (1983)]. The rationality of the survey data is examined by Grossman (1981) for the pre-October 1979 period and by Roley (1983) for the post-October 1979 period. These studies indicate that except for an additive bias in the pre-October 1979 period, usual hypotheses concerning the rationality of the expected money data used here cannot be rejected at low significance levels. For further analysis of these data, see Urich and Wachtel (1983).

8. In contrast to the other yield data used here, federal funds rate data provided by the Federal Reserve are in terms of daily averages. These data, however, predominately reflect federal funds trading before 3:30 p.m.

9. Following Urich and Wachtel (1981) and Roley (1983), more complicated specifications which disaggregated money surprises according to the relationship of money growth to its long-run policy ranges were also estimated. However, because of the larger standard errors of the equations estimated here due to the longer time interval over which the changes in rates were measured, the effects of policy ranges were not statistically significant for any of the yields in the post-October 1979 period. In the pre-October 1979 period, however, the effects of policy ranges were statistically significant in two instances, but only because of statistically significant coefficients with perverse signs. Also, the presence of statistically significant constant terms in some of the estimated equations in Table 1 may reflect measurement error in either the expected money data or the change in interest rates. Alternatively, they may reflect day-of-the-week effects [Gibbons and Hess (1981)].

10. To avoid potential problems associated with heteroscedasticity, the equations in each of the periods are weighted by the reciprocals of their estimated standard errors in the tests.

11. The role of the announcement in providing information on past money demand shifts is emphasized by Urich (1982) and Nichols, Small, and Webster (1983).

12. Equation (2) is similar to the policy rule used by Tinsley, von zur Muehlen, and Fries (1982), although they assume $\delta_1 = 0$.

13. McCallum and Hoehn (1983) analyze the optimal instrument choice in the context of lagged reserve accounting. For empirical evidence, see Sivesand and Hurley (1980).

14. In a similar specification of a biweekly money demand equation, Urich (1982) assumes u_t is serially uncorrelated.

15. Equation (10) can be compared with the results of other authors. Urich (1982) assumes ε_{t-2} provides no information on ε_t and that $\delta_1 = 0$. His expression for the announcement effect corresponds, therefore, only to the first term in (10). Nichols, Small, and Webster (1983) rely on an expected interest rate change in the money demand equation to motivate future expectations affecting current interest rates. They also assume m is the policy instrument of the Federal Reserve and that $m_{t-2} - E(m_{t-2}|\phi_t^b)$ reveals information on the net shock to both money supply and money demand during week t-2. However, under lagged reserve accounting, the major shocks generating week-to-week fluctuations in the money stock arise from the demand for money as modeled here.

16. In the empirical work, interest rates are measured in basis points at annual rates. This makes it necessary to multiply an n-week rate of change such as $p_{t+n} - p_t$ by 5200.

17. For computational convenience, certain limitations were placed on the number of digits taken by the parameters. In particular, λ, δ_1, and ρ were restricted to three decimal points, and three nonzero digits were found for α and δ_2. All parameters were restricted to take values between zero and one.

18. The increased interest-rate volatility in the post-October 1979 period coinciding with the change in operating procedures is capable of explaining this fall in interest elasticity in the model presented by Walsh (1982, 1983). In addition, this elasticity may have declined due to increased financial innovation and deregulation, which may not be totally independent of the rise in volatility. See, for example, Lindsey (1977) and Niehans (1982).

19. Note that a proxy for $m_t^T(\Omega_{t-k})$ is not needed in (24') since the money surprises ε_{t-j-2} (j=0,...,k-1) are, under rational expectations, uncorrelated with this variable. The proxy was instead included to reduce heteroscedasticity and serial correlation. In this model, as is common in many rational expectations models, standard serial correlation correction procedures would result in inconsistent coefficient estimates. In contrast, OLS estimation yields consistent coefficient estimates in this case, but potentially inconsistent estimated standard errors.

20. Polynomial lags were also estimated, and they yielded virtually the same qualitative results.

21. Extending both lags beyond the lengths reported in Table 4 suggested that the estimated coefficients do not once again increase. Furthermore, lagged money surprises were entered separately on the right-hand side of (24') (i.e., $c_i = 0$ (i≠j), $c_j \neq 0$) and the estimation results were comparable to those reported in the table.

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Appendix

This appendix contains a more detailed derivation of the results reported in sections II and III.

Policy Anticipations Model

From the term structure relationship equation (5),

$$r_t = (1/n)i_t + (1/n) \sum_{i=1}^{n-1} E(i_{t+i}^T | \Phi_t) \qquad (A.1)$$

since, from (7), $E(i_{t+i} | \Phi_t) = E(i_{t+i}^T | \Phi_t)$. Using the fact that $(1/n) \sum_{i=1}^{n-1} E(i_{t+i}^T | \Phi_t) = E(r_{t+1} | \Phi_t) - (1/n) E(i_{t+n} | \Phi_t)$, equation (A.1) can be manipulated to eliminate the future federal funds rates, yielding

$$r_t = (1/n)i_t + \sum_{j=0}^{\infty} E(r_{t+jn+1} - r_{t+jn+n} | \Phi_t) + ((n-1)/n)E(r_{t+\infty} | \Phi_t) \quad (A.2)$$

where it is assumed that $E(i_{t+\infty}^T | \Phi_t) = E(r_{t+\infty}^T | \Phi_t)$. The target values of r_{t+i} are found by using the money demand equation (3´):

$$r_{t+i}^T(\Omega_t) = \alpha^{-1}\alpha_0' - \alpha^{-1}m_{t+i}^T(\Omega_t) + \alpha^{-1}E(u_{t+i} | \Omega_t); \quad i=0,\ldots \qquad (A.3)$$

Taking expectations of (A.3) and substituting the result into (A.2) implies

$$r_t = (1/n)i_t - \alpha^{-1} \sum_{j=0}^{\infty} E(m_{t+jn+1}^T - m_{t+jn+n}^T | \Phi_t)$$

$$+ \alpha^{-1} \sum_{j=0}^{\infty} E(u_{t+jn+1} - u_{t+jn+n} | \Phi_t)$$

$$+ ((n-1)/n) E(r_{t+\infty}^T | \Phi_t). \qquad (A.4)$$

Equation (A.4) can be used to determine the interest rate response to the announcement:

$$r_t^a - r_t^b = -\alpha^{-1} \sum_{j=0}^{\infty} \{ E(m_{t+jn+1}^T | \Phi_t^a) - E(m_{t+jn+1}^T | \Phi_t^b)$$

$$- E(m_{t+jn+n}^T | \Phi_t^a) + E(m_{t+jn+n}^T | \Phi_t^b) \}$$

$$+ \alpha^{-1} \sum_{j=0}^{\infty} \{E(u_{t+jn+1}|\phi_t^a) - E(u_{t+jn+1}|\phi_t^b)$$

$$- E(u_{t+jn+n}|\phi_t^a) + E(u_{t+jn+n}|\phi_t^b)\}$$

$$+ \frac{n-1}{n} \alpha^{-1} [E(m_{t+\infty}^T|\phi_t^a) - E(m_{t+\infty}^T|\phi_t^b)] \tag{A.5}$$

To evaluate each of these terms, note that equation (2) implies, since $\phi_t^b = \Omega_{t-1}$ and $\phi_t^a = \Omega_t$,

$$E(m_{t+jn+1}^T|\phi_t^a) - E(m_{t+jn+1}^T|\phi_t^b) = (\delta_1 + (1-\lambda)^{jn+2}(1-\delta_1))\rho\epsilon_{t-2}. \tag{A.6}$$

Also, from (4),

$$E(u_{t+jn+1}|\phi_t^a) - E(u_{t+jn+1}|\phi_t^b) = \rho^{jn+3}u_{t-2} - \rho^{jn+4}u_{t-3} = \rho^{jn+3}\epsilon_{t-2}. \tag{A.7}$$

Using (A.6) and (A.7), equation (A.5) becomes

$$r_t - r_t^b = -\alpha^{-1} \sum_{j=0}^{\infty} \{[\delta_1 + (1-\lambda)^{jn+2}(1-\delta_1)] - [\delta_1 + (1-\lambda)^{jn+n+1}(1-\delta_1)]\}\rho\epsilon_{t-2}$$

$$+ \alpha^{-1} \sum_{j=0}^{\infty} [\rho^{jn+3} - \rho^{jn+n+2}]\epsilon_{t-2} - \frac{n-1}{n}\alpha^{-1}\delta_1\rho\epsilon_{t-2}$$

$$= \alpha^{-1}\left[\frac{\rho(1-\lambda)^2(1-\delta_1)[(1-\lambda)^{n-1} - 1]}{1 - (1-\lambda)^n} + \frac{(1-\rho^{n-1})}{1-\rho^n}\rho^3 - \frac{(n-1)\delta_1\rho}{n}\right]\epsilon_{t-2}.$$

which is equation (10).

To derive the response for longer term interest rates, equation (11) implies

$$R_t^a - R_t^b = (1/m)(r_t^a - r_t^b) + (1/m)\sum_{k=1}^{m-1}[E(r_{t+kn}|\phi_t^a) - E(r_{t+kn}|\phi_t^b)] \tag{A.8}$$

Using (A.3), since $E(r_{t+kn}|\phi_t) = E(r_{t+kn}^T|\phi_t)$,

$$R_t^a - R_t^b = (1/m)(r_t^a - r_t^b) + (1/m)\sum_{k=1}^{m-1}[-\alpha^{-1}[E(m_{t+kn}^T|\phi_t^a) -$$

$$E(m^T_{t+kn}|\phi^b_t)] + \alpha^{-1}[E(u_{t+kn}|\phi^a_t) - E(u_{t+kn}|\phi^b_t)]. \qquad (A.9)$$

From (A.6) and (A.7), equation (A.9) can be rewritten as

$$R^a_t - R^b_t = (1/m)(r^a_t - r^b_t) + (1/m)\alpha^{-1} \sum_{k=1}^{m-1} [(1-\lambda)^{kn+1}(1-\delta_1) + \rho^{kn+1}]\rho\varepsilon_{t-2}$$

$$+ [(1-m)/m]\,\alpha^{-1}\delta_1\rho\varepsilon_{t-2}.$$

This is equation (12).

For the post-October 1979 operating procedures, i_t does not necessarily remain constant in response to the announcement. From (A.4), this implies that a term, $(1/n)[E(i_t|\phi^a_t) - E(i_t|\phi^b_t)]$ must be added to (A.5). From (15),

$$E(i_t|\phi^a_t) - E(i_t|\phi^b_t) = \beta^{-1}(m_{t-2} - E(m_{t-2}|\phi^b_t)) = \beta^{-1}\varepsilon_{t-2}. \qquad (A.10)$$

adding $(1/n)\beta^{-1}\varepsilon_{t-2}$ to the response coefficient found in (10) yields (17).

Expected Inflation Model

From the Fisher relationship, equation (18),

$$r^a_t - r^b_t = (\gamma/n)[E(p_{t+n}|\phi^a_t) - E(p_{t+n}|\phi^b_t)]. \qquad (A.11)$$

The solution equation for p_t, given by (21), implies that

$$p_{t+n} = \alpha\mu - \alpha_0 + \frac{n}{n+\gamma\alpha}(m_{t+n} - u_{t+n})$$

$$+ \frac{n}{n+\gamma\alpha} \sum_{j=1}^{\infty} (\frac{\gamma\alpha}{n+\gamma\alpha})^j E(m^T_{t+n+jn}|\phi_t)$$

$$- \frac{n}{n+\gamma\alpha} \sum_{j=1}^{\infty} (\frac{\gamma\alpha}{n+\gamma\alpha})^j E(u_{t+n+jn}|\phi_t) \qquad (A.12)$$

Taking expectations of both sides of (A.12) yields

$$E(p_{t+n}|\phi_t) = \alpha\mu - \alpha_0 + \frac{n}{n+\gamma\alpha} \sum_{j=1}^{\infty} (\frac{\gamma\alpha}{n+\gamma\alpha})^{j-1} E(m^T_{t+jn}|\phi_t)$$

$$- (\frac{n}{n+\gamma\alpha}) \sum_{j=1}^{\infty} (\frac{\gamma\alpha}{n+\gamma\alpha})^{j-1} E(u_{t+jn}|\phi_t). \qquad (A.13)$$

From (A.11) and (A.13) it follows that

$$r_t^a - r_t^b = (\gamma/n) \left\{ \frac{n}{n+\gamma\alpha} \sum_{j=1}^{\infty} (\frac{\gamma\alpha}{n+\gamma\alpha})^{j-1} [E(m_{t+jn}^T|\phi_t^a) - E(m_{t+jn}^T|\phi_t^b)] \right.$$

$$\left. - \frac{n}{n+\gamma\alpha} \sum_{j=1}^{\infty} (\frac{\gamma\alpha}{n+\gamma\alpha})^{j-1} [E(u_{t+jn}|\phi_t^a) - E(u_{t+jn}|\phi_t^b)] \right\}. \qquad (A.14)$$

When (2´) is the policy rule,

$$E(m_{t+j}^T|\phi_t^a) - E(m_{t+j}^T|\phi_t^b) = [(j+1)\delta_2 + \delta_1 + (1-\lambda)^{j+1}(1-\delta_1)]\rho\varepsilon_{t-2}. \qquad (A.15)$$

Using (A.15) and (A.7), equation (A.14) can be written as

$$r_t^a - r_t^b = \gamma \left[\frac{(1-\lambda)^{n+1}(1-\delta_1)}{n+\gamma\alpha[1-(1-\lambda)^n]} - \frac{\rho^{n+1}}{n+\gamma\alpha(1-\rho^n)} + \frac{n+\gamma\alpha}{n}\delta_2 \right.$$

$$\left. + \frac{1}{n}(\delta_1 + \delta_2) \right] \rho\varepsilon_{t-2}.$$

This is equation (22).

To find the response of long-term interest rates, start with equation
(A.8). From the Fisher equation,

$$E(r_{t+kn}|\phi_t^a) - E(r_{t+kn}|\phi_t^b) = (\gamma/n)[E(p_{t+kn+n}|\phi_t^a) - E(p_{t+kn+n}|\phi_t^b)]. \qquad (A.16)$$

Using (A.13), (A.15), and (A.7), equation (A.8) under the inflation expectations
model yields equation (23):

$$R_t^a - R_t^b = (1/m)(r_t^a - r_t^b) + \gamma \left[\frac{m-1}{m}\delta_2 \right.$$

$$+ (1/m) \frac{(1-\lambda)^{n+1}(1-\delta_1)[1-(1-\lambda)^{-n}]}{n+\gamma\alpha[1-(1-\lambda)^n]} \sum_{i=1}^{m-1} (1-\lambda)^{in}$$

$$\left. - (1/m) \frac{\rho(\rho^n-1)}{n+\gamma\alpha(1-\rho^n)} \sum_{i=1}^{m-1} \rho^{in} \right] \rho\varepsilon_{t-2}.$$