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Reserves Announcements and Interest Rates: Does Monetary Policy Matter?

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ABSTRACT

The author provides evidence on the perceived existence of strong liquidity effect. The analysis is based on the response of the term structure of interest rates to the weekly Federal Reserve announcements of bank reserves during the post-October 1979 period. It is shown that unanticipated changes in the mix between borrowed and nonborrowed reserves *cause* expected real interest rates to change after the announcement because they provide information about a future change in the *supply* of money. A precise model is developed and tested during subperiods of nonborrowed and borrowed reserves targeting by the Fed.

THE TRADITIONAL TEXTBOOK ASSUMPTION that expansions (contractions) of the money supply decrease (increase) real interest rates in the short run has recently been challenged in the economics literature. Fama and Gibbons [5] claim that variations in the real rate of interest during the post-World War II period are not due to the textbook liquidity effect but are due to shifts of resources between consumption and investment. Mishkin [16], in a careful study, fails to find a negative correlation between nominal interest rates and unanticipated money. Other macroeconomists, such as Sims [20] and Litterman and Weiss [14], have provided similar evidence that money may not play a significant role in the propagation of business cycles since World War II.

In contrast to the above literature, macroeconomists who have studied the market reaction to the weekly announcements of M1 have argued that exogenous changes in the money supply are perceived by markets to have a strong effect on short-term real interest rates. Whenever the stock of money (M1) is announced larger (smaller) than markets anticipate, there is an immediate increase (decrease) in domestic interest rates. Two major hypotheses were proposed to explain this reaction. The first hypothesis claims that the reaction is due to an expected change in the real rate of interest. When last week's level of M1 is announced larger than previously anticipated, part of the increase is presumed to last.

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Therefore, if markets believe that the Fed will keep M1 within its annual target band, then they expect the Fed to counteract the increase by withdrawing reserves in the future. The anticipation of a future restriction in liquidity increases expected future real interest rates and drives nominal interest rates up immediately after the announcement. The second hypothesis claims that the reaction is due to an expected change in the rate of inflation. Markets distrust the Fed's preannounced M1 targets, and, when they observe a higher than expected level of M1, they believe the Fed is altering the growth rate of M1; thus, markets revise their expectations of future inflation upward. Previous authors have attempted to distinguish between the two hypotheses by utilizing the simultaneous price reactions of other financial instruments, such as foreign currencies or daily traded commodities. They found that the dollar appreciates and commodity prices decrease when interest rates increase, which is evidence that supports the hypothesis that the real rate of interest is expected to increase.[1]

The money announcements literature has shown that the real component of short-term interest rates is expected to change in the future, but it has not shown that the expected change in real interest rates is necessarily due to an expected discrepancy between the supply and demand for money, i.e., that it originates in the monetary sector. It is possible to observe the same market reactions in an economy with dichotomized monetary and real sectors. As Cornell [2] notes, the money surprise may simply provide information about an unobservable variable of the real sector of the economy that is itself responsible for the change in real interest rates.[2]

In contrast to the previous literature on money announcements, this paper is able to provide clear evidence on the crucial question of whether markets perceive that monetary policy can affect real interest rates through open-market operations. Its innovation is in the use of the weekly Federal Reserve announcements of the stock of bank reserves. Announced unanticipated changes in nonborrowed reserves, like announced unanticipated changes in M1, are predetermined causal variables sampled at regular and frequent time intervals. However, *unlike* unanticipated changes in M1 that provide information about both the demand for and

[1] If the real rate of interest is expected to increase in the U.S., investors will move out of foreign securities and domestic or foreign commodities into dollar-denominated securities, such as U.S. Treasury bills or bonds, thus decreasing the price of foreign securities (increasing foreign interest rates), foreign currencies (increasing the value of the dollar), and commodities. If, however, the expected inflation increases, then the opposite reactions take place. Evidence on exchange rates is provided by Cornell [1], Engel and Frankel [3], and Hardouvelis [9], on foreign interest rates by Hardouvelis [9], and on commodity prices by Frankel and Hardouvelis [6]. Roley and Walsh [17] used the reaction of interest rates to the unperceived component of M1 during the week that the change in M1 actually occurred also to claim that the expected future real interest rates increase.

[2] Fama [4] was the first to bring out this point in explaining the relation between stock returns and inflation; see also Geske and Roll [7] and James et al. [11]. King and Tehran [13] analyze a similar problem in the context of money-neutrality tests. In the money-announcements literature, Siegel [19] develops a model consistent with real business-cycle models (see King and Plosser [12]), in which expected future changes in money demand or money supply have no effect on real interest rates. Money is an endogenous variable that merely reflects (is a signal of) past unobserved changes in real economic activity, and its announcement causes a change in the expected future real activity and real interest rates.

the supply of money, announced unanticipated changes in nonborrowed reserves unambiguously reflect unanticipated changes in the *supply* of money caused by discretionary Fed actions. Thus, evidence that real interest rates change after the announcement of nonborrowed reserves is evidence for the existence of an expected liquidity effect.

Section I of the paper contains a formal equilibrium model of the market for bank reserves, which is then used to predict the interest rate responses to the announcement of the various components of bank reserves and the level of M1. The model clarifies why unanticipated changes in nonborrowed or borrowed reserves reflect changes in the supply of money. It assumes that the Fed's operating target is nonborrowed reserves. Section II shows how the interest rate responses may differ under the new post-October 1982 borrowed-reserves operating target. Section III presents the empirical evidence for the pre-October 1982 and the post-October 1982 subperiods, and Section IV contains the main conclusions.

I. A Model of the Market for Bank Reserves

The model is based on the weekly demand for and supply of bank reserves and their evolution over time. During our sample period (May 1980 through January 1984), every Friday afternoon, the Federal Reserve announced the level of the monetary base with its components (currency, borrowed reserves, nonborrowed reserves, etc.) for the fiscal week that ended on Wednesday, two days earlier, and the level of M1 with its components for the fiscal week that ended on Wednesday, nine days earlier. Thus, information about each component of the monetary base is new information, while information about M1 is about the monetary base multiplier. During our sample period, lagged reserve accounting was also in effect. As we see later, this implies that market participants had a fairly accurate estimate of the announced level of total reserves.

The key insight of the model is that markets react to the unanticipated *mix* between the supply of borrowed and nonborrowed reserves. The direction of the reaction is a function of the relative persistence of the unanticipated changes in borrowed and nonborrowed reserves. This key insight is illustrated in Figure 1 (Subsection D). Subsections A, B, and C present the model in detail.

A. Description

The problem is modeled in discrete time. Because of lagged-reserve accounting, the demand for total reserves, TR_t^d, depends on the level of deposits two weeks earlier:

$$TR_t^d = kM_{t-2} + e_{tr,t}, \tag{1}$$

where M_{t-2} refers to the level of M1 of fiscal week $t-2$, and $e_{tr,t}$ is a random-error term. Without any loss of generality, we use M1 instead of demand deposits to simplify the algebra.

The public's demand for money balances is expressed as follows:

$$M_t^d = -a_1 E_t i_{t+2} + a_t; \quad a_1 > 0, \tag{2}$$

$$a_t = a_{t-1} + u_t; \quad u_t \sim N(0, \sigma_u^2), \tag{3}$$

where E_t denotes the expectation operator conditional on information available at t, and i_{t+2} is the one-week spot nominal interest rate of week $t + 2$.[3]

The supply of total reserves consists of two components, borrowed, BR_t^s, plus nonborrowed, NBR_t^s. The supply of borrowed reserves increases when the current interest rate, i_t, increases because the individual bank profitability of borrowing from the Fed increases;[4] however, the supply of borrowed reserves decreases when interest rates are expected to increase in the next period because, given the progressive pressure that the Fed imposes on frequent borrowers, banks wish to increase access to the discount window next period when the profitability of borrowing from the Fed is expected to be high.[5] We express BR_t^s as follows:

$$BR_t^s = b_0 + b_1 i_t - b_2 E_t i_{t+1} + e_{br,t}; \quad 0 < b_2 < b_1, \tag{4}$$

$$e_{br,t} = q_b e_{br,t-1} + w_t; \quad w_t \sim N(0, \sigma_w^2); \quad 0 \leq q_b \leq 1. \tag{5}$$

The parameters b_1 and b_2 may change when the process generating the evolution of interest rates changes. For example, if changes in i_t are perceived as transitory, then b_1/b_2 is higher than if changes in i_t were perceived as permanent. When changes in i_t are transitory, a current increase in i_t is not expected to affect future profitability and future desired borrowing very much because it will not last. Thus, banks will react strongly and take advantage of the high profitability of current borrowing, knowing that the added implicit cost to future borrowing is relatively small.[6] The constant term, b_0, and the error term, $e_{br,t}$, reflect the amount of reserves that the Fed provides at the discount window at no added implicit cost to the discount rate. Thus, an increase in $e_{br,t}$ implies less "reserve pressure," and vice versa. The parameter q_b reflects the degree of persistence of changes in reserve pressure.[7]

The supply of nonborrowed reserves consists of three components. The first component reflects the use of nonborrowed reserves to counteract past deviations of M1 from its annual targets. The second component, $e_{tr,t}$, reflects the Fed's defensive open-market operations. The third component, $e_{nr,t}$, reflects the Fed's

[3] The demand for money is assumed to depend on $i_t(3)$, the interest rate of a security that matures in three weeks. Under the expectations hypothesis of the term structure of interest rates, $i_t(3) = (1/3)[i_t + E_t i_{t+1} + E_t i_{t+2}]$. In order to simplify the solution of the model, the terms i_t and $E_t i_{t+1}$ were dropped from equation (2). This does not affect our qualitative conclusions because the model is primarily driven by the demand and supply of reserves.

[4] Individual bank profitability depends on the spread between i_t and the Fed discount rate. The Fed discount rate is set to zero in the model because it does not change during the time interval of the weekly announcements of reserves and M1.

[5] Carl Walsh [23] uses a similar borrowing function, but, in his model, i_t is exogenous to the reserves market.

[6] Goodfriend [8] has developed a model of bank borrowing with progressive Fed pressure based on the individual bank's optimization problem, which emphasizes the differences between permanent and transitory changes in interest rates. Equation (4) above can be compared with Goodfriend's equation (8). Note that the condition $b_2 < b_1$ is a sufficient condition for the stability of the rational-expectations solution. (As can be seen later, the necessary condition is $b_2 < b_1 + (k+c_1)a_1$.)

[7] A more complicated way to model reserve pressure is to make the parameters b_1 and b_2 random as well. In Figure 1 (Subsection D), b_0 is set to zero, and reserve pressure is reflected in b_1, a random slope coefficient.

discretionary use of nonborrowed reserves to alter the future supply of money.[8] It can be interpreted as the Fed's attempt to change the intermediate targets.

$$NBR_t^s = c_0 - c_1(M_{t-1} - M_{t-1}^T) + e_{tr,t} + e_{nr,t}; \quad c_1 \geq 0, \tag{6}$$

$$e_{nr,t} = q_r e_{nr,t-1} + v_t; \quad v_t \sim N(0, \sigma_v^2); \quad 0 < q_r \leq 1, \tag{7}$$

where M^T denotes the Fed's preannounced annual target.

Finally, it is assumed that the reserves market clears:

$$TR_t^d = BR_t^s + NBR_t^s. \tag{8}$$

B. Solution

From equations (1), (2), (4), (6), and (8), we get

$$b_1 i_t + ka_1 E_{t-2} i_t - b_2 E_t i_{t+1} + c_1 a_1 E_{t-1} i_{t+1} = X_t, \tag{9}$$

$$X_t \equiv [-b_0 - c_0 - c_1 M_{t-1}^T] + ka_{t-2} + c_1 a_{t-1} - e_{br,t} - e_{nr,t}. \tag{10}$$

Moving forward n periods, taking expectations conditional on information available at t, and solving the first-order difference equation give

$$E_t i_{t+n} = (b_1 + ka_1)^{-1} [\textstyle\sum_{j=0}^{\infty} ((b_2 - c_1 a_1)/(b_1 + ka_1))^j E_t X_{t+n+j}]; \quad n > 1. \tag{11a}$$

The solutions for $E_t i_{t+1}$ and i_t are as follows:

$$E_t i_{t+1} = (1/b_1)[-ka_1 E_{t-1} i_{t+1} + (b_2 - c_1 a_1) E_t i_{t+2} + E_t X_{t+1}] \tag{11b}$$

$$i_t = (1/b_1)[-ka_1 E_{t-2} i_t - c_1 a_1 E_{t-1} i_{t+1} + b_2 E_t i_{t+1} + X_t]. \tag{11c}$$

Equations (10) through (11c) show that an expected increase in the discretionary component of nonborrowed reserves, $e_{nr,t+n+j}$, or an expected decrease in discount-window reserve pressure (an increase in $e_{br,t+n+j}$) decreases real interest rates.[9] Furthermore, an expected increase in money demand, a_{t+n+j}, increases real interest rates. These results hold even when the demand for money is completely insensitive to interest rates, i.e., when the parameter a_1 is set to zero.

C. Interest Rate Responses to Weekly Announcements

The announcement takes place during week t and refers to M_{t-2}, BR_{t-1}, and NBR_{t-1}, as well as all other components of the monetary base of week $t - 1$. Before the announcement, market participants know M_{t-j} for $j > 2$, NBR_{t-j} and BR_{t-j} for $j > 1$, and M_{t-j}^T for $j > 0$, as well as present and past interest rates. We also assume that they know the component $e_{tr,t-1}$, which implies that there is no surprise about TR_{t-1}. The announcement causes interest rates to change because market participants alter their expectations of some series contained in X_{t+j}.

[8] The Fed may employ a reserves reaction function to economic or political variables that is more complicated than equation (6), but, as long as the additional variables to which it responds are in the information set of market participants, the surprise about nonborrowed reserves, v, represents a *discretionary* Fed action.

[9] We assume that $b_2 > c_1 a_1$. Thus, $E_t i_{t+n}$ is positively related to $E_t X_{t+n+j}$.

Let D denote the difference operator at the instant of the announcement. From equations (3), (5), (7), and (10), we get:

$$DE_tX_{t+n+j} = -q_r^{n+j+1}DE_tv_{t-1} - q_b^{n+j+1}DE_tw_{t-1} + (k + c_1)DE_tu_{t-2}. \quad (12)$$

Next, lagging equation (9) one period, we observe that market participants know the linear combination:

$$v_{t-1} - c_1u_{t-2} + w_{t-1}.$$

Therefore,

$$DE_tw_{t-1} = -[DE_tv_{t-1} - c_1DE_tu_{t-2}]. \quad (13)$$

The item in the brackets is the surprise about nonborrowed reserves. It consists of two components: the surprise about a discretionary change in Fed policy, plus a surprise that is related to the counteraction of the deviation of M1 from its annual targets during week $t - 2$. The equation also shows that the surprise about borrowed reserves equals the negative of the surprise about nonborrowed reserves. This is depicted later in Figure 1.

Combining equations (12) and (13), we get:

$$DE_tX_{t+n+j} = -[q_r^{n+j+1} - q_b^{n+j+1}]DE_tv_{t-1} + [k + c_1(1 - q_b^{n+j+1})]DE_tu_{t-2}. \quad (14)$$

From equation (14), together with (11a,b,c), it is clear that an unanticipated increase in the discretionary component of nonborrowed reserves will have a negative impact on interest rates if $q_r > q_b$, that is, if the discretionary change in nonborrowed reserves is more persistent than the change in reserve pressure at the discount window. From equation (14), together with (11a,b,c), it is also clear that an unanticipated increase in M1 increases real interest rates.[10]

Finally, the reduced-form reaction coefficients of interest rates to the surprise about the discretionary component of nonborrowed reserves, DE_tv_{t-1}, and the surprise about M1, DE_tu_{t-2}, can be explicitly derived from equations (11a,b,c) and (14) as follows:

$$DE_ti_{t+n} = -d_{1n}DE_tv_{t-1} + d_{2n}DE_tu_{t-2}; \quad n > 1, \quad (15a)$$

$$d_{1n} \equiv [b_1 + ka_1 - q_r(b_2 - c_1a_1)]^{-1}q_r^{n+1} - [b_1 + ka_1 - q_b(b_2 - c_1a_1)]^{-1}q_b^{n+1},$$

$$d_{2n} \equiv (b_1 + ka_1 - b_2 + c_1a_1)^{-1}(k + c_1) - [b_1 + ka_1 - q_b(b_2 - c_1a_1)]^{-1}c_1q_b^{n+1}.$$

Similarly, for E_ti_{t+1} and i_t, we get

$$DE_ti_{t+1} = -(1/b_1)[(b_2 - c_1a_1)d_{12} + (q_r^2 - q_b^2)]DE_tv_{t-1}$$
$$+ (1/b_1)[(b_2 - c_1a_1)d_{22} + k + c_1 - c_1q_b^2]DE_tu_{t-2}, \quad (15b)$$

$$Di_t = (b_2/b_1)DE_ti_{t+1}. \quad (15c)$$

Observe that, as n increases, the reaction to the nonborrowed reserves surprise weakens, and, when $n \to \infty$, $d_{1n} \to 0$; i.e., expected future interest rates do not change at all. The expected liquidity effect disappears because the autoregressive

[10] Recall that c_1 is assumed positive, i.e., that the Fed does not ratify deviations from its targets; instead, it counteracts them. In Section III, we find that $c_1 \geq 0$.

parameter q_r (and q_b) was assumed less than unity. In contrast, the expected liquidity effect stemming from the announcement of M_{t-2} does not disappear when $n \rightarrow \infty$ ($d_{2n} > 0$) because the error term in the money-demand equation was assumed to be a random walk.

D. An Example

Figure 1 illustrates the main insight of the model by an example in which an unanticipated and permanent increase in nonborrowed reserves occurs together with an unanticipated but temporary increase in reserve pressure at the discount window. The demand for total reserves is represented by the vertical line TR^d, which is known because of lagged reserve accounting. The actual supply of reserves is the line $CC'X$. The CC' segment represents the supply of nonborrowed reserves, and the $C'X$ segment represents the supply of borrowed reserves, plotted as an increasing function of the spread between the federal funds rate and the discount rate, i_d. Market participants believe that the supply of reserves is the line $BB'Y$ and are unaware of the change in the composition of total reserves because both $BB'Y$ and $CC'X$ intersect TR^d at the observed i_1. The announcement reveals the shift from $BB'Y$ to $CC'X$ and alters the market expectations about the future supply of reserves to the new line $CC'Z$. That is, market participants interpret the increase in nonborrowed reserves as permanent but the increase in reserve pressure (the increase in the slope of the borrowing

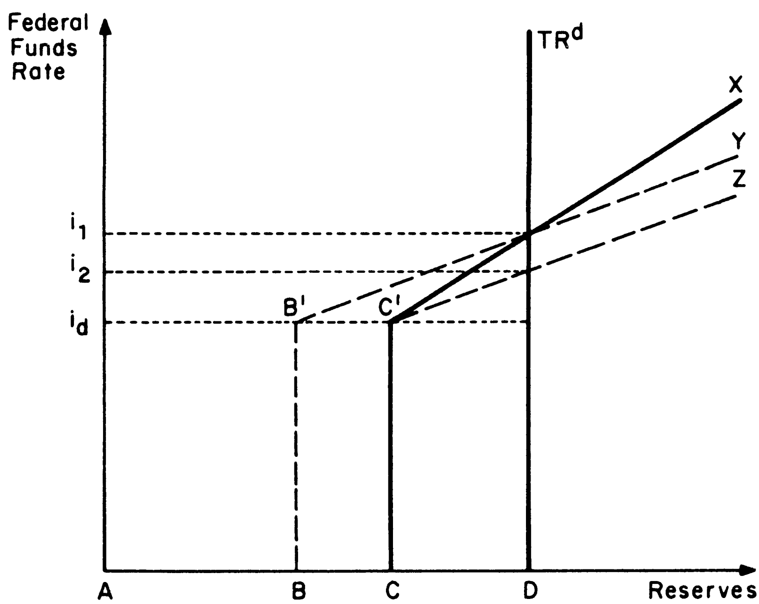

Figure 1. Interest rate response to weekly announcements of bank reserves. i_d = discount rate; $TR^d \equiv$ demand for total reserves, known before the announcement; $CC'X \equiv$ supply of total reserves; $BB'Y \equiv$ expected supply of total reserves before the announcement; $CC'Z \equiv$ expected supply of total reserves after the announcement; AC = actual nonborrowed reserves; CD = actual borrowed reserves; BC = positive (negative) surprise about nonborrowed (borrowed) reserves.

function) as a temporary control error that will be corrected. They anticipate a future drop in the federal funds rate of i_2 and will, therefore, drive interest rates down. Clearly, the exogenous causal variable is expected future Fed behavior.

II. Responses under Nonborrowed- and Borrowed-Reserves Targets

The model will be tested by estimating equations (15a,b,c). However, the sample period will be partitioned into two subperiods, pre- and post-October 1982, because we have reason to suspect structural instability. From October 1979 until October 1982, nonborrowed reserves were both the interweek operating target for monetary policy and the daily (intraweek) instrument of monetary control; however, after October 1982, borrowed reserves became the interweek target, and nonborrowed reserves remained only as the daily instrument of monetary control. The switch to borrowed-reserves targets may have had a major effect on the persistence of discretionary changes in nonborrowed and borrowed reserves (the parameters q_r and q_b) and, thus, on the interest rate responses to weekly reserves announcements.

The October 1982 change in operating procedures affected primarily the way in which independent shifts in money demand (and thus total reserves) are accommodated. In the pre-October 1982 period, independent shifts in the demand for total reserves affected the level of borrowed reserves in the same direction but left nonborrowed reserves intact. Given the increasing penalty of borrowing larger amounts at the discount window, the federal funds rate adjusted in a direction that opposed the initial shift in the demand for total reserves and money. Occasionally, to speed up the process of bringing M1 back on path, nonborrowed reserves would also change in the opposite direction (as it is assumed in the model). In the post-October 1982 period, independent shifts in the demand for total reserves affect nonborrowed reserves in the same direction but leave borrowed reserves intact. Thus, interest rates do not have to change as much as in the first period to clear the reserves market.

Although independent shifts in money demand, u_{t-3}, which affect the demand for total reserves, TR^d_{t-1}, have different effects under the two operating procedures, they are part of the public's information set at time t of the announcement and thus do not affect the market responses. However, the change in operating procedures may have affected the market responses in other ways. An unanticipated change in the discretionary component of nonborrowed reserves, v_{t-1}, is likely to be interpreted as an intentional change under a nonborrowed-reserves target but as a random control error under a borrowed-reserves target. Thus, we would expect the parameter q_r to decline after October 1982. Conversely, a change in the reserve pressure at the discount window is likely to be interpreted as a random control error under a nonborrowed-reserves target but as an intentional policy change under a borrowed-reserves target. Thus, we would expect the parameter q_b to increase after October 1982. The difference between q_r and q_b is likely to decrease to zero and may even become negative. Thus, we predict that, after October 1982, the interest rate responses to the announcements of bank reserves will be weak and may even change sign.

The change in operating procedures may have been accompanied by other changes. We mentioned that the new procedures are likely to decrease the volatility of the federal funds rate. An examination of average weekly data on the federal funds rate shows that its autocovariance structure changed. From October 1979 to October 1982, we obtained the following results:

$$DFF_t = \underset{(.06)}{-.01} + \underset{(.08)}{.21}\, DFF_{t-1}; \; \bar{R}^2 = .036, \; D\text{-}W = 2.04, \; SEE = .81,$$

where DFF is the first difference of the weekly average federal funds rate, $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom, $D\text{-}W$ is the Durbin-Watson statistic, SEE is the regression standard error, and standard errors are inside parentheses. From October 1982 to early February 1984, the same regression equation is as follows:

$$DFF_t = \underset{(.04)}{-.01} - \underset{(.10)}{.44}\, DFF_{t-1}; \; \bar{R}^2 = .202, \; D\text{-}W = 2.29, \; SEE = .36.$$

After October 1982, both the volatility of the federal funds rate (as evidenced from the drop in SEE) and the persistence of weekly changes in the federal funds rate declined. This may affect some of the parameters, which are treated as structural in the model. First, Walsh [22] argues that a drop in the conditional variance of interest rates increases the interest sensitivity of money demand, a_1. Equations (11a,b,c) show that an increase in a_1 implies weaker interest rate responses to both announcements. Second, in Section I, Subsection A, we argued that a decline in the autocorrelation of interest rates increases the parameter b_1 relative to b_2. Equations (11a,b,c) show that an increase in b_1 or a decrease in b_2 decreases the response of interest rates to both announcements. Thus, we further predict that, after October 1982, the change in the autocovariance function of the federal funds rate may have contributed to a decline in the magnitude of the short-term interest rate responses to both announcements.

III. Empirical Evidence

A. Data

The sample begins on May 2, 1980,[11] and ends on January 30, 1984, at the end of the period of lagged reserve accounting. There are 196 sample observations, but sixteen of them were deleted because, in these instances, the announcement of M1 was made at a later day than the announcement of bank reserves.

Our data on interest rates were provided by Data Resources Incorporated. They are annualized yields to maturity expressed in percentages. Forward interest rates for Treasury notes and bonds are constructed using Shiller's [18] linear-approximation method. The point of linearization was chosen to be the average

[11] This is the first date for which we have survey data on bank reserves. Extending the sample back to October 1979 by constructing a measure of expectations about nonborrowed reserves based on an autoregressive model does not alter the results.

annual yield to maturity of a twenty-year Treasury bond, which was 12.3 percent during the sample period. The dependent variables in the regressions represent changes in interest rates from the afternoon of the day of the announcement, before the announcement occurs, to the afternoon of the next trading day. The announcements were made regularly at approximately 4:15 P.M. Eastern Time.[12]

Our two main independent variables are constructed using survey data on market expectations. Every Tuesday morning of fiscal week $t-1$, Money Market Services of San Francisco surveys approximately forty-five Fed watchers about the change in the seasonally adjusted M1 during fiscal week $t-2$, DM_{t-2}, and the seasonally unadjusted level (a seasonally adjusted level is never announced) of net borrowed reserves (borrowed minus excess reserves) of fiscal week $t-1$, $NETBR_{t-1}$, both of which will be announced three days later, on Friday of fiscal week t. The reported survey medians, although not necessarily efficient or unbiased, outperform forecasts based on simple econometric models. (See Hardouvelis [10].) Our definitions of the unanticipated components of nonborrowed reserves and M1 are as follows:

$$UNBR = -[NETBR_{t-1} - \text{Forecast}(NETBR_{t-1})],$$

$$UMY = [M_{t-2} - M_{t-3} - \text{Forecast}(DM_{t-2})].$$

Both variables are expressed in billions of dollars. Consistent with the survey data, *UNBR* refers to seasonally unadjusted data, while *UMY* refers to seasonally adjusted data.[13]

B. Regression Equations

Our aim is to estimate the reduced-form parameters of equations (15a,b,c), d_{1n} and d_{2n}, i.e., the responses to the unanticipated *discretionary* component of nonborrowed reserves, $DE_t v_{t-1}$, and the unanticipated component of M1, $DE_t u_{t-2}$. Notice that *UMY* is a direct empirical proxy for the unanticipated component of M1. However, *UNBR* is not a direct empirical proxy of the unanticipated *discretionary* component of nonborrowed reserves. *UNBR* is a proxy for the unanticipated component of total nonborrowed reserves, which consists of two parts: the discretionary part, $DE_t v_{t-1}$, and the part that reflects the monetary authority's automatic counteraction of past levels of M1 from their

[12] The federal funds rate is a weighted average of rates that prevail throughout the trading day until 3:30 P.M. Eastern Time, and its original source is the quotation sheets of the Federal Reserve Bank of New York. The original source for the remaining interest rates is Bank of America. These data represent market quotes at approximately 3:30 P.M. Eastern Time.

[13] M_{t-3} refers to the first announced (at $t-1$) level of M1 of week $t-3$, not the revised level of M1 of week $t-3$, which is announced at t, because the latter is not part of market participants' information set prior to the announcement at t. An alternative formulation of the independent variables would be to express both surprises in percentage form, but the results are qualitatively the same. We also assume that the unanticipated component of excess reserves is zero; thus, the surprise about borrowed reserves equals the surprise about net borrowed reserves, and $UNBR = -DE_t w_{t-1}$. The assumption is reasonable because the results remain the same when, instead of the unanticipated component of net borrowed reserves, we use a proxy for the unanticipated component of borrowed reserves based on an autoregressive model.

target, $-c_1 DE_t u_{t-2}$. This was shown earlier in equation (13), which can be rewritten as follows:

$$UNBR = DE_t v_{t-1} - c_1 UMY. \tag{13'}$$

According to the model, *UNBR* and *UMY* are rational forecast errors but contemporaneously correlated. This is because, during $t - 1$, the Fed changes the level of nonborrowed reserves based on information about M_{t-2} that is not yet available to financial-market participants. Thus, a surprise about M_{t-2} contributes to the surprise about total nonborrowed reserves. Therefore, in an OLS regression with *UNBR* as the only explanatory variable, the estimated coefficient would be a biased estimate of d_{1n}. In order to get an unbiased estimate of d_{1n}, it is necessary always to include in the regression the variable *UMY*. However, in a regression equation of the form

$$DE_t i_{t+n} = h_{0n} + h_{1n} UNBR + h_{2n} UMY + e_{tn},$$

the estimated coefficient h_{2n} is an unbiased estimate of $d_{2n} - c_1 d_{1n}$ instead of d_{2n}. If we wish also to get an unbiased estimate of d_{2n}, we have to regress $DE_t i_{t+n}$ on *UMY* alone. Alternatively, we may perform the following regression:

$$DE_t i_{t+n} = l_{0n} + l_{1n} UUNBR + l_{2n} UMY + e_{tn}, \tag{16}$$

where *UUNBR* is the series of residuals from a regression of *UNBR* on *UMY*, l_{1n} is an unbiased estimate of d_{1n} (and is equal to h_{1n}), and l_{2n} is an unbiased estimate of d_{2n}. Tables I and II present the results of regression equation (16).

Equation (13′) can be utilized to find an estimate of c_1, the parameter that describes how nonborrowed reserves respond to last week's deviation of M1 from its target. In the period May 1980 through October 1982, c_1 is estimated to be 0.0376, with a standard deviation of 0.0146 (i.e., it is significantly larger than zero); in the period October 1982 through January 1984, c_1 is estimated to be 0.0064, with a standard deviation of 0.0175 (i.e., it is not significantly different from zero). These results are consistent with the assumption of the model that $c_1 \geq 0$.[14]

C. Results

Table I presents the results for the first subperiod until October 1982, and Table II presents the results for the second subperiod after October 1982, as well as tests of parameter stability across the two subperiods. Table I shows that there is a negative reaction of short-term interest rates to the unanticipated component of nonborrowed reserves, which is significantly different from zero. For example, a one billion unanticipated increase in the discretionary component of nonborrowed reserves decreases the three-month forward rate three months ahead, $f(3,3)$, by thirty-one basis points. Long-run forward interest rates also react negatively to the unanticipated component of nonborrowed reserves, but

[14] The drop in the magnitude of c_1 after October 1982 may be an outcome of the abandonment of nonborrowed reserves as the operating target.

Table I

Interest Rate Responses to the Announcement of Nonborrowed Reserves and M1[a]

	Independent Variable					
Dependent Variable	Constant	*UUNBR*	*UMY*	$\bar{R}^2$	*D-W*	*SEE*
Federal Funds	−.016	−.339*	.087*	.129	2.96	.594
	(.055)	(.147)	(.023)			
One-Month T-Bill	.100*	−.061	.049*	.050	1.89	.446
	(.041)	(.110)	(.017)			
f(1,1)	.019	−.314*	.093*	.136	1.85	.594
	(.056)	(.147)	(.024)			
f(2,1)	−.010	−.511*	.092*	.100	2.09	.806
	(.076)	(.200)	(.032)			
f(3,3)	.062	−.308*	.079*	.206	2.32	.414
	(.039)	(.103)	(.017)			
f(6,6)	−.012	−.206*	.060*	.217	2.10	.297
	(.028)	(.074)	(.012)			
f(12,12)	−.001	−.190*	.062*	.143	1.95	.379
	(.035)	(.094)	(.015)			
f(24,12)	.004	.061	.032*	.025	2.13	.382
	(.036)	(.095)	(.015)			
f(36,12)	.052	−.266*	.022	.034	1.91	.492
	(.046)	(.122)	(.020)			
f(48,12)	.035	−.182	.040*	.036	1.75	.500
	(.047)	(.124)	(.020)			
f(60,24)	−.010	−.102	−.013	.016	1.57	.270
	(.025)	(.067)	(.011)			
f(84,36)	.070	−.061	.003	−.009	2.06	.267
	(.025)	(.066)	(.010)			
f(120,120)	.030	−.159*	−.009	.031	1.76	.285
	(.026)	(.070)	(.011)			
f(240,120)	−.080	−.093	.029	−.007	1.52	.759
	(.071)	(.188)	(.029)			

[a] Sample consists of weekly data from May 2, 1980, through October 6, 1982. Standard errors are in parentheses. *UUNBR* is the unanticipated discretionary change of nonborrowed reserves in billions, and *UMY* is the unanticipated change of M1 in billions. There are 119 (128 minus nine omitted) observations. *D-W* is the Durbin-Watson statistic adjusted for six gaps. (Some of the omitted observations are consecutive.) $\bar{R}^2$ is the coefficient of determination adjusted for degrees of freedom. *SEE* is the regression standard error. Interest rates are changes in annualized yields to maturity expressed in percentages from 3:30 P.M. of the day of the announcement to 3:30 P.M. of the next trading day. A regression coefficient of −.339 denotes a drop of thirty-four basis points. *f*(n,m) denotes the *m*-month forward rate n months ahead.

* Statistically significant at the 95% level in a two-tailed test.

their statistical significance is marginal. (However, the reaction of the ten-year rate ten years ahead, *f*(120,120), is surprisingly strong.) Table II shows that, after October 1982, the reactions to reserves announcements become insignificantly different from zero (and significantly different from the pre-October 1982

Table II

Interest Rate Responses to the Announcement of Nonborrowed Reserves and M1[a]

Dependent Variable	Independent Variable					$\bar{R}^2$	*D-W*	*SEE*
	Constant	*UUNBR*	(H_0)	*UMY*	(H_1)			
Federal Funds	.073*	.004		.014		−.021	1.97	.236
	(.031)	(.117)	1.83	(.016)	−2.64*			
One-Month T-Bill	.029	−.086		.032*		.161	1.98	.140
	(.018)	(.069)	−0.20	(.009)	−0.86			
f(1,1)	−.023	.046		.020		.000	2.27	.212
	(.027)	(.105)	1.99*	(.014)	−2.67*			
f(2,1)	−.022	.004		.053*		.197	2.14	.196
	(.025)	(.097)	2.33*	(.013)	−1.14			
f(3,3)	.008	.006		.053*		.300	2.47	.154
	(.020)	(.076)	2.46*	(.010)	−1.32			
f(6,6)	−.022	−.076		.041*		.271	2.39	.131
	(.017)	(.065)	1.33	(.009)	−1.28			
f(12,12)	.017	.035		.033*		.174	2.54	.132
	(.017)	(.065)	1.97*	(.009)	−1.68			
f(24,12)	−.040	−.064		.033*		.033	1.52	.252
	(.033)	(.125)	−0.80	(.017)	0.03			
f(36,12)	.005	.154		.029		.053	1.20	.233
	(.030)	(.115)	2.50*	(.015)	0.29			
f(48,12)	.009	−.052		.039*		.195	1.65	.147
	(.019)	(.073)	0.90	(.010)	−0.06			
f(60,24)	.021	.051		.019*		.050	2.21	.135
	(.017)	(.067)	1.63	(.009)	2.33*			
f(84,36)	−.005	−.040		.021*		.126	1.60	.102
	(.013)	(.050)	0.25	(.007)	1.47			
f(120,120)	.001	.091		.018*		.071	2.34	.129
	(.017)	(.064)	2.64*	(.009)	1.92			
f(240,120)	−.021	−.106		.028*		.049	1.99	.208
	(.027)	(.103)	−0.06	(.014)	0.03			

[a] Sample consists of weekly data from October 10, 1982, through January 30, 1984. See footnote a of Table I. There are sixty-one (sixty-eight minus seven omitted) observations. H_0 is the null hypothesis that the coefficient of *UUNBR* is the same across the two subperiods, and H_1 is the same null hypothesis for *UMY*; the columns H_0 and H_1 present Wald *t*-statistics, which are calculated using weighted least squares with weights equal to the *SEE* of each subperiod. (Thus, the *t*-tests do not restrict the error variance of the dependent variables to be the same across the subperiods.)

* Statistically significant at the 95% level in a two-tailed test.

reactions; see column H_0). The post-October 1982 drop in the magnitude of the reactions is consistent with our predictions of Section II.[15]

The negative interest rate reaction of the unanticipated component of nonborrowed reserves provides evidence that the real rate of interest is expected to

[15] In the model, we assumed that total reserves are known with certainty because they are a function of lagged known values of M1. To check the sensitivity of our results to this assumption, we added to the regression equations a constructed surprise about total reserves based on an autoregressive model. We also added a similarly constructed surprise of the currency component of the monetary base because it represents additional new information. The inclusion of these two variables does not affect our results.

change.[16] That is, even if the inflation premium changes, we are observing a negative change in the real rate. An unanticipated increase in nonborrowed reserves may increase the inflation premium, which increases interest rates and particularly long-run forward interest rates. However, the observed decrease in nominal interest rates implies that, if the inflation premium increases, then the real rate decreases more than the nominal rate. Furthermore, the expected change in the real rate of interest is due to expected Fed intervention; thus, it represents an expected liquidity effect and shows the perceived effectiveness of monetary policy.[17]

Contrary to the interest rate responses to the announcement of nonborrowed reserves, which provide unambiguous evidence that the real rate is expected to change and, furthermore, that this is due to an expected liquidity effect, the interest rate responses to the announcement of M1 cannot provide similar evidence. Interest rates respond positively, which is what previous authors also have found.[18] However, as we mentioned in the introduction, the positive response could be the result of an increase in the inflation premium or the result of an increase in the real rate that does not originate in the monetary sector. The interest rate responses to the announcement of M1 cannot provide conclusive evidence for the effectiveness of monetary policy.[19]

IV. Conclusion

The paper provides unambiguous positive evidence on the perceived ability of monetary policy to alter real interest rates in the short run. It analyzes the response of the term structure of interest rates to the weekly announcements of bank reserves. During our sample period, lagged reserve accounting was still in effect. This implied that market participants had a fairly accurate estimate of the previous fiscal week's announced level of total reserves. (Required reserves of week $t - 1$ were a function of bank deposits of week $t - 3$, which were known prior to the announcement of week t.) However, the division of total reserves

[16] In subsequent work (Hardouvelis [10]), we found that the dollar depreciates after a positive nonborrowed reserves surprise. This is additional evidence that the real rate of interest drops in the U.S.

[17] One could argue that the observed change in real interest rates is due not to an expected liquidity effect but to a change in the risk premium. We tested and rejected a plausible version of the inflation-risk hypothesis, which predicts a positive correlation when M1 is above targets and a negative correlation when M1 is below targets. According to the inflation-risk hypothesis, when the Fed's actions push M1 further away from its targets, that is, when the supply of reserves expands (contracts) when M1 is above (below) the midpoint of its annual target band, inflation risk increases and real interest rates increase; conversely, when the Fed's actions push M1 closer to its targets, that is, when the supply of reserves expands (contracts) when M1 is below (above) the midpoint of its annual target band, inflation risk decreases and real interest rates decrease.

[18] For example, in addition to the previously cited literature, see Urich and Wachtel [21] or Loeys [15].

[19] Consistent with our predictions of Section II, the reaction of short-term interest rates to the announcement of M1 is weaker after October 1982. Notice, however, that the reaction of long-run forward interest rates is slightly stronger. This is perhaps due to a stronger expected inflation effect, which originates from shocks to the monetary base multiplier and was left out of the model.

between borrowed and nonborrowed reserves was unknown to market participants. An underestimate of nonborrowed reserves, say, due to the New York Desk's unanticipated attempt at expanding the level of the money supply, implied an equal overestimate of borrowed reserves, which, at the known levels of the federal funds rate and the discount rate, was due to an unanticipated increase in reserve pressure at the discount window.

We found that, until October 1982, both short- and long-term interest rates would decrease after the announcement of a higher than anticipated level of nonborrowed reserves (or lower than anticipated level of borrowed reserves). Apparently, market participants believed that the unanticipated increase in nonborrowed reserves was more persistent than the unanticipated increase in reserve pressure at the discount window. They would expect a future increase in the supply of reserves and, thus, lower future real interest rates due to the expected liquidity effect. This would drive nominal interest rates down immediately following the announcement. It is possible that the expected increase in reserves increases the inflation premium. However, even if the inflation premium increases, the observed negative reaction of long-run forward interest rates (or the depreciation of the dollar) shows that the *real* rate of interest is expected to decrease.

After October 1982, the reaction to the announcement of nonborrowed and borrowed reserves disappears. In October 1982, the Federal Reserve adopted borrowed reserves as its operating target. Changes in the degree of reserve pressure were explicitly mentioned at the FOMC meetings. Market participants would now interpret the unanticipated change in reserve pressure at the discount window as reflecting a conscious policy change and, therefore, being more persistent than before October 1982. The *relative persistence* between the surprises about borrowed and nonborrowed reserves declined after October 1982, and, similarly, the strength of the market reactions declined.

The unanticipated components of nonborrowed and borrowed reserves reflected surprises about *Fed supply behavior*. Thus, hypotheses that originate in real business-cycle models and attempt to explain a correlation between money and real interest rates outside the sphere of discretionary monetary policy are not potential candidates for the observed interest rate reactions to announced changes in reserves. This is why we can claim that the expected change in the real rate of interest is due to an expected *liquidity* effect.

REFERENCES

1. Bradford Cornell. "Money Supply Announcements, Interest Rates, and Foreign Exchange." *Journal of International Money and Finance* 1 (August 1982), 201–08.
2. ———. "The Money Supply Announcements Puzzle: Review and Interpretation." *American Economic Review* 73 (September 1983), 644–57.
3. Charles Engel and Jeffrey A. Frankel. "Why Interest Rates React to Money Announcements: An Explanation from the Foreign Exchange Market." *Journal of Monetary Economics* 13 (January 1984), 31–39.
4. Eugene F. Fama. "Stock Returns, Real Activity, Inflation, and Money." *American Economic Review* 71 (September 1981), 545–65.
5. ——— and Michael R. Gibbons. "Inflation, Real Returns, and Capital Investment." *Journal of Monetary Economics* 9 (May 1982), 297–324.

6. Jeffrey A. Frankel and Gikas A. Hardouvelis. "Commodity Prices, Money Surprises, and Fed Credibility." *Journal of Money, Credit, and Banking* 17 (November 1985), 425–38.
7. Robert Geske and Richard Roll. "The Fiscal and Monetary Linkage Between Stock Returns and Inflation." *Journal of Finance* 38 (March 1983), 1–34.
8. Marvin Goodfriend. "Discount Window Borrowing, Monetary Policy, and the Post-October 6, 1979 Federal Reserve Operating Procedure." *Journal of Monetary Economics* 12 (September 1983), 343–56.
9. Gikas A. Hardouvelis. "Market Perceptions of Federal Reserve Policy and the Weekly Monetary Announcements." *Journal of Monetary Economics* 14 (September 1984), 225–40.
10. ———. "Economic News, Exchange Rates, and Interest Rates." Forthcoming, *Journal of International Money and Finance.*
11. Christopher James, Sergio Koreisha, and Megan Partch. "A VARMA Analysis of the Causal Relations among Stock Returns, Real Output, and Nominal Interest Rates." *Journal of Finance* 40 (December 1985), 1375–84.
12. Robert G. King and Charles I. Plosser. "Money, Credit, and Prices in a Real Business Cycle." *American Economic Review* 74 (June 1984), 363–80.
13. Robert G. King and Bharat Tehran. "Money: Endogeneity and Neutrality." *Journal of Monetary Economics* 14 (November 1984), 385–93.
14. Robert B. Litterman and Lawrence M. Weiss. "Money, Real Interest Rates, and Output: A Reinterpretation of Postwar U.S. Data." *Econometrica* 53 (January 1985), 129–56.
15. Jan G. Loeys. "Changing Interest Rate Responses to Money Announcements." *Journal of Monetary Economics* 15 (May 1985), 323–32.
16. Frederic S. Mishkin. "Monetary Policy and Short-Term Interest Rates: An Efficient Markets-Rational Expectations Approach." *Journal of Finance* 37 (March 1982), 63–72.
17. V. Vance Roley and Carl E. Walsh. "Unanticipated Money and Interest Rates." *American Economic Review* 74 (May 1984), 49–54.
18. Robert J. Shiller, John Y. Campbell, and Kermit L. Schoenholtz. "Forward Rates and Future Policy: Interpreting the Term Structure of Interest Rates." *Brookings Papers on Economic Activity* 1 (Spring 1983), 173–224.
19. Jeremy J. Siegel. "Money Supply Announcements and Interest Rates: Does Monetary Policy Matter?" *Journal of Monetary Economics* 15 (March 1985), 163–76.
20. Christopher A. Sims. "Comparison of Interwar and Postwar Cycles: Monetarism Reconsidered." *American Economic Review* 70 (May 1980), 250–57.
21. Thomas J. Urich and Paul Wachtel. "Market Responses to the Weekly Money Supply Announcements in the 1970's." *Journal of Finance* 36 (December 1981), 1063–72.
22. Carl E. Walsh. "Interest Rate Volatility and Monetary Policy." *Journal of Money, Credit and Banking* 16 (May 1984), 133–50.
23. ———. "Monetary Information and Interest Rates." Unpublished Working Paper, Princeton University, January 1985.