Money and Interest Rates under a Reserves Operating Target

by Robert B. Avery and Myron L. Kwast

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Introduction

Between October 1979 and mid-summer 1982, the Federal Reserve focused its attention on controlling a narrow monetary aggregate (M1) and relied primarily on nonborrowed reserves as the short-run instrument for achieving its monetary target. This brief but important period provides a unique opportunity to examine the dynamic effects of the short-run monetary supply process.

Although many interesting issues could be examined, we concentrate on two that have received little empirical attention: 1) the speed and dynamic response patterns of both money and short-term interest rates to changes in nonborrowed reserves, and 2) the extent of "feedback" effects between short-run shocks to money and the central bank's provision of nonborrowed reserves.

We provide unique estimates of liquidity effects following changes in the supply of nonborrowed reserves. This work originated over a decade ago in the midst of heated debate about Federal Reserve operating procedures and monetary control. Although the debate has cooled, there is renewed interest in understanding liquidity effects because they are central to the monetary policy transmission mechanism.[1] Using monthly data, Leeper and Gordon (1992) show that evidence about the existence of liquidity effects is ambiguous. They conclude that a successful characterization of such effects requires the identification of private and public behavior. This paper identifies liquidity effects through temporal disaggregation and a structural specification based on the mechanisms of monetary control.

Our approach is to disaggregate the time dimension of the analysis into the shortest period of practical concern for most monetary policy decisions. Thus, our estimation procedures exploit daily data collected by the Federal Reserve. A simplified structural model of the short-run money supply process is developed that, because of the paucity of variables available on a daily basis, is estimated using lagged endogenous variables. We further emphasize the short-run nature of the model by estimating separate statistical models, and therefore separate effects, for each day of the week. Each model includes controls for the Federal Open Market Committee's (FOMC) M1 target growth paths and is estimated in first-difference form. Thus, the models focus only on very short-term

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[1] Bernanke and Blinder (1992) make a persuasive case for the presence of liquidity effects in the U.S. economy. Christiano and Eichenbaum (1992), Christiano (1991), and Coleman, Labadie, and Gilles (1993) build explicit models of liquidity effects.

behavior and abstract from longer-term relationships and policymaking. In essence, we examine the reaction of money and interest rates to deviations of nonborrowed reserves from weekly and longer-term target growth paths. Thus, we control for those factors that are generally the focus of monthly or quarterly models and examine the variability that is averaged out in such analyses.

Statistical tests of the importance of day-by-day effects are performed. We then use the estimation results to simulate the short-run dynamic relationships between nonborrowed reserves, the federal funds rate, and a measure of transaction accounts. These experiments provide insights regarding the short-run money supply process that are not accessible using the more time-aggregated data of previous studies.[2]

I. The Model

On October 6, 1979, the Federal Reserve announced that it was switching its short-run operating target from the federal funds rate to nonborrowed reserves in an effort to better control the money supply. By the latter part of 1982, the Fed had begun to deemphasize M1 as its monetary target, with a resulting decline in the use of nonborrowed reserves as its operating target.[3] During this brief period, however, nonborrowed reserves appear to have been the primary short-term instrument of central bank policy, while the federal funds rate was determined primarily by market factors.[4]

Stevens (1981) characterizes Federal Reserve nonborrowed reserves policy during this period as consisting of five steps. Steps one and two occurred at the FOMC meetings and involved the setting of yearly and short-run (inter-FOMC meeting) paths for M1. In the third step, the staff derived the target growth paths for borrowed and nonborrowed reserves on the basis of the short-run path for M1. Step four was repeated each week. Incoming information about the money multiplier, unexpected changes in the mix of deposits, and unexpected changes in the demands for currency, excess reserves, and borrowed reserves were used to translate the inter-meeting objective for nonborrowed reserves into a target for the reserve maintenance week. "On Friday," Stevens argues, "...objectives ... can be set, reflecting any technical corrections and judgmental adjustments to the inter-meeting reserve objectives ...." Step five translated the weekly objective into a daily program. At this level, changes in nonborrowed reserves were primarily reactive to very short-run changes in the market factors absorbing and supplying reserve funds. These factors included such items as Treasury operations, Federal Reserve float, and unexpected discount window borrowing. Although federal funds rate targeting was not explicitly used, funds rate changes were sometimes read by policymakers as indicators of changes in these underlying factors, which would have prompted daily adjustments in nonborrowed reserves.

We focus on the last two steps, examining how unexpected shocks to money and the federal funds rate influenced weekly and daily reserve operations. We also examine how reserve changes affected money and the funds rate. Open market operations have a direct effect on money via the creation or destruction of bank deposits, while indirect effects may work through the funds rate. The use of daily data allows us to study feedback effects. That is, changes in reserves induce changes in money and the federal funds rate, which may ultimately cause additional changes in reserves because policymakers cannot distinguish them from other money or interest-rate shocks.[5]

The general lack of daily data and the analytical complexity of combining five daily models into an empirically tractable system forces us to restrict our description of the daily money supply process to a straightforward structure.[6] In this spirit, a reasonably accurate—but admittedly simplified—model of the bank reserves

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[2] Other studies have used weekly and often monthly or quarterly data to examine what are frequently very short-run issues. See, for example, Spindt and Tarhan (1983, 1987), Tinsley et al. (1982), Jones (1981), Johannes and Rasche (1981), Feige and McGee (1977), and Gavin and Karamouzis (1985).

[3] See Axilrod (1982, 1985).

[4] Poole (1982) disputes this claim, arguing that the Fed actually used borrowed reserves as its short-run target and that under the lagged reserve requirements in effect at the time, it should have been using free reserves. Notice, however, that since free reserves equal nonborrowed reserves minus required reserves, which are fixed in any given week under lagged reserve requirements, over any weekly period nonborrowed reserves and free-reserves targeting are functionally equivalent. Spindt and Tarhan (1987) present evidence supporting the view that over an inter-FOMC operating horizon, the Federal Reserve, from fall 1979 through fall 1982, followed a nonborrowed reserves operating target. Over shorter (weekly) intervals, however, their results are ambiguous.

[5] Avery (1979) models monetary policy as an endogenous variable. His results suggest that over the 1955–75 period, feedback effects occurred within a month.

[6] A more complex model of short-run money supply over the period studied here is provided in Goodfriend et al. (1986). Other authors, including Judd and Scadding (1982), have suggested linkages between the federal funds rate and money demand, working through interest-rate term structures. Since the current model and subsequent empirical work ignore interest rates other than the federal funds rate, the maintained assumption is that the term structure shifts proportionately with changes in the funds rate. Spindt and Tarhan (1987) provide results that support this assumption for our sample period.

market during the November 1979 to midsummer 1982 period would focus on three key variables: 1) nonborrowed reserves (*NBR*), 2) the federal funds rate (*FFRT*), and 3) the equilibrium quantity of transaction money (*TRAN*). Such a model may be written as

$$(1)\quad NBR_t = a_{11}\, FFRT_t + a'_{12} X_t + e_{1t},$$

$$(2)\quad FFRT_t = a_{21}\, NBR_t + a'_{22} X_t + e_{2t},$$

$$(3)\quad TRAN_t = a_{31}\, NBR_t + a_{32}\, FFRT_t + a'_{33} X_t + e_{3t},$$

where

X_t is a vector of relevant exogenous variables, a_{ij} represents behavioral parameters (or vector a' of parameters), t is time measured in days, and e_{it} is normally distributed random disturbances, which are serially uncorrelated (though they may be correlated with each other).

This is a block recursive model in which nonborrowed reserves and the funds rate are determined simultaneously in the federal funds market (equation [1] represents *NBR* supply and equation [2] *NBR* demand), and the equilibrium quantities of *NBR* and *FFRT* help to contemporaneously determine *TRAN*. Thus, feedback is allowed between *FFRT* and *NBR*, but not between *TRAN* and *NBR*. The rationale for this is based both on the institutional fact of lagged reserve requirements, under which required reserves held in week three were based on transaction accounts held in week one, and on the view that neither the Federal Reserve nor the market observed changes in aggregate money during the day.

Analysis of the dynamic relationships among the endogenous variables is facilitated by considering the reduced form of the model:

$$(4)\quad NBR_t = P'_1 X_t + v_{1t},$$

$$(5)\quad FFRT_t = P'_2 X_t + v_{2t},$$

$$(6)\quad TRAN_t = P'_3 X_t + v_{3t},$$

where the *P*'s are reduced-form coefficients, and

$$v_{1t} = \frac{a_{11} e_{2t} + e_{1t}}{1 - a_{11} a_{21}}$$

$$v_{2t} = \frac{a_{21} e_{1t} + e_{2t}}{1 - a_{11} a_{21}}$$

$$v_{3t} = a_{31} v_{1t} + a_{32} v_{2t} + e_{3t}.$$

The functional relationships among the reduced-form errors (the *v*'s) are identical to the contemporaneous relationships that exist among the endogenous variables in the structural model. That is,

$$(7)\quad v_{1t} = a_{11} v_{2t} + e_{1t},$$

$$(8)\quad v_{2t} = a_{21} v_{1t} + e_{2t},$$

$$(9)\quad v_{3t} = a_{31} v_{1t} + a_{32} v_{2t} + e_{3t}.$$

Thus, analysis of the reduced-form errors in equations (7)-(9) will provide impulse-response functions identical to those obtained by analyzing the structural model directly.[7]

The reduced-form equations (4)-(6) are estimated as a set of vector autoregressions (VARs), where the *X*'s in each equation are a set of lagged endogenous variables (with some minor additions). This particular choice of exogenous variables implies that the *v*'s in (7)-(9) will be one-step-ahead forecast errors.

The VAR methodology, pioneered by Sims (1980, 1982), was adopted primarily because of the difficulty of collecting more-traditional exogenous variables on a daily basis.[8] Many exogenous variables that have been used in weekly or monthly money-demand models are simply not available on a daily basis. Use of the VAR methodology allows us to get around this problem by thinking of the lagged endogenous variables as instruments for a more complex set of *X*'s. An additional advantage of using lagged endogenous variables is that it allows us to perform a relatively simple calculation of the dynamic

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[7] Briefly, this can be seen as follows. Consider the simultaneous equation system

$$Y_t = BY_t + PX_t + e_t,$$

where Y_t, X_t, and e_t are vectors of endogenous, exogenous, and random errors, respectively, and B and P are matrices of coefficients. The reduced form of this system is

$$Y_t = (I - B)^{-1} PX_t + u_t,$$

with

$$u_t = (I - B)^{-1}\, e_t.$$

From the latter relationship, it is clear that

$$u_t = Bu_t + e_t,$$

of which equations (7) - (9) are but a special case.

[8] A few examples will give the flavor of the types of variables that might be used in a more explicit model. Under the system of lagged reserve requirements in existence during the study period, required reserves were fixed within each reserve maintenance week (Thursday–Wednesday) and were determined by required reserve ratios and the two-week lagged values of reservable liabilities. The demand for excess reserves is affected by a number of factors, including the volume of reserve account transactions and the risk preferences of individual banks. The supply of reserves is influenced by the demand for borrowed reserves, which depends in part on the spread between the federal funds rate and the discount rate, and the degree of "moral suasion" exerted at the discount window.

reaction of the system to shocks without having to specify or estimate the dynamic behavior of the exogenous variables separately.

Even with the assumption that money is determined recursively, the structural parameters of equations (7)-(9) cannot be calculated from the reduced-form equations without further restriction because of the simultaneous determination of *NBR* and *FFRT*. A traditional identifying assumption would be that the reserve supply is set during the previous period and thus is exogenous. However, we decided that this assumption is inappropriate in the daily model, since we are focusing on the reaction of the Federal Reserve Open Market Desk to unforeseen changes in the economic environment. Moreover, as shown in the next section, it also turns out to be inconsistent with the positive contemporaneous relationship observed empirically between the two variables (or between their one-step-ahead forecast errors, v_1 and v_2). An alternative, albeit arbitrary, restriction was therefore imposed.

We assumed that the structural coefficient representing the effect of a contemporaneous change in reserves on the federal funds rate, a_{21}, was identical to the structural coefficient of the previous day's reserve change on the funds rate (an element of a'_{22}). This additional assumption, which identifies the entire system, centers around the belief that banks trading in the federal funds market smooth the price of reserves from day to day. This may occur for two reasons. First, because of lags in the system, it isn't clear that traders can actually detect "new" reserves within a day. Second, during the study period, reserve accounting took place on a weekly rather than daily basis. Reserves on any one day of the maintenance period were almost perfect substitutes for reserves on another day. Thus, the relevant reserve quantity in determining the funds rate was an estimate of "weekly" reserves, which would be equally affected by contemporaneous and one-day-lagged shocks.[9]

II. Data

Our empirical analysis is based on the dynamic relationships of the three variables discussed above—nonborrowed reserves, the federal funds rate, and money as measured by transaction accounts. Data on each of these variables were collected for the five working days (Thursday through Wednesday) of the 139 reserve maintenance weeks from November 7, 1979 through June 30, 1982. This represents a relatively homogeneous period with respect to the operating procedures of monetary policy following the Federal Reserve's October 1979 adoption of reserve targeting. The only likely deviation occurred during the April–August 1980 period of credit controls. Our calculations for this interval are characterized by an intercept shift in all estimated equations.

Data were collected from several sources. Systemwide nonborrowed reserves were taken from the Federal Reserve's daily balance sheet and then corrected for "as-of" adjustments and overdrafts.[10] Transaction accounts were measured as the sum of gross demand deposits, automatic transfers from savings accounts, telephone and preauthorized transfer accounts, and NOW accounts and share drafts, minus demand balances due from depository institutions in the United States, less cash items in the process of collection. These data, designated *TRAN*, were gathered at the individual bank level and then aggregated daily across all Federal Reserve member banks.[11] The federal funds rate was measured as the daily weighted average computed by the Federal Reserve.

Sample means and standard deviations for the variables used in this study are presented in table 1. Average levels for each variable are given, as are average changes by day of the week. The data show substantial variation in the day-by-day change in every variable. For example, Friday and Monday appear to have been especially atypical for member-bank transaction accounts. Each Friday, an average of $9.8 billion flowed out of these accounts, and on Monday $13.4 billion flowed in. The Friday outflow may have resulted either from the weekend migration of transaction accounts to higher yields, from Eurodollar arbitrage behavior by the big banks that was common

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[9] The robustness of this assumption was tested in estimating the impulse-response functions (presented in the next section) by resetting the coefficient a_{21} to one-half and to two times the structural coefficient of the previous day's reserve change. In neither case were the substantive conclusions drawn from calculating the impulse-response functions changed.

[10] As-of adjustments are corrections made up to three weeks later to reflect errors in the original accounting. Overdrafts are negative balances not reflected in the original accounting.

[11] *TRAN* is taken from the Report of Deposits submitted to the Federal Reserve for the purpose of computing required reserves. The data used are final "hard" numbers subject to little revision. It should be noted that the money supply data were released each Friday and were computed from different sources than those used for *TRAN*. However, the *TRAN* definition was chosen after extensive conversations with the Federal Reserve staff responsible for computing the monetary aggregates over the sample period. They indicated that *TRAN* would be extremely highly correlated with the aggregate measures of transaction money used at the time.

TABLE 1

Sample Means[a]

Variable	Average Daily Level	Average Daily Change				
		Thursday	Friday	Monday	Tuesday	Wednesday
NBR	40,361	149	–126	–39	–726	690
		(3,549)	(2,055)	(3,079)	(2,599)	(3,115)
FFRT	1,467	40	–9	3	–10	–25
		(88)	(52)	(62)	(67)	(110)
TRAN	213,329	570	–9,849	13,432	–4,394	421
		(3,751)	(7,308)	(8,753)	(9,109)	(3,972)
Total system excess reserves	531	–873	116	–220	–778	1,721
		(3,839)	(2,037)	(3,087)	(2,662)	(3,543)
Total system reserve borrowings	1,426	–1,052	247	–181	–52	1,031
		(1,298)	(431)	(395)	(332)	(1,433)

a. The federal funds rate is measured in basis points. All other variables are measured in millions of dollars. All data are nonseasonally adjusted.

NOTE: Standard deviations are in parentheses.

SOURCE: Board of Governors of the Federal Reserve System.

over part of the estimation period, or from banks' attempts to reduce reservable liabilities over the Friday to Sunday period.

The more-than-compensating Monday inflow may reflect the return of Friday's funds and the Monday posting of weekend transactions.[12] In addition, it is interesting to observe that the average federal funds rate fell on both Tuesday (10 basis points) and Wednesday (25 basis points). However, these declines were more than offset by the 40-basis-point average increase on Thursday. This may reflect either a falloff in reserve demand toward the end of the reserve maintenance week (because risk-averse banks obtained their reserves earlier) or an expansion of reserve supply. It may also indicate risk-averse actions on the part of the Federal Reserve Board to supply reserves and thus avoid a large swing in the funds rate.

Prior to use in the regression analysis, the raw data had to be adjusted. To control for trends, we converted each variable to a daily first difference. Because data were not otherwise seasonally adjusted, variables were further transformed to deviations around seasonal (monthly) means. We computed values for the 10 bankers' holidays per year using predicted values from auxiliary regressions similar in form to those ultimately used in the analysis, but employing only those observations with complete data.

The basic VARs were estimated utilizing all three variables: *NBR*, *TRAN*, and *FFRT*. Results for these regressions are available in Avery and Kwast (1986). We regressed the daily change in each variable against both the lagged daily changes in the current and previous reserve week and the weekly changes of the second through fourth lagged reserve weeks for each of the three series.[13] In addition, we used variables representing the FOMC's short-run path for M1, an intercept shift for the April–August 1980 credit control period, and binary variables for the day, the day after, and two days after a Social Security payment (generally the third of each month), as well as for the end of a quarter. These variables were designed to capture what are commonly recognized as the most important seasonal effects not accounted for by the transformation using monthly means. Each regression was fit separately for all five days in the reserve week, utilizing the 139 sample weeks of data.

The first-differencing and VAR forms of the regressions appear to have removed most first-

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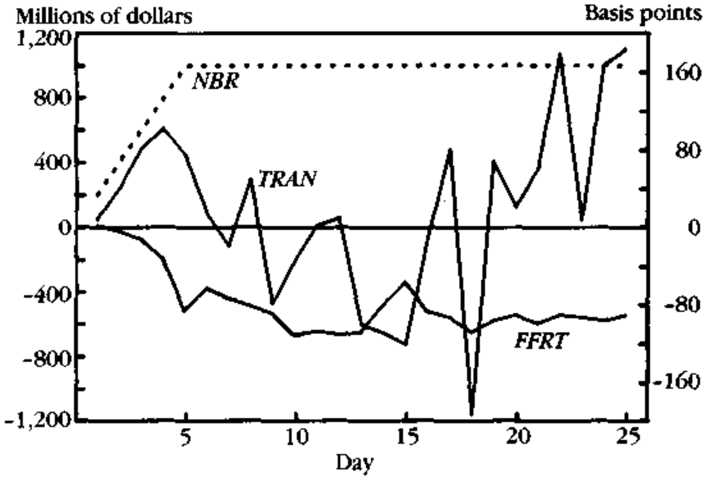
[12] Such transactions include deposits by retail stores and automated teller machine activity.

[13] The choice of lag structure reflects a trade-off between nonrestrictive completeness and estimation parsimony. Once daily observations for the previous week were included, the model results were not particularly sensitive to the lag specification of the endogenous variables.

FIGURE 1

Cumulative Response to a $200-Million-per-Day Net Shock to *NBR* Maintained for Five Days



NOTE: Cumulative net change.
SOURCE: Authors' calculations.

TABLE 2

Cumulative Response to a $200-Million-per-Day Net Shock to *NBR* Maintained for Five Days

Variable	One Week	Two Weeks	Three Weeks	Four Weeks	Five Weeks
NBR change[a]	1,000	1,000	1,000	1,000	1,000
	(–)	(–)	(–)	(–)	(–)
Percent change[b]	2.48	2.48	2.48	2.48	2.48
FFRT change[c]	–87.7	–113.0	–56.9	–90.9	–91.0
	(15.5)	(31.5)	(26.6)	(27.3)	(40.9)
Percent change[b]	–5.98	–7.70	–3.88	–6.20	–6.20
TRAN change[a]	447.8	–209.4	–734.2	122.8	1,098.7
	(170.0)	(601.0)	(822.3)	(788.4)	(896.7)
Percent change[b]	0.21	–0.10	–0.34	0.06	0.52

a. Cumulative net change, millions of dollars.
b. Based on average values over the estimation period.
c. Cumulative net change, basis points.
NOTE: Standard errors are in parentheses.
SOURCE: Authors' calculations.

order serial correlation from the equation residuals, with estimated first-order serial correlation coefficients of 0.02, -0.02, and 0.06 for *NBR*, *TRAN*, and *FFRT*, respectively.[14] The average contemporaneous residual correlation is 0.27 between *NBR* and *TRAN*, 0.10 between *FFRT* and *TRAN*, and 0.15 between *NBR* and *FFRT*. As mentioned earlier, the positive correlation between *NBR* and *FFRT* led us to adopt our somewhat arbitrary identifying restriction for the model. When structural parameters were determined using the lagged identifying restriction, the imposed coefficient was the "right" sign and "a reasonable order of magnitude" in all five cases (there is a separate model for each day of the week).[15]

III. Dynamic Behavior

We are concerned here with the magnitude, sign, and significance of the impulse-response functions of each endogenous variable with respect to an exogenous shock to both itself and the other endogenous variables. The contemporaneous effects follow directly from estimates of the a_{ij}'s computed by solving the sample analog of equations (7)-(9). The effect of exogenous shocks on future values of the endogenous variables does not follow as straightforwardly. However, given a solution to the contemporaneous relationships of (7)-(9), future effects could be computed by solving for the moving-average representation of the VAR structure in equations (4)-(6).

Below, we examine the reactions of the system to two different shocks. The first is the estimated impact of an unexpected change in nonborrowed reserves, and the second is the reaction of policymakers to a shock to money demand.

Response to a Change in Nonborrowed Reserves

Figure 1 displays calculated responses of each variable to a *net* $1.0 billion positive shock to

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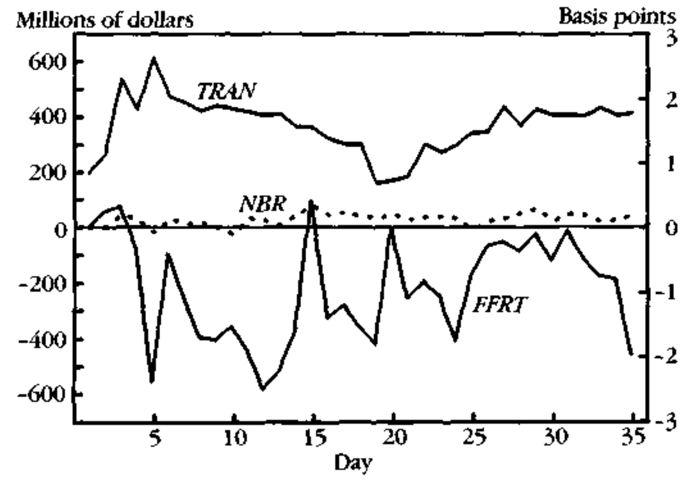
[14] Higher-order serial coefficients were smaller in absolute magnitude than these, and none was statistically significant.

[15] The structural parameter estimates are not reported here because the impulse-response functions derived from them are, for purposes of this paper, more meaningful. The impulse-response functions are presented in the next section.

FIGURE 2

Cumulative Response to a $200-Million-per-Day Gross Shock to *TRAN* Maintained for Five Days



NOTE: Cumulative net change.
SOURCE: Authors' calculations.

NBR ($200 million per day for five days).[16] A net change was simulated to represent a shift in the weekly objective for *NBR* growth, which presumably would be represented by a net rather than a gross change in *NBR*. Because the model is first-differenced, the figures presented are cumulative moving averages. Approximate standard errors at intervals of one through five weeks are displayed in table 2. These were calculated using bootstrap methods, since analytic derivation would have been extremely difficult.[17]

As seen in the figure, *FFRT* responds quite *rapidly* and inversely to the change in *NBR*. In fact, the two-week response is greater than the five-week response. By five weeks, *FFRT* has declined more than 6 percent. Given the 2.4 percent change in *NBR*, this implies a short-run elasticity with respect to nonborrowed reserves of -2.5.

Initially, *TRAN* rises, fueled primarily by the contemporaneous correlation that is probably due to the open market operation itself. During weeks two and three, cumulative *TRAN* changes are actually negative, and it is not until week five that there is any appreciable increase. Even then, the implied "money multiplier" (ignoring currency and other transaction accounts) is only slightly larger than one. This suggests that most of the effects of an unexpected change in nonborrowed reserves were absorbed by changes in borrowing, excess reserves, or cash—not by changes in transaction accounts. To investigate this possibility, reduced-form models identical to those of *NBR*, *FFRT*, and *TRAN* (same independent variables and lagged endogenous variables) were run for excess and borrowed reserves. Assuming a recursive contemporaneous ordering, response functions similar to those shown in figure 1 were calculated for both variables. After three weeks, declines in borrowing and increases in excess reserves were estimated to total $1,187 million more than the injection of reserves. By week five, decreases in borrowing totaled $423 million and increases in excess reserves were estimated at $323 million. Together, these results imply that almost three-quarters of the reserve injection was absorbed by these short-term "buffers."

Feedback Effects: Response of Nonborrowed Reserves to a Change in Money Demand

The short-run reaction of the money market, particularly nonborrowed reserves, to a change in money may be examined with calculations similar to those utilized in the previous subsection. The difference is that in this case, a shock is exerted on *TRAN*, and feedback (on *TRAN*) is allowed. Figure 2 presents the results of a $200-million-per-day gross positive shock to *TRAN* maintained for five days.[18] For reasons that will become apparent below, the results of this simulation are displayed out to seven

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[16] The linearity of the model makes the size of the shock unimportant, since the values of the multipliers are independent of the shock's size. The shock simulated is one that offsets any implied feedback (even in the near future) and that provides an additional $200 million injection per day for five days. Thus, the shock is equivalent to a net injection.

[17] The estimated covariance of the VARs was calculated assuming a three-equation system with contemporaneously correlated, but serially uncorrelated, errors. The resulting coefficient covariance matrix was used to generate 50 random multivariate normal coefficient vectors centered on the estimated parameter vector. Simulated moving-average responses were then derived for each of the random coefficient vectors (contemporaneous coefficients were also adjusted), and the sample standard deviation of the cumulative responses was calculated at each point in time. These estimates suggest that the cumulative moving averages are significantly different from zero

[18] Ceteris paribus, this is also a large shock and would increase *TRAN* by 25 percent if continued for one year with no feedback. With feedback, the shock would increase *TRAN* by 8.5 percent. We handle contemporaneous correlations the same way as in the *NBR* simulations. Neither *NBR* nor *FFRT* is assumed to react to contemporaneous *TRAN*; thus, there is no intraday feedback.

TABLE 3

Cumulative Response to a $200-Million-per-Day Gross Shock to *TRAN* Maintained for 5 Days

Variable	One Week	Two Weeks	Three Weeks	Four Weeks	Five Weeks	Six Weeks	Seven Weeks
NBR change[a]	−21.8	−27.0	80.2	37.1	−11.4	21.0	43.0
	(23.2)	(30.7)	(29.3)	(32.6)	(32.6)	(37.4)	(32.7)
Percent change[b]	−0.05	−0.07	0.20	0.09	−0.03	0.05	0.11
FFRT change[c]	−2.38	−1.52	0.43	−0.01	−0.74	−0.51	−1.96
	(1.27)	(1.67)	(1.81)	(1.83)	(2.16)	(1.82)	(2.12)
Percent change[b]	−0.16	−0.10	−0.03	−0.001	−0.051	−0.03	−0.13
TRAN change[a]	607.9	427.5	360.3	168.2	342.9	404.7	413.0
	(40.4)	(73.6)	(78.9)	(72.0)	(76.0)	(74.2)	(80.8)
Percent change[b]	0.28	0.20	0.17	0.08	0.16	0.19	0.19

a. Cumulative net change, millions of dollars.
b. Based on average values over the estimation period.
c. Cumulative net change, basis points.
NOTE: Standard errors are in parentheses.
SOURCE: Authors' calculations.

weeks. Approximate standard errors are given in table 3.

Without feedback, the gross change in *TRAN* would have been $1.0 billion. The data plotted in figure 2, however, show that at the end of five weeks the net increase is only $343 million. Thus, only about 35 percent of the gross increase in *TRAN* persists for five or more weeks. The path of this change is also of interest. After an initial increase, *TRAN* declines through week four and then begins to rise. The time path of *FFRT* is similar (though reversed in sign) to that of *TRAN*. After an initial decline, *FFRT* rises through week three and then starts to fall again. The decline in *FFRT* at the end of five weeks is somewhat surprising, although small and, as judged by estimated standard errors, apparently insignificant.

The most interesting results of this simulation are suggested by the *NBR* data. During the first two weeks of the positive money shock, the Federal Reserve withdraws reserves, perhaps in response to the initial decline in the funds rate. By the end of three weeks, however, $80 million of *NBR* has been injected. After five weeks, $11 million has been withdrawn, while a net addition of $43 million is observed at the end of seven weeks. This pattern of withdrawals and injections is roughly consistent with the changes in reserve demand that occur under lagged reserve requirements. In that case, an increase in money translates into greater reserve demand in the third week of these calculations (the second week after the monetary shock). Thus, the simulated pattern for *NBR*, reflecting the timing required by lagged reserve requirements, strongly suggests that under this system, the Federal Reserve did accommodate at least some of the increase in money.

An estimate of the extent of central bank accommodation may be computed as follows. Consider the $43 million net increase in *NBR* supplied by the end of week seven. Clearly, this would not support the total $1.0 billion shock to *TRAN*. However, the Federal Reserve never really observes the $1.0 billion increase, but sees only the net changes shown in figure 2. The appropriate procedure is to compare the permanent increase in *NBR* with the increase in required reserves resulting from the permanent increase in *TRAN*. Assuming that the shock to *TRAN* is the only shock to money, that all of the net increase in nonborrowed reserves goes to member banks, and that the marginal reserve requirement is the transaction account limit in effect over the estimation period (16.25 percent), then the data underlying figure 2 imply that the Federal Reserve

TABLE 4

Cumulative Response after Five Weeks to a One-Day, $1.0 Billion Net Shock to *NBR* Administered on Different Days

Variable	Thursday	Friday	Monday	Tuesday	Wednesday
TRAN change[a]	1,091.1	1,445.0	1,030.3	1,133.8	692.3
	(941.0)	(984.0)	(953.3)	(977.5)	(797.2)
Percent change[b]	0.51	0.68	0.48	0.53	0.32
FFRT change[c]	–74.0	–81.2	–95.3	–119.3	–89.4
	(42.3)	(43.9)	(43.9)	(45.1)	(37.3)
Percent change[b]	–5.0	–5.5	–6.5	–8.1	–6.1

a. Cumulative net change, millions of dollars.
b. Based on average values over the estimation period.
c. Cumulative net change, basis points.
NOTE: Standard errors are in parentheses.
SOURCE: Authors' calculations.

accommodated about 65 percent of the increase in required reserves during the sample period.[19]

As an additional test, a shock was simulated that was identical to that of figure 2 in week one, but negative and offsetting in week two (so that the cumulative change in *TRAN* was close to zero after two weeks). In this case, we estimated that the Federal Reserve would supply more than 100 percent of the reserves required (assuming a 16.25 percent reserve requirement) for the week-one shock. This suggests that the Fed may have been even more willing to accommodate money shocks when they appeared to be temporary.

Day-of-the-Week Effects

One of the premises underlying the use of the particular model forms employed in this paper is the view that causal relationships might have differed by the day of the week. The estimated model system allows us to test this premise.

To examine the importance of a given day, we performed calculations identical to those presented in figure 1, but with the shock applied to only one day of the week. Results are displayed in table 4. The five-week multiplier for *TRAN* ranges from a high of $1.45 per dollar of *NBR* for a Friday shock to a low of $0.69 for a Wednesday shock. The five-week interest-rate multiplier ranges from a Tuesday high of 1.119 basis points per million dollars of *NBR* to a low of -0.074 for a Thursday shock. To examine whether these differences are statistically significant, we performed "Wald-type" chi-square tests using the approximate covariance matrix of the five-week multipliers. Chi-squares testing the equality of daily coefficients were 3.46 for *TRAN* and 8.49 for *FFRT*, with only the latter significant at the 10 percent level. Thus, while the quantitative variation is large, it is difficult to tell decisively whether the daily variations are important.

IV. Conclusion

The short-run money multiplier for nonborrowed reserves appears, at least over the period considered here, to be quite small relative to its potential long-run value. The estimated short-run multiplier for total transaction accounts of 1.1 is only 18 percent of the long-run value of 6.2 implied by the highest reserve ratio in effect over the estimation period. In the short run, banks appear to accommodate almost three-quarters of a change in nonborrowed reserves by altering their holdings of excess reserves and borrowings. Thus, the size of the open market operation needed to achieve a desired change in money appears to be much larger in the short run than that needed to effect the same change in the long run.

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[19] Using weekly data for the October 1979 – October 1982 period and a somewhat different methodology, Spindt and Tarhan (1987) estimate virtually the same degree of accommodation in nonborrowed reserves. They suggest that "... of an increase in required reserves caused by an increase in money almost 2/3 were supplied in non-borrowed form and about 1/3 in borrowed form." (p. 113)

The Federal Reserve's short-run influence over the funds rate is considerably greater than that over money. The estimated short-run elasticity of the funds rate with respect to nonborrowed reserves is -2.5. This contrasts with an estimated short-run elasticity of transaction accounts with respect to nonborrowed reserves of 0.2. Taken together, these results suggest that (again over the time period considered) although a short-run change in nonborrowed reserves could quickly and substantially affect the federal funds rate, the induced change in money in the short run was much smaller. Thus, the Fed may have had to accept substantial interest-rate volatility in counteracting short-term shocks to money. Viewed from this perspective, the apparent Federal Reserve policy in 1979–82 of supplying about 65 percent of the increase in reserves needed to accommodate a short-run increase in money may have been prudent, since it helped to avoid an even larger increase in short-term interest rates.

Finally, over much of the period covered here, there was considerable debate about whether, given its reserves operating procedure, the Federal Reserve should have substituted a system of contemporaneous reserve requirements for the extant lagged reserves system. A contemporaneous system, it was argued, could have substantially improved short-run money control.

The results presented here suggest that, during the period under examination, depository institutions at least partially delayed their response to a money shock by two weeks—the exact timing implied by lagged reserve requirements. Specifically, a positive shock to money was estimated to lower the funds rate initially and then to put upward pressure on it in the second week after the shock. This suggests that contemporaneous reserve requirements would likely have accelerated the response of the funds rate to a change in money demand, since reserve demand would have responded contemporaneously rather than with a lag. However, the modest short-run interest elasticity of money estimated in this study suggests that the quicker response of the funds rate would not, ceteris paribus, have resulted in a substantial short-run reversal of the shock to money. Thus, it appears that while contemporaneous reserve requirements would likely have resulted in a modest improvement to short-run monetary control, the Federal Reserve would still have faced a rather sharp short-run trade-off between interest-rate volatility and monetary control.[20]

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[20] Indeed, the Fed implemented a contemporaneous reserves system in February 1984, but only after switching to a borrowed reserves (interest-rate-smoothing) procedure.

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