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Predicting the Money Stock: A Comparison of Alternative Approaches

Brian Motley and Robert H. Rasche*

This paper develops two alternative procedures for making short-term predictions of the M1 money stock and compares their forecasting performance over the period from 1981 to 1984. The first procedure is the Rasche-Johannes money multiplier approach while the second involves the simulation of a structural model of the money market developed at the Federal Reserve Bank of San Francisco. Although the money market model provided better forecasts in 1983 and 1984, neither model is clearly dominant over the other. However, the relatively large forecast errors of both models suggest that the Federal Reserve's ability to "fine-tune" the money stock in the short run is very limited.

During the last ten years, and especially in the period from October 1979 to October 1982, the Federal Reserve System has stated its policy objectives in terms of the growth rates of monetary aggregates. During most of this time, the principal emphasis has been on M1, which consists of the public's holdings of currency and checking accounts, and thus represents a measure of the stock of "transactions money" outstanding. Since variations in the growth of M1 have been found historically to be closely related to variations in the growth of nominal GNP, the Federal Reserve has sought to affect the course of output and prices by influencing the growth of this aggregate.

Since the bulk of M1 consists of checking accounts, which are the liabilities of private depository institutions, the Federal Reserve cannot directly control the stock of transactions money outstanding. The central bank can, however, affect the money stock indirectly, through its influence over both the public's demand to hold money and the private banking system's ability and willingness to supply checking accounts.

Depository institutions are required to hold reserves equal to specified proportions of certain of their deposit liabilities, and the supply of these reserves is controlled by the Federal Reserve. When the Federal Reserve's Trading Desk buys securities in the open market, it increases the quantity of bank reserves because the transaction is settled by crediting the reserve account the seller's bank maintains at its Federal Reserve Bank. Similarly, when the central bank lowers the discount rate it charges for short-term borrowing by private depository institutions, the lower rate will tend, everything else being equal, to lead to a greater volume of such borrowing and thus, to a larger stock of bank reserves. Both ways of increasing the supply of reserves not only add to the quantity of deposit liabilities that the private banking system is able to supply but also, because they cause short-term interest rates to fall, increase the amount of M1 that the public demands to hold.

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The effects on M1 growth of changes in interest rates and the supply of bank reserves do not occur instantaneously. Instead, they tend to be spread over a period of several months in a pattern that cannot be predicted precisely. As a result, close short-run control of the stock of M1, such as was attempted in the 1979-82 period, requires the Federal Reserve continually to forecast the likely course of M1 growth in the weeks and months ahead. When the forecast indicates that M1 is likely to deviate from the target set by the Federal Open Market Committee (FOMC), the Trading Desk must adjust the supply of reserves with a view to bringing the aggregate back toward target. Thus, the success of policymakers in controlling M1 growth depends heavily on their ability to make accurate short-run forecasts.

Closer short-run control of the money stock after October 1979 was generally expected to make interest rates more variable (because the central bank would no longer accommodate short-run shocks to financial markets), and M1 growth less variable. In fact, although the Federal Reserve was "controlling" M1, the aggregate remained volatile, and unanticipated month-to-month fluctuations in its growth rate continued.

The fact that control of M1 is necessarily *indirect* and requires the use of *forecasts* suggests one reason[1] for this (at the time) surprising outcome. If the Federal Reserve cannot forecast M1 well enough to choose the correct settings of the discount rate and the stock of reserves needed to keep M1 close to its short-run targets, the central bank may destabilize the aggregate as it tries to control it.

It must be recognized, however, that while the ability to make good forecasts of M1 is necessary to the successful short-run control of the aggregate, it is not sufficient. Successful short-run control also depends on the operating instrument the Federal Reserve chooses to use. For an exhaustive discussion of various instruments, see David Lindsey and others (1981).

This paper seeks to throw light on the relationship between forecasts of M1 and short-run control of the monetary aggregate. It studies two methods for forecasting and compares their respective 3-months-ahead forecasting performance over the period from 1981 to 1984.[2] One model is a reduced form, money multiplier model; the other is a structural model of the supply of and demand for bank reserves and the principal monetary aggregates.

Both models have been used in the past for predicting M1.[3] The first is a variant of the money-multiplier component model that was developed by Johannes and Rasche (1979, 1981). That model is employed regularly by Rasche to develop forecasts of M1 as background for deliberations of the "Shadow" Open Market Committee — a group of private economists who meet periodically to discuss the Federal Reserve's monetary policy. The second model is the San Francisco Money Market Model, developed by Judd and Scadding (1981, 1982, 1984), that is used regularly by the staff of the San Francisco Federal Reserve Bank to make short-run forecasts of the monetary aggregates and to examine the likely effect of alternative policy actions.

For each of the four years 1981 to 1984, we estimated each model using data extending through December of the preceding year. In the case of the monetary aggregates and reserves series, we used the data actually available *at the time.*[4] For income and prices, we used the data available *now* (September 1985) since complete historical series were not easily accessible. Data on interest rates are never revised. Each estimated model for each of the four sample periods was then used to make four separate three-months-ahead forecasts of M1 in the year following the end of the sample period with information through December, March, June, and September, respectively. Thus, for each model, sixteen separate 3-months-ahead forecasts of M1 were constructed.

For each 3-months-ahead forecast, we used the reserves and monetary aggregates data *actually* available at the beginning of the period to which the forecast refers. For example, in projecting M1 growth over the three months from June to September 1983, we assumed that the forecaster was able to use the revised money stock data through December 1982 published in February 1983 and the preliminary data for January-June 1983 published monthly over that period. The former set of data was used to estimate the parameters of the two models, whereas the latter was used as the base for simulating the models.

The resulting forecasts were compared both with the preliminary actual data published immediately after each 3-month forecast period and with the revised data issued at the beginning of the succeeding year. Their accuracy was measured by examining the forecast errors both over each year and over the four years as a whole.

The next section of the paper outlines the principal features of the two models used in our forecasting experiments. Sections II and III describe the estimation and simulation of each model in detail. The simulation results are set out in Tables 3-5 and discussed in the second last section. Our calculations show that the money market model would have provided more accurate M1 forecasts over the 1981-84 period, but that the errors from both models were sufficiently large to make close short-run control of M1 growth by the central bank quite difficult. The final section of the paper summarizes our results and offers some concluding comments.

I. The Models

In the *multiplier component approach* of Johannes and Rasche, the stock of M1 is modeled as the product of a money multiplier and a reserve aggregate:

$$M1 = m \cdot R$$

According to this decomposition, all changes in M1 reflect changes either in the reserve aggregate — assumed to be under actual or potential Federal Reserve control — or in the money multiplier. In a 1981 contribution, Johannes and Rasche argued that the multiplier may be forecasted with sufficient accuracy to make it possible for the Federal Reserve to control the growth of M1 quite closely over periods of six months to a year.

In this paper's version of the model, the reserve aggregate employed is the stock of nonborrowed reserves, adjusted for changes in reserve requirements, plus the quantity of extended-credit borrowings from Federal Reserve Banks. This is the reserve aggregate used by the Federal Reserve as its short-run operating instrument in the period from October 1979 to October 1982. Using this reserve aggregate, the money multiplier is defined as

$$m = \frac{1 + k(1 + tc)}{rb(1 + t_1 + t_2 + g + z)} \qquad (2)$$

where

- k = the ratio of the currency component of M1 to the transactions deposit component
- tc = the ratio of nonbank travelers checks to the currency component of M1 (for 1982-84 only).
- rb = the ratio of nonborrowed reserves (adjusted for changes in reserve requirements) plus extended credit borrowings to total deposits (M3 + government deposits + foreign deposits − currency − nonbank travelers checks).
- t_1 = the ratio of the difference between M2 and M1 to transactions deposits
- t_2 = the ratio of the difference between M3 and M2 to transactions deposits
- g = the ratio of U.S. government deposits at commercial banks to transactions deposits
- z = the ratio of foreign deposits at commercial banks to transactions deposits

An ARIMA model was estimated for each of these component ratios for each of four overlapping sample periods ending in December 1980 to December 1983. That is, each component was modeled as a linear function of its own past values. These estimated models then were used to generate 3-months ahead forecasts of the components and thus of the complete multiplier. The stock of nonborrowed reserves plus extended credit was treated as exogenously determined by the Federal Reserve.

Although the components of the money multiplier are influenced by the behavior of the non-bank public (which largely determines k, t_1, t_2 and tc), the "spirit" of the multiplier approach is that changes in the stock of M1 are caused mainly by changes in the quantity of reserves available to the banking system to support transactions deposits, and thus, that the stock of M1 is determined primarily from the *supply* side.

The second model used in the forecasting experiment, the *San Francisco Money Market Model,* is a structural model that describes the behavior of the public, the banking system and the Federal Reserve in the markets for money, reserves and bank credit. A unique feature of this model is that M1 is viewed as serving a "buffer-stock" function in the public's asset portfolio. In the short-run, the public is assumed passively to accept at least part of any changes in the supply of money brought about by variations in the quantity of bank credit outstanding. Suppose, for example, there were an increase in the public's demand for loans which the banking system accommodates. The model posits that the public will hold a portion of the resulting rise in the supply of money temporarily without a change in interest rates (see Judd 1984), even though there has been no permanent increase in its demand to hold money balances. The public's willingness to hold "extra" money is due to the transactions costs associated with adjusting money balances quickly to desired levels. Also, although individual transactors can alter their money holdings by varying their rate of spending on goods and services, the nonbank public as a group cannot do so.

The San Francisco model may be used to generate forecasts of M1 growth under a variety of alternative assumptions about the Federal Reserve's short-run operating procedure. In most recent years, the Federal Reserve's short-run policy — although seeking to keep M1 growth within an annual target range — has generally been concerned with influencing money market conditions rather than closely controlling bank reserves or money on a month-to-month basis. This certainly was true prior to October 1979, when the Federal Open Market Committee (FOMC) directed the Trading Desk to keep the federal funds rate within a very narrow range through manipulating the supply of reserves. It also has been largely true since October 1982, when the operating instrument has been the level of borrowed reserves. (The current operating procedure is described in Wallich, 1984.) As Motley and Bisignano noted recently (1985), the use of discount window borrowing as the System's short-run operating objective is similar to a funds rate control procedure because it requires short-run variations in the banking system's demand for reserves to be accommodated by variations in the supply of nonborrowed reserves. This means that shocks to the reserves market are not permitted to affect the funds rate.

Between October 6, 1979 and the fall of 1982, the Federal Reserve's operating instrument was the supply of nonborrowed reserves rather than the federal funds rate. However, given its short-run money stock objectives, the Federal Reserve did not choose its target for nonborrowed reserves by projecting the money multiplier from its own past values as the Rasche-Johannes procedure would have recommended (see Rasche-Johannes, 1981). Instead, the Federal Reserve believed that changes in the supply of nonborrowed reserves affected the money stock through changing interest rates, and thus altering the underlying demand to hold transactions money. The nonborrowed reserves procedure therefore was similar in many ways to one in which the Federal Reserve varied the funds rate to attain its money stock objectives.

These considerations led us to treat the federal funds rate as exogenous in all the forecasting experiments with the San Francisco model. In effect, the federal funds rate that emerged in any given month was assumed to be the rate which the Federal Reserve believed *at the time* was required to attain its short-run M1 target.[5]

II. Estimating and Forecasting with the Multiplier Model

To forecast M1 with the money multiplier approach requires the use of separate forecasts of each of the component ratios that make up the multiplier expression in equation 2. These forecasts were provided by dynamic simulations of an estimated ARIMA model for each component ratio. Each of the estimation sample periods for these models started in January 1971 and extended through the December of the year prior to that being forecast. We used the same specifications of the ARIMA models for all of the estimation periods. Results from various subsequent diagnostic tests of the estimated equations supported this procedure by indicating that the structure of the models did not change. The parameter estimates for each of the samples are given in Table 1.

In addition to the parameter estimates indicated in Table 1, dummy variables were included in the

TABLE 1

Estimated Coefficients of ARIMA Models for Multiplier Component Ratios

k				
1980	$(1-B)(1-B^{12})\ln k =$	$(1+.2097B)$		$(1-.5805B^{12})a_t$
1981		$+.2490$		$-.6017$
1982		$+.2714$		$-.5899$
1983		$+.2507$		$-.6701$
t_1				
1980	$(1-B)(1-B^{12})\ln t_1 =$	$(1+.2983B)$		$(1-.5433B^{12})a_t$
1981		$+.3467$		$-.5900$
1982		$+.3703$		$-.6037$
1983		$+.3020$		$-.6899$
t_2				
1980	$(1-B)(1-B^{12})\ln t_2 =$	$(1-.5239B)$		$(1-.7438B^{12})a_t$
1981		$-.5145$		$-.7461$
1982		$-.5071$		$-.8106$
1983		$-.5409$		$-.8124$
g				
1980	$(1-B)(1-B^{12})\ln g =$	$(1-.5335B$	$-.1949B^4)$	$(1-.5871B^{12})a_t$
1981		$-.5265$	$-.2077$	$-.5969$
1982		$-.4996$	$-.2057$	$-.5707$
1983		$-.5117$	$-.2317$	$-.5884$
z				
1980	$(1-B)(1-B^{12})\ln z =$	$(1+.1786B)$		$(1-.5813B^{12})a_t$
1981		$+.1235$		$-.6440$
1982		$+.1710$		$-.6640$
1983		$+.1727$		$-.6778$
rb				
1980	$(1-B)(1-B^{12})\ln rb =$	$(1+.1273B)$		$(1-.6522B^{12})a_t$
1981		$+.1562$		$-.7060$
1982		$+.1107$		$-.7068$
1983		$+.0910$		$-.7109$
tc				
1981	$(1-B)(1-B^{12})\ln tc =$	$(1-.5165B)$		$(1-.4635B^{12})a_t$
1982		$-.4925$		$-.4796$
1983		$-.4321$		$-.5208$

Notation: $B^iX_t = X_{t-i}$, ln = logarithm estimating equations for k, t_1, t_2, g and z for the sample periods ending in December 1981 through December 1983. These dummy variables allowed for the introduction of nationwide NOW accounts in January 1981. At the time, that institutional change was judged to have induced many holders of passbook savings accounts and other small time deposits, which are included in M2 but not in M1, to consolidate their transactions and savings funds into a single NOW account. This consolidation would have raised the *level* of transaction deposits *permanently* and the *growth rate* of those deposits *temporarily* as the process was proceeding. These changes would, in turn, have affected the levels and growth rate of k, t_1, t_2, g and z. During 1981, the Federal Reserve published estimates of "shift-adjusted MIB"[6] that excluded that portion of the NOW account total judged at the time to represent funds transferred from savings accounts. A detailed discussion of this adjustment of the data is given in Bennett (1982). These estimates suggest that the consolidation of funds was largely complete by mid-1981.

The coefficients on the dummy variables in the fitted equations for k, t_1, t_2, g and z were not estimated jointly with the other parameters. They were chosen to approximate the effect on the component ratios of a shift into NOW accounts from deposits outside M1 of the magnitude represented by the difference between total and shift-adjusted M1 as published at the time. Although the coefficients on the dummy variables do not capture the exact month-to-month behavior of the difference between actual and shift-adjusted M1, they do represent the general trend in that difference. In particular, they include the assumption that the shift of funds into NOW accounts (and thus its effect on the ratios) was completed by mid-1981. The same adjustment was imposed on each of the various component models. The experience here, as with earlier adjustments of this form, is that the ARIMA coefficients remain stable once this adjustment is made. Our use of the dummy variable approach causes no problems for *ex ante* forecasts for 1982-84 since the coefficients on these variables were constructed with data publicly available in 1981.

Ex ante forecasts for 1981 raise other difficulties. At the end of 1980, there was no firm information available to measure the effect of nationwide NOW accounts on the various monetary aggregates. Our approach here was to regard the multiplier models estimated through the end of 1980 as appropriate for forecasting the levels of *shift-adjusted* M1B during 1981. Shift-adjusted M1B was the aggregate the Federal Reserve used to guide its policy decisions during most of that year. However, since the portfolio shift that necessitated the adjustment in the aggregate was essentially completed by the middle of 1981, the growth rate of unadjusted M1B in the second half of that year was close to the growth rate of shift-adjusted M1B. Thus, as far as growth rates are concerned, the forecasts for the second half of 1981 may be viewed as predictions either of adjusted or of unadjusted M1B.

In examining the errors in the forecasts for 1981, we compared the forecasted values with the published estimates of shift-adjusted M1B. It must be recognized, however, that any evaluation of model forecasts for 1981 is problematic.[7] The shift-adjustments to the data were made on the basis of estimates by the Board of Governors staff of the extent to which the introduction of NOW accounts would cause the public to consolidate their savings and transactions. Hence, the accuracy of the Board staff's estimates, and thus the shift adjustments applied to the data, affected the model forecasting errors in 1981. Yet even with the benefit of hindsight, it is impossible to measure the extent of portfolio shifts precisely since the composition of a NOW account between transactions and savings funds is known only to the accountholder.

One other modification was made to the multiplier model before using it to forecast M1 growth in 1981. Preliminary simulations of the ARIMA equations produced particularly large prediction errors in the first half of that year. In an earlier paper, Johannes and Rasche (1981, p. 305) found that the forecasting accuracy of their multiplier model deteriorated sharply in 1980 and that this deterioration was largely attributable to errors associated with the imposition of credit controls in March of that year. Examination of the "within-sample" residuals from the estimated ARIMA models in Table 1 revealed that the equation describing the ratio of non-borrowed reserves to total deposits (rb) significantly (relative to the standard error) underestimated this ratio in April and May of 1980.

Although the earliest forecasting experiment in this study was for 1981, the structure of the ARIMA model for the rb ratio implies that errors in April-May 1980 would have significantly affected the M1-forecasts for those same months of 1981 if, as seems possible, the 1980 errors were the result of a unique event associated with the imposition and later removal of credit controls and thus not repeated in 1981. A detailed discussion of this issue has been placed in an Appendix. To prevent the forecasts of M1 in 1981 from being contaminated by the 1980 experience with credit controls, the ARIMA equation reported in Table 1 for the rb ratio in the sample period ending in December 1980 was modified to include dummy variables for March-May 1980. The result was a significant reduction of the money multiplier model's errors in the first half of 1981.

The effect of changes in legal reserve requirements on the time series of adjusted nonborrowed reserves posed a further problem. Each time there is a change in legal reserve requirements (about twice a year under the phase-in of the new requirements mandated by the Monetary Control Act of 1980), the procedure used in constructing adjusted nonborrowed reserves requires the entire history of the series to be reconstructed. This is a problem in principle for the forecasting of the rb ratio since it means that the historical data used to *estimate* the ARIMA model for rb through the end of the preceding year may be different from those available at the time of the *forecast*. In practice, the problem is not serious since the rb model in Table 1 (along with all other component models) is a model of the *rate of change* of rb rather than of its *level*. Adjustments to the history of the nonborrowed reserves series when reserve requirements change are fundamentally adjustments to the *level* of the series that preserve rates of change. The component model therefore should remain valid even if the data are adjusted for a change in reserve requirements between the end of the estimation period and the beginning of the forecasting period.

For each of the four sets of estimated coefficients in Table 1, four sets of three-month ahead forecasts of the component ratios were constructed for the year following the end of the estimation period. These four sets of forecasts were for December-March, March-June, June-September, and September-December. The forecasts of the component ratios can be combined to produce forecasts of the *not-seasonally-adjusted* nonborrowed reserves multiplier using the formula in equation 2. However, since the desired output of the forecasting experiment is *seasonally adjusted* M1, equation 2 must be modified to yield a forecast of the multiplier connecting *seasonally adjusted* M1 and nonborrowed reserves *not seasonally adjusted*. This modification was made using the seasonal factors that were published at the beginning of each year for the components of the monetary aggregates. If s_d, s_k and s_{tc} are the seasonal factors for transactions deposits, currency and travelers checks, respectively, the forecast of the multiplier connecting seasonally adjusted M1 and not-seasonally-adjusted nonborrowed reserves is:

$$(3)\ \hat{m} = \frac{\frac{1}{s_d} + \frac{\hat{k}}{s_k} + \frac{\hat{k}t\hat{c}}{s_{tc}}}{\hat{r}b(1+\hat{t}_1+\hat{t}_2+\hat{g}+\hat{z})}$$

where $\hat{m}$ represents the forecasted value of the seasonally adjusted multiplier, and $\hat{k}$, $\hat{t}_1$, $\hat{t}_2$, $\hat{g}$, $\hat{z}$, $\hat{r}b$ and $\hat{t}c$ represent the forecasted values of the multiplier components from the individual ARIMA models.[8]

Finally, the forecasts of *seasonally adjusted* M1 are constructed by multiplying the computed values of the multiplier, $\hat{m}$, from equation 3 by the not-seasonally-adjusted values of nonborrowed reserves plus extended credit in the forecast period.[9]

III. Estimation and Forecasting with the Money Market Model

The San Francisco money market model is a structural model of the supply of and demand for the monetary aggregates. A full description of the version of the model used in this paper is provided in Judd (1984). Given projections of personal income, prices, the discount rate and the federal funds rate, dynamic simulation of this model yields forecasts of M1, M2, various other short-term interest rates, and the stocks of bank loans and of borrowed and nonborrowed reserves.[10]

As with the multiplier model, the money market model was estimated over four overlapping sample periods. In the case of this model, the sample periods began in August 1976 and ended in December 1980 to December 1983. The choice of August 1976 as the starting date for all four samples was dictated by the widely acknowledged fact that the demand for money shifted in 1974-75. This shift made model estimates over those years produce unreliable coefficient values.

Because of the pivotal roles played in the model by the M1 demand function and the equation explaining bank loans, the coefficients of these equations in the four sample periods are reported in Table 2. As indicated earlier, the income, price and interest rate data used in this estimation were those available in September 1985, while the monetary and reserve aggregates were those available shortly after the end of each sample period.

For the three sample periods ending in December 1981, 1982, and 1983, each of which included 1981, a set of dummy variables also is included to allow the intercepts of the M1 and transactions deposits demand equations to shift upward in 1981 and thereby capture the effect of the nationwide introduction of NOW accounts. As discussed in the previous section, this institutional change apparently led some holders of passbook savings and small time accounts to consolidate their savings and transactions deposit holdings in a single NOW account. The result was an upward shift in the demand for M1. Coefficients on the dummy variables represent this demand shift. In contrast to our procedure with the multiplier component models, these coefficients were estimated directly from the non-shift-adjusted data. As in the multiplier model, the size of the upward shift in M1 demand during 1981 was estimated with data available at the end of that year, thus eliminating any problem in using the shift-adjusted data to make forecasts for 1982 and subsequent years.

The forecasts of M1 made for December 1980-March 1981 and for March-June 1981 on the basis of the model estimated through December 1980 were treated as forecasts of "shift-adjusted M1B" as published by the Federal Reserve at that time. As we pointed out earlier, this adjustment to the data was made on the basis of staff estimates of the extent to which savings funds would flow into new NOW accounts and thus cause an upward shift in M1 demand. In forecasting the growth of shift-adjusted M1 from March to June 1981, however, an "add factor" was introduced into the M1 demand equation to put the model "on track" at the beginning of that period. This add factor was structured so that any error in the staff's judgment of the demand shift from December to March, does not affect the model forecast of the M1 *growth rate* from March to June.

Since the shift of funds into NOW accounts seemed largely completed by mid-1981, and therefore affected the growth rate of M1 only temporarily, the model simulations for the third and fourth quarters of 1981 were regarded as forecasts of the growth rate of non-shift-adjusted M1. For these two quarters, add-factors were again introduced to put the model on track at the beginning of each forecast period and thereby ensure that shifts in the *level* of M1 did not affect the forecasted *growth rate*. Since a shift in money demand of unknown proportions was anticipated in 1981, an actual forecaster most likely would have used this add-factor procedure (or something like it) to take advantage of the information about the size of the shift that became available as the year advanced. (In forecasting the *growth rate* of M1 at the time, the staff of the San Francisco Federal Reserve Bank largely ignored the *level* of the aggregate because it was known to be distorted by the demand shift).

Unlike the multiplier model, in which forecasted values depend only on *past* values of the multiplier components, the money market model is a *structural* model in which forecasts of M1 growth depend also on the expected course of income and prices.

This aspect has two implications for the forecasting experiments. First, because the money market model uses more information, one would expect, *ceteris paribus,* its forecasts of M1 growth to be subject to smaller errors than those using the multiplier approach. Second, because the model requires more information, the quality of its forecasts depends on the accuracy of that information. If income and price predictions are wide of the mark, the M1-forecasts generated by the model are likely also to be poor. Thus, comparing the usefulness of the structural approach to that of the multiplier model requires striking a balance between these two conflicting considerations.

We attempted to deal with this dilemma by making two sets of M1 forecasts using the money market model. In the first set, we used the actual (presently-available) values of income and prices during each forecasting period. The resulting M1 forecasts were those that would have been possible with the model had the policymaker been able to predict income and prices perfectly. Clearly, in practice, this would not be possible, so actual M1-forecasting errors would be expected to be somewhat larger.

The second set of M1 forecasts used predictions of the growth rates of income and prices made by a well-known economic consulting firm and published close to the beginning of each forecasting period.[11] These forecasts, which may be more representative of those that an actual policymaker would have been able to achieve, would be expected *a priori* to exhibit greater errors than those generated under the assumption that future income and prices are known perfectly. *A priori,* the forecasting errors of an actual policymaker using the money

TABLE 2

Money Demand & Bank Loan Equations in the Money Market Model

Specifications

LM1 = A0 + A1 · DLBL + A2 · (LY-LP) + A3 · CPRT + A4 · NOWDUM + A5 · NOWDUM2 + A6 · NOWDUM3 + A7 · LP + A8 · (LLM1 − LP)
where A7 = 1

DLBL = B1 · DCPRT + B2 · DPRIME + B3 · DLY + B4 · CREDUM
where B1, B2 and B3 represent sums of distributed lag coefficients

Definitions of Variables

LM1	=	Log of M1
LLM1	=	Lagged value of LM1
DLBL	=	Monthly change in log of total bank loans
LY	=	Log of nominal personal income
DLY	=	Monthly change in LY
LP	=	Log of personal consumption expenditures deflator
CPRT	=	Three month commercial paper rate
DCPRT	=	Monthly change in CPRT
NOWDUM	=	1, 2, . . ., 12 during January - December 1981; zero before 1981; 12 after 1981
NOWDUM2	=	Square of NOWDUM
NOWDUM3	=	Cube of NOWDUM
DPRIME	=	Monthly change in commercial bank prime lending rate
CREDDUM	=	1 in April - September 1980 otherwise zero.

market model would be expected to lie between those of the two sets of forecasts generated in this article. As it happened, the differences between the two sets of forecasts were small in most cases.

For each of the sixteen forecasting experiments, the forecasted M1 growth rate was constructed by performing a three-month-ahead dynamic simulation of the model with the actual values of the monetary and credit aggregates in the immediately preceding month presumed to be known. Thus, the forecast of the level of M1 in September 1983, for example, used the model coefficients estimated using revised data for the sample period which ended in December 1982, and took as given the actual value of M1 for June 1983 published early in July. The simulated level of M1 in September and the actual level in June then were used to construct the forecast of the growth rate of M1 over the three-month span.[12] These simulated growth rates then were compared with the realized growth rates both from the preliminary data published during the year being forecast (1983 in the above example) and from the revised data published early in the succeeding year (1984 in the example).

TABLE 2 (Continued)

Estimated Coefficients (t statistics are in parentheses)

	August 1976-December 1980	August 1976-December 1981	August 1976-December 1982	August 1976-December 1983
Money Demand				
A0	0.421 (1.730)	0.098 (0.370)	0.063 (0.335)	−0.038 (0.301)
A1	0.560 (4.85)	0.407 (3.18)	0.425 (4.38)	0.333 (3.37)
A2	0.082 (3.79)	0.113 (4.65)	0.123 (6.84)	0.130 (6.74)
A3	−0.0014 (4.67)	−0.0020 (6.28)	−0.0022 (9.52)	−0.0023 (9.08)
A4	0	0.0032 (1.74)	0.0037 (2.56)	0.0030 (1.91)
A5	0	−0.0009 (1.97)	−0.0009 (2.70)	−0.0007 (1.97)
A6	0	0.00005 (1.79)	0.00004 (2.40)	0.00003 (1.70)
A7	1	1	1	1
A8	0.819 (23.16)	0.889 (21.10)	0.833 (27.41)	0.842 (36.87)
Bank Loans				
B1	0.0197 (2.23)	0.0119 (1.69)	0.0110 (2.03)	0.0103 (2.14)
B2	−0.0193 (2.17)	−0.0127 (1.84)	−0.0116 (2.17)	−0.0103 (2.19)
B3	1.237 (12.55)	1.172 (14.03)	1.157 (16.41)	1.151 (16.73)
B4	−0.0055 (2.17)	−0.0056 (2.43)	−0.0057 (2.67)	−0.0056 (2.65)

IV. The Results of the Forecasting Experiments

The results of the forecasting experiments are set out in Tables 3, 4, and 5. Both the preliminary and revised actual growth rates of M1 are shown. Since the multiplier model in the first instance predicts the *level* of M1 and the size of the portfolio shift into NOW accounts in 1981 was not known when the year began, the forecast and actual growth rates for the multiplier model in that year are for shift-adjusted M1B. For the money market model, the forecasts for the first half of 1981 also were regarded as predictions of the shift-adjusted aggregate. However, since the demand shift was completed by mid-year and the presence of a lagged, dependent variable in the M1 demand equation adjusts the forecasts for upward-shifts in the *level* of M1 (that is, the model in the first instance predicts the *growth rate* of M1 rather than its level), the projections of growth in the second half of the year are regarded as

TABLE 3

Forecasts of M1 Growth
Multiplier Model

Date	Actual Growth Rate		Forecast	Forecast Error	
	Preliminary	Revised	Growth Rate**	Preliminary	Revised
1981*					
March	3.99	2.24	7.78	3.79	5.54
June	−0.96	1.94	−6.45	−5.49	−8.39
September	2.12	1.74	18.52	16.40	16.78
December	7.30	7.68	5.86	−1.44	−1.82
1982***					
March	6.62	6.99	1.45	−5.17	−5.54
June	2.86	4.28	2.50	−0.36	−1.78
September	8.06	8.65	13.11	5.05	4.46
December	15.64	13.13	16.33	0.69	3.20
1983					
March	16.05	15.05	6.44	−9.61	−8.61
June	11.33	11.68	8.52	−2.81	−3.16
September	4.22	6.26	0.00	−4.22	−6.26
December	3.09	4.93	−4.72	−7.81	−9.65
1984					
March	7.54	7.05	11.96	4.42	4.91
June	8.15	7.44	10.24	2.09	2.80
September	2.12	3.07	4.98	2.86	1.91
December	4.01	5.22	12.90	8.89	7.68

*For 1981, data refer to "shift-adjusted M1B" excluding non-bank travellers checks which were omitted from the monetary aggregates before July 1981.

**For March, "Forecast Growth Rate" refers to growth from the actual level of *revised* M1 in the preceding December (which was known when forecasts were made) to the forecasted level in March. For June, September and December, "Forecast Growth Rates" refers to growth from *preliminary* M1 in March, June and September to the forecasted level 3 months later.

***Growth rates from December 1981 to March 1982 are for M1, without shift adjustments and including travellers checks.

projections of actual (not-shift-adjusted) M1.

Over the four year period as a whole, the mean error in forecasting the annualized growth rate of M1 compared to the preliminary actual data published immediately after each forecasting period was 0.46 percent using the multiplier model and 3.06 percent using the money market model (assuming income and prices were known[13]). The corresponding mean *absolute* errors (that is, the average errors without regard to their signs) were 5.07 percent and 4.31 percent respectively.

Examination of Tables 3 and 4 shows that the different ranking of the two models according to these alternative criteria largely reflects the fact that in 1981, the forecast errors from the money market model were not only large but all in the same direction making the mean error the same as the mean absolute error in that year. By contrast, the multiplier model's errors in 1981, which also were large in the absolute sense, were both positive and negative, making the mean error smaller. Again, however, we should point out that the measured growth of shift-adjusted M1 in 1981 was based on estimates of the amount of funds shifted into NOW accounts from outside M1. Thus the size of both models' forecast errors in 1981 depends on the correctness of those judgments.

The tendency of the money market model to overestimate the growth of shift-adjusted M1 in 1981 was recognized at the time. The explanation for this over-estimate then suggested (see Bennett 1982) was that M1 growth was slowed in 1981 by

TABLE 4

Forecasts of M1 Growth
Money Market Model

Date	Actual Growth Rate		Forecast Growth Rate+		Forecast Errors			
			Income	Income	Income Known		Income Forecasted	
	Preliminary	Revised	Known	Forecasted	Preliminary	Revised	Preliminary	Revised
1981								
March*	3.99	2.24	9.87	9.16	5.88	7.63	5.17	6.92
June	−0.96	1.94	9.15	9.17	10.11	7.21	10.13	7.23
September**	2.54	2.45	12.12	10.82	9.58	8.28	9.67	8.37
December	9.64	9.37	17.36	15.73	7.72	7.99	6.09	6.36
1982								
March++	6.62	6.99	9.46	10.26	2.84	2.47	3.64	3.27
June	2.86	4.28	6.44	5.56	3.58	2.16	2.70	1.28
September	8.06	8.65	12.71	11.64	4.65	4.06	3.58	2.99
December	15.64	13.13	16.52	18.83	0.88	3.39	3.19	5.70
1983								
March	16.05	15.05	11.55	13.72	−4.50	−3.50	−2.33	−1.33
June	11.33	11.68	7.23	7.58	−4.10	−4.45	−3.85	−4.10
September	4.22	6.26	3.42	2.68	−0.80	−2.84	−1.54	−3.58
December	3.09	4.93	5.12	5.61	2.03	0.19	2.52	0.68
1984								
March	7.54	7.05	9.47	8.73	1.93	2.42	1.19	1.68
June	8.15	7.44	7.59	5.25	−0.56	0.15	−2.90	−2.19
September	2.12	3.07	4.91	3.55	2.79	1.84	1.43	−0.28
December	4.01	5.22	11.01	11.38	7.00	5.79	7.37	6.16

*For the first six months of 1981, data refer to "shift-adjusted M1B" excluding non-bank travellers checks.

**For the second six months of 1981, data refer to unadjusted M1B excluding non-bank travellers checks.

+For March, "Forecast Growth Rate" refers to growth from the actual level of revised M1 in the preceding December to the forecasted level in March. For June, September and December, "Forecasted Growth Rates" refers to growth from preliminary M1 in March, June and September to the forecasted level three months later.

++Growth rates from December 1981 to March 1982 are for M1, without shift adjustment, and including travellers checks.

the massive surge in ownership of money market mutual funds. These funds provided high yields and allowed some limited check-writing. As a result, they were strong competitors to the checkable accounts provided by commercial banks, the yields on which remained regulated. Thus, at the same time the nationwide introduction of NOW accounts was boosting the growth of M1, the spread of money funds was reducing it. The shift-adjustment of the data in 1981, which had the effect of reducing measured M1 growth, was designed to account for the first of these institutional developments, but no adjustment was made for the second. As a result, the model over-predicted shift-adjusted M1 growth.

In fact, in the first half of 1981, the money market model provided better forecasts of *non*-shift-adjusted M1B growth. This suggests that the effects of the two institutional developments on M1 demand tended to offset one another. Non-shift-adjusted M1 grew at an average rate of 6.4 percent in the December 1980-June 1981 period; the money market model forecast 9.5 percent and the multiplier model, 0.7 percent growth. Thus, if the comparison is made in terms of the unadjusted data, the money market model outperforms the multiplier model by a significant margin. In the second half of 1981, the shift of funds into NOW accounts was largely complete but that from M1 into money market funds actually accelerated. As a result, both models overpredicted the growth in both measures of M1.

In 1982, the mean absolute error was about the same for both models. But in 1983 and 1984, the money market model performed significantly better. Since October 1982, the Federal Reserve's operating instrument has been the level of borrowed reserves. This change to a new operating instrument has resulted in a reduction of the short-run volatility of short-term interest rates compared to the prior period in which the stock of nonborrowed reserves was the central bank's policy instrument. As the short-run volatility of interest rates was reduced, however, their longer run swings increased. Thus, one would expect a model using information about movements in interest rates as well as their impact on income and prices to have performed better in this period. By contrast, the components of the money multiplier may have become more difficult to forecast as financial deregulation increased the amount of shifting of funds among different classes of deposits.

The summary error statistics reported in Table 5 also were computed using the revised actual M1 data published early in the year following that being forecast. The results did not alter our conclusions regarding the relative forecasting efficiency of the two models, but they did reveal one noteworthy point. The revised forecast errors from the money multiplier model tended to be larger than those computed from the preliminary data, whereas errors from the money market model tended to be a little smaller. Over the four years as a whole (sixteen separate forecasts), the mean absolute error of the money market model was 4.3 percent with respect

TABLE 5

Summary Error Statistics*

Date	Mean Error			Mean Absolute Error		
	Multiplier Model	Money Market Model: Actual Income	Money Market Model: Predicted Income	Multiplier Model	Money Market Model: Actual Income	Money Market Model: Predicted Income
1981	3.32	8.32	7.77	6.78	8.32	7.77
1982	0.05	2.99	3.28	2.82	2.99	3.28
1983	−6.11	−1.84	−1.30	6.11	2.86	2.56
1984	4.57	2.79	1.77	4.57	3.07	3.22
1981-84	0.46	3.06	2.88	5.07	4.31	4.21

*The forecast errors were defined as the differences between the actual and predicted annualized growth rate of M1. They were computed from the preliminary actual data since these were forecast errors the Federal Reserve would have observed at the time.

to the preliminary data and 4.0 percent with respect to the revised data. The corresponding error statistics for the multiplier model were 5.1 percent and 5.8 percent.

We believe that the most likely explanation of this result is that the process of revising the data at the end of each year included revisions to the *seasonal adjustment* factors. As we described earlier, the multiplier component approach initially yields projections of not-seasonally-adjusted M1. It was used to generate seasonally-adjusted M1 forecasts by using the seasonal adjustment factors published *ex ante* to modify the expression which defines the multiplier in terms of its components (compare equations 2 and 3). Clearly, if these seasonal adjustment factors were later revised, the forecasts derived from the preliminary factors would tend to exhibit larger errors.

The forecasts generated by simulating the money market model are of seasonally-adjusted M1. Since the process of revising the seasonals for an economic time series tends to yield a "smoother" series, one expects the forecasting errors from the revised series to be smaller than those from the original published series. Our results confirm this expectation.

However, the fact that the money market model yielded better forecasts of the revised than of the preliminary data may provide little comfort to the real world policymaker who frequently is forced by the pressure of events to make decisions on the basis of preliminary data. Nonetheless, sharp departures of model forecasts from the preliminary published data may alert the policymaker to the possibility that preliminary data will be significantly revised later and thus should be treated with caution in making policy decisions. On occasion, the staff of the San Francisco Reserve Bank has found that model forecast errors are predictors of subsequent data revisions.

V. Conclusion

In summarizing the results of our calculations, two features stand out as important to policymakers. First, although the money market model provided better forecasts in 1983 and 1984, neither model is clearly better than the other. This conclusion suggests that both the supply conditions emphasized in the multiplier approach and the demand factors considered by the money market model play roles in determining monetary growth. Second, the relatively large errors in forecasting suggest that the central bank's ability to "fine tune" the money stock in the short-run is very limited. In sixteen separate forecasts, the multiplier model missed even the *direction of change* of the M1 growth rate five times; the money market model missed it three times.

Given that the central bank's control over the monetary aggregates is necessarily indirect, our results make the Federal Reserve's apparent inability to control M1 closely in the short run easy to understand. The empirical findings of this article strongly suggest that both the Federal Reserve itself and the small army of "Fed-watchers" who keep tabs on its activities from the sidelines should focus their attention on longer run movements in money growth.

Given the apparent difficulty of forecasting short-run movements in money growth, even when either the federal funds rate or the stock of nonborrowed reserves is assumed to be fully under the Federal Reserve's control, it seems unlikely that the central bank will be able successfully to counter unforeseen developments in the real economy by quickly varying the rate of money growth. This suggests to us that an operating procedure that *automatically* reverses short-run variations in the rate of money growth — and therefore does not require Federal Reserve officials to make judgements on the basis of forecasts — would tend to produce better long-run results.

APPENDIX

The Effect of the 1980 Credit Controls on Estimates of the Money Multiplier

As pointed out in the text of this article, the ARIMA model for the rb ratio exhibited large residuals in April and May of 1980. Although our forecasts began in 1981, one-time errors in 1980 would have had a significant effect on the M1 forecasts for 1981. This can be seen by rewriting the estimated ARIMA model for rb in Table 1 as:

$$\text{(A1)} \quad \ln\hat{r}b_t = \ln rb_{t-1} + (\ln rb_{t-12} - \ln rb_{t-13}) + .1273\hat{a}_{t-1} - .6522\hat{a}_{t-12} - .0830\hat{a}_{t-13}$$

where $\ln\hat{r}b_t$ is the predicted value of $\ln rb_t$ and $\hat{a}_{t-1}$, $\hat{a}_{t-12}$ and $\hat{a}_{t-13}$ are the estimated residuals from those previous periods. This equation in turn can be rewritten in terms of the previous predictions of rb and the associated prediction errors as:

$$\text{(A2)} \quad \ln\hat{r}b_t = \ln\hat{r}b_{t-1} + (\ln\hat{r}b_{t-12} - \ln\hat{r}b_{t-13}) + 1.1273\hat{a}_{t-1} + .3478\hat{a}_{t-12} - 1.0830\hat{a}_{t-13}$$

Now consider the implication of a situation in which the model accurately forecasts rb_{t-1} and rb_{t-13}, but predicts a small change in rb from date $(t-13)$ to date $(t-12)$ when a large increase actually occurs. That is, there is a large one-time innovation in the data at date $(t-12)$ that is not modeled explicitly. Under these circumstances, the large positive prediction error at date $(t-12)$ $(\hat{a}_{t-12} > 0)$ would be carried forward to generate a large positive predicted change between dates $(t-1)$ and t through the $.3478\hat{a}_{t-12}$ term.

By assumption, this change would not occur in the actual data series since the experience at date $(t-12)$ was a one-time occurrence. Consequently, rb_t would be overpredicted by a considerable amount. Since the elasticity of the multiplier with respect to rb is -1.0, the error in rb would appear as a large underprediction of the multiplier and the money stock at t. This phenomenon appears to be at least partially responsible for the large errors in the preliminary forecasts for March and June 1981.

There is no way to estimate accurately the month-to-month effects of credit controls in the spring of 1980 since we only had the single experience. One technique involves re-estimating the ARIMA model for rb with the addition of individual dummy variables for March-May, 1980. This model would take the form:

$$\text{(A3)} \quad (1 - B)(1 - B^{12})[\ln rb_t - \alpha_0 CR1_t - \alpha_1 CR2_t - \alpha_3 CR3_t] = (1 - \theta_1 B)(1 - \theta_{12} B^{12})a_t$$

where CR1, CR2 and CR3 are dummy variables that take the value one in March, April and May of 1980, respectively, and zero in all other months. The estimate of equation A3 for the sample ending in December 1980 is:

$$\text{(A4)} \quad (1 - B)(1 - B^{12})[\ln rb_t \underset{(.0100)}{+ .0364\,CR1_t} \underset{(.0115)}{+ .0195 CR2_t} \underset{(.0099)}{- .0165 CR3_t}] = (1 + \underset{(.1020)}{.0320B})(1 - \underset{(.0928)}{.5869B^{12}})a_t$$

The first order moving average factor is no longer significant in this specification, and the credit control dummy variables have signs that are consistent with an increase in excess reserve holdings (or a reduction in borrowed reserves) at the initiation of the credit controls. This effect in March and April 1980 is subsequently, although only partially, offset as indicated by the negative coefficient on the May 1980 dummy variable.* The effect of the inclusion of these credit control dummies is substantial as they reduce the estimated error of the rb equation by approximately 9 percent.

In principle, the effect of the credit controls experience on other component ratios of the multiplier also should be investigated. We did not pursue this investigation here both because no systematic pattern in the residuals of the other component ratios was observed during spring 1980 and because, except in the case of the t_1 ratio, the elasticity of the multiplier to the remaining component ratios is quite low. Therefore, even if the effects of the credit controls filter through to produce forecast errors in these other component ratios, they should exert only a minor influence on the multiplier forecasts.

The forecasts of M1 for 1981 shown in Table 3 are those computed using Equation A4 to simulate rb and the other component models in Table 1 to simulate the other components. Adding the credit control dummies improved the forecasting performance in March and June 1981 dramatically, while slightly hurting the already bad performance in September 1981. Over the year as a whole, the credit control dummies reduced the mean absolute error in the forecasted annual growth rate of shift-adjusted M1 from 9.20 percent to 6.78 percent.

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* If the effect of the credit controls on the reserve ratio is strictly temporary, then the sum of the coefficients on the variables should be zero. The sum of the three coefficients in equation A4 is .0394, which suggests, on the surface, that the impact may not have been fully reversed by the end of May 1980. However, the sum is not significantly different from zero (s.e. = .0259), so the case for introducing additional dummies for subsequent months is weak. Equation A3 could be re-estimated with the sum of the three coefficients on the credit control dummies restricted to zero, but that has not been done for these forecasting exercises.

FOOTNOTES

1. Other reasons for the volatility of M1 growth during the 1979-82 period have been suggested. For example, the credit control program imposed in 1980 was associated with very large changes in M1. Some economists have argued that even in the 1979-82 period, the Federal Reserve in practice did not attempt to control M1 closely in the short-run.

2. Our forecasts *assume* that the settings of the Federal Reserve's policy instruments over the forecast period are fully known. However, the Federal Reserve itself also makes M1 forecasts using both econometric and "judgmental" methods. If it changed policy in response to these forecasts, the *actual* values of the policy instruments in our models may be different from those that an outsider would have assumed at the beginning of any forecast period.

3. An earlier study examining the forecasting performance of both the Johannes-Rasche and San Francisco models — together with several other approaches to forecasting M1 — is reported in David Lindsey and others, 1981.

4. The Federal Reserve typically issues revised historical data for the monetary aggregates in February of each year. We used these revised data in our estimations.

5. Occasionally during the October 1979-October 1982 period, the Trading Desk permitted nonborrowed reserves to diverge from target in order to avoid temporary short-run interest rate fluctuations that were expected to disrupt financial markets but have little effect on M1 growth.

6. Prior to January 1982, the monetary aggregate that consisted of currency, demand deposits and NOW accounts was described as M1B. Since January 1982, this aggregate has been termed M1.

7. This comment applies equally to forecasts from the multiplier model and the money market model.

8. In February 1984, the Federal Reserve moved to a system of contemporaneous reserve requirements (CRR) from its previous system of lagged reserve requirements. This institutional change might have altered the statistical properties of the time-series of the rb ratio and thus affected our forecasts of the multiplier in 1984. In practice, tests conducted by Rasche subsequent to the completion of this article indicate that the effect of CRR on the monthly behavior of the multiplier has been small.

9. In cases where there were revisions to the nonborrowed reserves series between the end of the estimation period and the forecast period, the monthly growth rates of the revised series for nonborrowed reserves were used to extrapolate the unrevised series from the last available observation. The resulting constructed values of unrevised nonborrowed reserves were multiplied by the forecasted multiplier to generate a forecast for M1.

10. If either nonborrowed or borrowed reserves were regarded as the exogenous policy instrument, the model may be used to derive a forecast of the federal funds rate as well as the other endogenous variables. This procedure was not followed in the experiments reported here.

11. Unfortunately, it was not possible to obtain income and price predictions made precisely at the beginning of each forecast period.

12. The procedure was more complicated in 1981. The first three-month forecast (December 1980 to March 1981) was treated as a prediction of "shift-adjusted M1B" taking the level of actual M1B in December 1980 as given.

The second forecast (March-June 1981) took the level of *shift-adjusted* M1B in March as given and forecast its level in June after adjusting for the error made by the model in March. Since the portfolio shift into NOW accounts was complete by mid-year, the June-September and September-December forecasts were regarded as predictions of *non shift-adjusted* M1B, taking the level of that aggregate at the beginning of each period as given but again adjusting for the errors made in the model forecasts for June and September.

13. Table 5 shows that the forecasting errors using the predicted values of personal income and prices rather than the actual values were almost identical. This reflects partly the fact that the income and price forecasts we used were quite good and partly the fact that the *short-run* impact of income and price changes on money demand is quite small.

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