Forecasting the Money Multiplier: Implications for Money Stock Control and Economic Activity

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ONE approach to controlling money stock growth is to adjust the level of the monetary base conditional on projections of the money multiplier. That is, given a desired level for next period's money stock and a prediction of what the level of the money multiplier next period will be, the level of the adjusted base needed to achieve the desired money stock is determined residually. For such a control procedure to function properly, the monetary authorities must be able to predict movements in the multiplier with some accuracy.[1]

This article focuses, first, on the problem of predicting movements in the multiplier. Two models' capabilities in forecasting the M1 money multiplier from January 1980 to December 1982 are compared. One procedure is based on the time series models of Box and Jenkins.[2] The other model, a more general one, is based on the technique of Kalman filtering.[3] Although the Box-Jenkins type of model has been used in previous studies to forecast the M1 multiplier, this study is the first to employ the Kalman filtering approach to the problem.

The second purpose of this study is to use the multiplier forecasts in a simulation experiment that implements the money control procedure cited above. Given monthly money multiplier forecasts from each of the forecasting methods, along with predetermined, hypothetical M1 growth targets, monthly and quarterly M1 growth rates are simulated for the 1980–82 period.

Finally, the importance of reduced volatility of the quarterly M1 growth is examined in another simulation experiment. Using a reduced-form "St. Louis" GNP equation estimated through IV/1979, nominal GNP is simulated for the 1980–82 period using actual M1, desired M1 and the M1 growth rates derived from our forecast/control procedure simulation. The outcome shows that the volatility of simulated GNP growth during the 1980–82 period is halved when the M1 growth simulated from our forecast/control procedure is used in place of actual M1 growth. This finding indicates that, other things equal, reducing the

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[1]One of the earlier attempts to develop a multiplier forecasting model is presented in Albert E. Burger, Lionel Kalish III and Christopher T. Babb, "Money Stock Control and Its Implications for Monetary Policy," this *Review* (October 1971), pp. 6–22. More recent attempts, which almost exclusively have used some form of time-series model, are represented by Eduard J. Bomhoff, "Predicting the Money Multiplier: A Case Study for the U.S. and the Netherlands," *Journal of Monetary Economics* (July 1977), pp. 325–45; James M. Johannes and Robert H. Rasche, "Predicting the Money Multiplier," *Journal of Monetary Economics* (July 1979), pp. 301–25; H.-J. Buttler, J.-F. Gorgerat, H. Schiltknecht and K. Schiltknecht, "A Multiplier Model for Controlling the Money Stock," *Journal of Monetary Economics* (July 1979), pp. 327–41; and Michele Fratianni and Mustapha Nabli, "Money Stock Control in the EEC Countries," *Weltwirtschaftliches Archiv* (Heft 3: 1979), pp. 401–23.

[2]For an in-depth discussion of these models, see George E. P. Box and Gwilym M. Jenkins, *Time Series Analysis, Forecasting and Control* (Holden-Day, Inc., 1970).

[3]Kalman filtering was introduced first in the field of engineering. See R. E. Kalman, "A New Approach to Linear Filtering and Prediction Problems," *Journal of Basic Engineering* (1960), pp. 34–45; and R. E. Kalman and R. S. Bucy, "New Results in Linear Filtering and Prediction Theory," *Journal of Basic Engineering* (1961), pp. 95–108. For an introduction to Kalman filtering, see Richard J. Meinhold and Nozer D. Singpurwalla, "Understanding the Kalman Filter," *The American Statistician* (May 1983), pp. 123–27.

quarterly volatility of money growth would tend to produce more stable economic growth.

THE MULTIPLIER FORECASTING MODELS

Box-Jenkins Model

The first forecasting strategy considered is based on the techniques of Box and Jenkins (hereafter BJ). This approach requires the identification and estimation of the appropriate model before predicting the money multiplier. A consideration of the autocorrelation and partial autocorrelation function suggested an ARIMA (0, 1, 1) process. Estimating this model for the period January 1959 to December 1979 yields the following relationship:

$$(1)\quad m_t - m_{t-1} = \underset{(-4.40)}{-0.002} + \underset{(4.31)}{0.263\varepsilon_{t-1}} + \varepsilon_t,$$

$$SE = 0.011 \qquad Q(30) = 41.5$$

where m_t is the M1 multiplier (M1 divided by the adjusted monetary base), ε_t is the unforeseen current shock to the change in the multiplier, ε_{t-1} is the unforeseen shock to the change in the multiplier last period, and the value -0.002 is a negative drift in the level of the multiplier.[4]

Equation 1 suggests that changes in the multiplier can be explained partially by the error in the multiplier process last month (ε_{t-1}). The reported t-statistic, which appears in parentheses below the respective coefficient estimate, reveals that last month's error exerts a statistically significant effect on the current change in the multiplier. Moreover, the constant term reveals a slight negative, but statistically significant, trend in the level of the multiplier. Finally, the Q-statistic indicates that the model's residuals pass the test for white noise.[5] The moving-average model given by equation 1 will be used subsequently to forecast the M1 multiplier.

Kalman Filter Model

Multiplier forecasts also are derived from a general Kalman filtering model, the so-called Multi-State Kalman Filter (MSKF) method.[6] This technique is described in more detail in the insert.

The MSKF model used here is a set of four parallel models, each equivalent to a different ARIMA (0, 1, 1) specification with the coefficients fixed *a priori*. These models are used to simultaneously distinguish among four types of shocks to the multiplier: small or large, temporary or permanent. Thus, unlike the BJ procedure, the MSKF technique tries to identify the nature of the different shocks and use this information in forecasting. Given this period's prediction error and given the "state" of the system represented by all former information, the MSKF algorithm determines the probability that the shock was large or small, the proportion of this forecast error that should be viewed as temporary, and the portion that is likely to be permanent. Once this evaluation is made, the probabilities associated with the four different states are revised, and the weights associated with each are adjusted accordingly. In this way, the MSKF method allows the forecaster to reassess the structure of the forecasting model as new data become available.

Since the BJ method has been shown to work well and the MSKF procedure appears more flexible in evaluating new information, the MSKF method should be useful in forecasting the multiplier.

FORECASTING THE MULTIPLIER USING BOX-JENKINS AND MSKF METHODS

The M1 multiplier was forecast, *ex ante*, for the period January 1980 to December 1982 using the BJ and MSKF models. In each case, the forecasts are

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[4]This model was identified from an examination of the autocorrelation derived from the level and first difference of the multiplier. The first-difference specification was chosen because the autocorrelations of the level series did not display the stationarity characteristic necessary to properly analyze time series.

[5]The Q-statistic is used to determine if the estimated model has transformed the error series into white noise. Since the reported Q-statistic is less than the critical χ^2 value at the 5 percent level (43.8), one cannot reject the hypothesis of white noise residuals and, therefore, the appropriateness of the estimated model.

[6]Development of this method is presented in D. J. Harrison and C. E. Stevens, "A Bayesian Approach to Short-Term Forecasting," *Operational Research Quarterly* (4:1971), pp. 341–62, and "Bayesian Forecasting," *Journal of the Royal Statistical Society* (3:1976), pp. 205–47. Applications are found in Eduard J. Bomhoff, "Predicting the Price Level in a World that Changes All the Time," in Karl Brunner and Allan H. Meltzer, eds., *Economic Policy in a World of Change*, Carnegie Rochester Conference Series on Public Policy (Autumn 1982), pp. 7–38; Eduard J. Bomhoff and Clemens J. M. Kool, "Learning Processes and the Choice Between Abrupt and Gradual Counter-Inflation Policies," unpublished manuscript, Erasmus University (May 1982); and Eduard J. Bomhoff and Pieter Korteweg, "Exchange Rate Variability and Monetary Policy Under Rational Expectations: Some Euro-American Experience, 1973–1979," *Journal of Monetary Economics* (March 1983), pp. 169–207.

Exposition of the MSKF Model

The MSKF model used to describe the behavior of the M1 multiplier is of the form

(A1) $m_t = \overline{m}_t + \varepsilon_t$

and

(A2) $\overline{m}_t = \overline{m}_{t-1} + \gamma_t$.

This model suggests that the time series of the multiplier's growth rate (m_t) is subject to two kinds of shocks: one is a temporary level shock, represented by ε_t, the other a permanent level shock, given by γ_t.[1] Thus, the model shows that the unobservable expected value of the multiplier ($\overline{m}_t$) — sometimes referred to as the "permanent" value — behaves as a "random walk" over time, where γ_t represents once-and-for-all shifts in this expectation. Equation A1 indicates that the actual multiplier (m_t) will fluctuate randomly about this permanent value, since ε_t only affects the realization of the multiplier but not the underlying expectation.

Equations A1 and A2 yield an ARIMA (0, 1, 1) representation by shifting equation A1 one period backward in time and subtracting the result from the original equation. This transformation along with equation A2 results in

(A3) $\Delta m_t = \varepsilon_t - \varepsilon_{t-1} + \gamma_t$.

The ARIMA (0, 1, 1) model can be written as

(A4) $\Delta m_t = (1 - \phi B)\,\alpha_t$.

Writing out the autocorrelation function of both equations A3 and A4 reveals a unique correspondence between the specification of the variance of ε_t and γ_t on the one hand, and of the moving average parameter ϕ and the variance of α_t on the other. Specification of equation A3 in terms of pinning down the values of the two model parameters var(ε_t) and var(γ_t) uniquely determines the values of ϕ and var(α_t) in equation A4 and vice versa. So there is an equivalence in functional form between the ARIMA (0, 1, 1) model that is used in the Box-Jenkins estimation technique and the model we use in our Kalman filter algorithm. In methodology, estimation and forecasting, however, there is a substantial difference between the Box-Jenkins technique and the Kalman filter approach.

The application of the Box-Jenkins technique to equation A4 essentially reduces to estimating the parameter ϕ and the variance of α_t, both of which are assumed to be constant for the whole sample period.[2] Even a recursive Box-Jenkins technique combined with the weighting of past observations would not really change the characteristics of the methodology, although the ability to detect and describe slow movements of ϕ and var(α_t) over time would increase. The MSKF method goes beyond this because it allows for feedback from the data to the forecasting procedure. In this way, the MSKF model can cope with changes in the mixture of permanent and transitory shocks over time by changing the probabilities associated with the occurrence of these shocks.

The MSKF method is implemented by using four separate representations of equations A1 and A2. For each model, the ratio between the variances of ε_t and γ_t is specified *a priori*. This is equivalent to determining the parameter ϕ in equation A4. During the estimation the level of the variance of ε_t and γ_t or, correspondingly, the variance of α_t is computed adaptively from the forecast errors by means of a robust method. The specific procedure used is discussed in more detail by Kool.[3]

Table A1 presents the correspondence between equations A3 and A4. As can be seen from the table, each of the four alternative Kalman filter models can be viewed as having a fixed parameter (ϕ) that corresponds to a certain time series process. Using equation A4, the expectations of m_t at time $t-1$ can be written as

Table A1
Model Specification

Model	d	Var(ε_t)	Var(γ_t)	Var(α_t)
Small temporary	0.95	0.95	0.0025	1
Small permanent	0.05	0.05	0.9025	1
Large temporary	0.99	15.84	0.0016	16
Large permanent	0.01	0.16	15.6816	16

[1] The terms ε_t and γ_t are assumed to be mutually independent and serially uncorrelated error terms.

[2] Applications of the Box-Jenkins approach to forecasting the multiplier can be found in Bomhoff, "Predicting the Money Multiplier;" Johannes and Rasche, "Predicting the Money Multiplier;" and R. W. Hafer and Scott E. Hein, "The Wayward Money Supply: A Post-Mortem of 1982."

[3] See Clemens J. M. Kool, "Statistical Appendix A: The Multi-State Kalman Filter Method," and "Statistical Appendix B: A Recursive Prediction Error Method," both appended to Bomhoff, "Predicting the Price Level in a World that Changes All the Time," pp. 39–51.

$$(A5)\quad E_{t-1}[m_t] = m_{t-1} - \phi[(m_{t-1} - E_{t-2}(m_{t-1})] = (1 - \phi)m_{t-1} + \phi E_{t-2}(m_{t-1}).$$

Thus, for each model the expectation of next period's m_t is a weighted average of the last observed value (m_{t-1}) and the prediction for m_{t-1}, made at time $t-2$. The *lower* the value of ϕ, the more weight is given to the observed value m_{t-1} and the more probable it is that the difference between m_{t-1} and its prediction is caused by a permanent shift. A *high* value of ϕ, on the other hand, indicates that there is a high probability that differences between m_{t-1} and its expectation are of a more temporary nature. In this case, it is best to largely ignore these prediction errors and not to incorporate them into next period's prediction. The first model in the table A1, the small temporary shock model, is such a representation. It has a ϕ parameter value of 0.95, indicating that only 5 percent of this period's prediction error is incorporated in next period's forecast.[4]

At first glance, the simultaneous use of four ARIMA (0, 1, 1) models, each with an *a priori* fixed coefficient, does not seem to be a great improvement compared with a free estimation of that moving average parameter by means of the Box-Jenkins method. There is room for improvement, however, as the actual forecast of m_t in the next period is a weighted forecast of the four Kalman filter models used. The weight attached to each of individual models for next period's prediction is equal to the (posterior) probability that the multiplier process at that moment in time is indeed described by that model. These weights can vary considerably over time and even from period to period. Moreover, the Kalman filter composite forecast can be described as the forecast of a single ARIMA model with the parameter free to change from period to period.[5] In this respect, the use of four fixed models in fact increases the flexibility of the method in describing the multiplier process.

The feedback from data to the forecasting models provides us with a tool to aid in forecasting a given time series. The data provide information on both the posterior weights of the respective models and on the current value of the parameter ϕ, which is relevant for forecasting next period's multiplier. The data also contain information concerning the probabilities that each model will adequately describe the multiplier's behavior in the future. In general, it is true that the probability — posterior to the observation of the multiplier value in period t — that model j is describing the multiplier process correctly, is calculated as a combination of the *a priori* probability at time $t-1$ that model j will be the right model to describe the process in period t and the information contained in observation m_t. This combination determines the posterior probability for each model and at the same time the weight of each model in next period's forecast.

The feedback from data to the model can take place by using the data a second time looking back at period $t-1$ after the observation of the multiplier value in period t. It is highly probable that the combined information of observations of periods $t-1$ and t will give a better evaluation of the state of the process in period $t-1$ than the observation of period $t-1$ alone. So the posterior probabilities for period $t-1$ are recalculated, using the observation at time t. These recalculated probabilities then are used to adjust the prevailing prior probabilities. The prior probabilities for the various models can be said to be updated adaptively over time as new observations become available, thereby influencing future forecasts.

[4]For ease of exposition, we present the level of the different variances instead of their ratios by normalizing with respect to the variance of α_t, which in fact is updated adaptively as argued above. Observations more than two standard deviations away from the expected value of a variable are defined to be outliers. We choose the variance of the two large error models 16 times as large as the variance of the normal error models.

[5]The weighted sum of a specified number of moving average processes is again a moving average process under relatively loose conditions, whereby the moving average parameter of the resulting process is a non-linear function of the weights and the parameters of the various models. See David E. Rose, "Forecasting Aggregates of Independent ARIMA Processes," *Journal of Econometrics* (May 1977), pp. 323–45.

one-step-ahead predictions of the multiplier, based on data through the most recent month.[7] Specifically, suppose a forecast for the June 1981 money multiplier is desired. Given the parameter estimates in, say, equation 1, the data through May 1981 are used to construct the June forecast. This data set is then updated to include June to construct the July forecast, and so on. By continually updating the information set available to the forecaster, the procedure used here closely imitates the process by which a policymaker actually would generate multiplier forecasts.

Chart 1 plots the multiplier forecast errors (actual minus predicted multiplier) for each of the two procedures. As shown there, the errors follow a similar pattern during the sample. The forecast error derived

[7]This procedure is used in R. W. Hafer and Scott E. Hein, "The Wayward Money Supply: A Post-Mortem of 1982," this *Review* (March 1983), pp. 17–25. See also Anatol B. Balbach, "How Controllable is Money Growth?" this *Review* (April 1981), pp. 3–12.

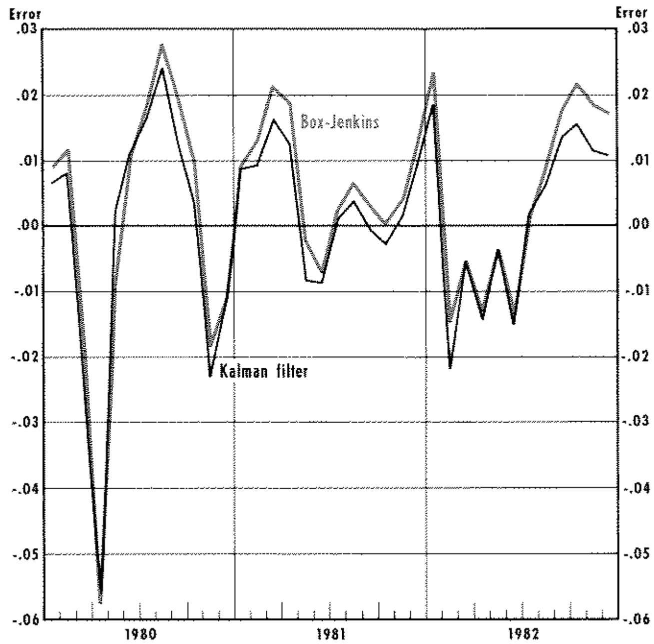
from the MSKF procedure is closer to zero, on average, than using BJ. The largest forecast errors for both models come in March-April 1980. During this period, when special credit controls were enacted by the Carter administration, the actual multiplier fell sharply from 2.603 in February 1980 to 2.578 in March and 2.524 in April. This decline, though small in absolute magnitude, is quite large compared with other changes in the multiplier.

To assess further the relative capabilities of the two forecasting procedures, summary forecast statistics for 1980 to 1982 are presented in table 1. Turning first to the full-period results, the notion that the MSKF procedure, on average, produced better forecasts than the BJ model is corroborated statistically: the mean error (ME) from the MSKF model is 75 percent smaller than the mean error from the BJ model. In both cases, however, the mean error is quite small, indicating very little bias in either forecasting procedure. Indeed, the Theil decomposition statistics indicate that less than 5 percent of the forecast error is due to bias (B). Further, there is a 13 percent reduction in the mean absolute error (MAE) and a 9 percent reduction in the root-mean-squared error (RMSE) for the MSKF procedure relative to the BJ approach. Thus, the evidence in table 1 demonstrates the relative superiority of the MSKF procedure over the BJ method in forecasting the multiplier.

The full-period results indicate that an improvement in the multiplier forecasts can be attained by using the MSKF procedure. This improvement, gauged on a year-by-year basis, varies. For example, in 1980 the reduction in RMSE gained by using the MSKF model is 4 percent; in 1981 it is 26 percent; in 1982, 15 percent. The characteristics of the forecast errors also vary from year to year. For example, in 1981 bias accounted for 42 percent of the BJ forecast error, compared with only 17 percent for the MSKF model. While in 1982 the fraction of error due to bias was reduced for the BJ model from the previous year, this fraction is still higher than that of the MSKF model and, as chart 1 indicates, the BJ procedure underpredicted the actual multiplier more often than the MSKF model.

Given the behavior of the money multiplier, the improved relative performance of the MSKF model in 1981 and 1982 is not too surprising. As indicated in chart 2, 1981 and 1982 were the first years since 1959 in which the money multiplier grew. Over the previous years, there was a consistent negative trend in the multiplier. As we saw before, this trend is significant in the BJ model (−0.002), and its assumed continuation

Chart 1
Box-Jenkins and Multi-State Kalman Filter



marks this forecast procedure. Because the multiplier did not continue to decline, the BJ forecast underpredicted quite frequently.

As suggested, the MSKF model adapts more easily and more rapidly to changing conditions. Thus, it is not too surprising that the MSKF model tends to underpredict the money multiplier less than the BJ model. Probably the most striking feature of the forecasts, given the sharp break in the multiplier trend, is the small degree of bias derived from either forecast procedure.

The forecast evidence on the whole indicates that the MSKF model provides relatively more accurate one-step-ahead forecasts of the money multiplier than the BJ model. It should be noted, however, that this improvement is small relative to the absolute forecast errors. Even so, the evidence suggests that more accurate forecasts of the multiplier can be made; we now consider the policy relevancy of this finding.

MONEY GROWTH: 1980–82

The growth of the money stock during the past few years has been the subject of heated debate. Some have argued that the large swings in money growth

Table 1

Summary Statistics for One-Step-Ahead Multiplier Forecasts: January 1980–December 1982

Summary statistics[1]	1/1980 – 12/1982		1/1980 – 12/1980		1/1981 – 12/1982		1/1982 – 12/1982	
	BJ	MSKF	BJ	MSKF	BJ	MSKF	BJ	MSKF
ME	−0.0036	−0.0009	0.0009	0.0023	−0.0068	−0.0035	−0.0048	−0.0015
MAE	0.0134	0.0116	0.0185	0.0165	0.0083	0.0069	0.0132	0.0115
RMSE	0.0168	0.0153	0.0226	0.0216	0.0106	0.0084	0.0148	0.0129
U	0.0065	0.0059	0.0088	0.0084	0.0041	0.0033	0.0058	0.0050
B	0.0459	0.0035	0.0015	0.0112	0.4200	0.1741	0.1049	0.0132
V	0.0228	0.0021	0.0061	0.0009	0.0332	0.0954	0.0549	0.0262
C	0.9314	0.9944	0.9924	0.9879	0.5468	0.7305	0.8402	0.9606

[1]ME is the mean error; MAE is the mean absolute error; RMSE is the root-mean-squared error; U is the Theil inequality coefficient; B, V and C represent the amount of forecast error due to bias, variation and covariation, respectively, between actual and forecasted series.

Chart 2

Level of the M1 Money Multiplier

resulted from erratic changes in the public's demand for money.[8] Others have suggested that certain technical changes, such as implementing contemporaneous reserve accounting, revising discount rate policy and the restructuring of reserve requirements, must be made in order to better control the money stock.

Table 2 reports the monthly and quarterly growth rates of M1 for the period January 1980 to December 1982. The monthly growth rates indicate a significant degree of variability in the series. During 1980, for example, the average monthly growth rate for M1 was 7.18 percent with a standard deviation of 12.50 percent. This relatively high degree of variability is due primarily to the large downturn in money growth during the February-April period when the special credit controls were implemented.

The years 1981 and 1982 show a reduction in money growth variability. In 1981, the average monthly growth of M1 declined to 6.56 percent with a standard deviation of 5.97 percent. In 1982, average monthly money growth and variability, although smaller than 1980, showed some increase over 1981: money growth averaged 6.56 percent with a standard deviation of 6.80 percent.

The quarterly growth rates in table 2 also indicate an erratic pattern to money growth. During the three years examined, the standard deviations of quarterly M1 growth are 8.60 percent in 1980, 2.85 percent in 1981 and 4.71 percent in 1982.

Table 2
M1 Growth Rates: 1980–82

Period	Monthly growth rate	Period	Quarterly growth rate
1/1980	7.66%		
2/1980	13.66	I/1980	7.03%
3/1980	−1.81		
4/1980	−21.53		
5/1980	6.38	II/1980	−3.84
6/1980	17.27		
7/1980	15.98		
8/1980	23.56	III/1980	16.94
9/1980	17.17		
10/1980	10.69		
11/1980	4.12	IV/1980	9.77
12/1980	−6.97		
1/1981	7.80		
2/1981	9.62	I/1981	4.97
3/1981	13.97		
4/1981	15.73		
5/1981	0.00	II/1981	9.25
6/1981	0.56		
7/1981	6.02		
8/1981	5.41	III/1981	3.17
9/1981	−1.01		
10/1981	−0.55		
11/1981	7.44	IV/1981	3.24
12/1981	13.73		
1/1982	21.47		
2/1982	0.54	I/1982	10.99
3/1982	1.62		
4/1982	1.89		
5/1982	8.60	II/1982	3.22
6/1982	2.68		
7/1982	2.68		
8/1982	10.80	III/1982	6.28
9/1982	13.61		
10/1982	15.22		
11/1982	14.45	IV/1982	13.74
12/1982	11.17		

SIMULATING MONEY GROWTH

It has been argued that policymakers could achieve a more stable pattern of quarterly money growth by implementing the following control procedure:

1) In period t, using all available information, a forecast of the money multiplier for period t+1 is made.
2) Given this forecast and the level of M1 desired in t+1, the amount of adjusted monetary base to support that money stock is determined, and the base is changed to achieve this new desired level. Thus, any deviation of the money stock from the desired level is the result solely of a money multiplier forecast error.
3) In period t+1, the forecast of the multiplier is recalculated for t+2, taking into account money multiplier information available through period t+1.
4) Again in t+1, the adjusted base necessary to achieve the desired money stock in t+2 is calculated.

The process continues month by month, always attempting to achieve the desired level of money stock. Clearly, an accurate money multiplier prediction is important for this control procedure to achieve the

[8]This view is disputed in Scott E. Hein, "Short-Run Money Growth Volatility: Evidence of Misbehaving Money Demand," this *Review* (June/July 1982), pp. 27–36; Kenneth C. Froewiss, "Speaking Softly But Carrying a Big Stick," *Economic Research* (Goldman Sachs, December 1982); and John P. Judd, "The Recent Decline in Velocity: Instability in Money Demand or Inflation?" Federal Reserve Bank of San Francisco *Economic Review* (Spring 1983), pp. 12–19.

Table 3
Simulating M1 Growth Using Box-Jenkins Multiplier Forecast: January 1980–December 1982 (seasonally adjusted)

Period	Targeted M1[1]	Actual multiplier	Forecasted multiplier	Simulated base[1]	Simulated M1[1]	Simulated M1 growth rate	
						Monthly	Quarterly
1/1980	$390.7	2.5955	2.5866	$151.0	$392.0	9.67%	
2/1980	392.3	2.6026	2.5909	151.4	394.1	6.63	5.32%
3/1980	394.0	2.5783	2.5973	151.7	391.1	−8.70	
4/1980	395.7	2.5235	2.5811	153.3	386.9	−12.35	
5/1980	397.4	2.5266	2.5364	156.7	395.8	31.76	2.11
6/1980	399.1	2.5373	2.5270	157.9	400.7	15.77	
7/1980	400.8	2.5508	2.5324	158.3	403.7	9.32	
8/1980	402.5	2.5715	2.5437	158.2	406.9	9.95	12.15
9/1980	404.2	2.5812	2.5620	157.8	407.2	1.02	
10/1980	406.0	2.5837	2.5739	157.7	407.5	0.72	
11/1980	407.7	2.5605	2.5789	158.1	404.8	−7.70	0.65
12/1980	409.4	2.5514	2.5632	159.7	407.5	8.52	
1/1981	416.1	2.5612	2.5523	163.0	417.6	10.50	
2/1981	418.1	2.5698	2.5566	163.6	420.3	8.15	5.10
3/1981	420.2	2.5853	2.5641	163.9	423.6	9.99	
4/1981	422.2	2.5964	2.5775	163.8	425.3	4.83	
5/1981	424.3	2.5870	2.5892	163.9	423.9	−3.87	4.19
6/1981	426.3	2.5789	2.5854	164.9	425.3	3.90	
7/1981	428.4	2.5806	2.5784	166.2	428.8	10.41	
8/1981	430.5	2.5843	2.5778	167.0	431.6	8.11	6.09
9/1981	432.6	2.5834	2.5804	167.6	433.1	4.32	
10/1981	434.7	2.5807	2.5804	168.5	434.8	4.66	
11/1981	436.8	2.5824	2.5784	169.4	437.5	7.81	6.29
12/1981	439.0	2.5918	2.5791	170.2	441.1	10.37	
1/1982	442.0	2.6096	2.5862	170.9	446.0	15.85	
2/1982	443.5	2.5866	2.6012	170.5	441.0	−12.73	6.64
3/1982	444.9	2.5826	2.5882	171.9	444.0	8.42	
4/1982	446.4	2.5689	2.5819	172.9	444.2	0.46	
5/1982	447.9	2.5661	2.5701	174.3	447.2	8.44	2.20
6/1982	449.3	2.5515	2.5649	175.2	447.0	−0.49	
7/1982	450.8	2.5542	2.5528	176.6	451.1	11.51	
8/1982	458.3	2.5603	2.5516	177.2	453.8	7.62	7.20
9/1982	453.8	2.5733	2.5558	177.5	456.9	8.36	
10/1982	455.2	2.5881	2.5665	177.4	459.1	5.93	
11/1982	456.7	2.5987	2.5802	177.0	460.0	2.47	5.58
12/1982	458.2	2.6088	2.5916	176.8	461.3	3.37	

[1]Billions of dollars.

desired money stock objective. In this regard, the MSKF approach should yield a quarterly money stock series of lower variability than the BJ model.

Before examining the simulation results, it must be noted that the control procedure discussed here is not designed to reduce the monthly variability in M1 growth. The objective is to achieve a monthly target and, because the procedure attempts to correct errors in money growth each month, the month-to-month variability in the simulated growth rates may be large. An important feature of this control procedure, however, is that it alters the distribution of monthly growth rates in such a way that growth rate variability over quarterly or longer time horizons is likely to be reduced. Given existing empirical evidence on the relationship between real economic activity and quarterly money growth, success can be measured in terms of the reduction in the variability of both the quarterly money growth series and in economic activity.

Money Growth Simulations: Box-Jenkins Multiplier Forecasts

The money multiplier forecasts generated from the BJ model, reported in table 1, are used to simulate money growth from January 1980 to December 1982.[9] Table 3 summarizes the results using these forecasts and the control procedure described above. The posited M1 growth targets for 1980, 1981 and 1982 are 5.25 percent, 6.00 percent and 4.00 percent, respectively.

The results in table 3 indicate that, on average, the simulated level of M1 is close to the desired amount. The largest discrepancies occur in early 1980, the period of the special credit controls. For example, the simulated level of M1 in April 1980 is more than $8 billion below the targeted level. As explained, the monthly growth rates for the simulated series are expectedly erratic under this control procedure. Compared with the actual M1 growth rate data in table 2, however, the *pattern* of growth rates is quite different. For example, in 1980, actual M1 increased during the first two months at an average rate of 10.7 percent. During the next two months, it declined at an average rate of 11.7 percent. From April to August, M1 steadily increased at an average rate of 15.8 percent and, during the last of the year, increased at a 6.25 percent rate.

[9]It has been argued that the actual pattern of the multiplier and, therefore, the money stock would have been different had the Federal Reserve operated under a monetary control procedure like the one discussed in this study. Two points need to be made: First, this argument can be raised against all simulation experiments. Their purpose, after all, is to investigate the outcomes under different sets of conditions. There is generally no way to determine the validity or usefulness of this criticism.

Second, this argument is based on the assumption that multiplier forecasts are rendered useless by the endogeneity of the monetary base during the multiplier forecasting period. This problem has been examined by Lindsey (and others) and found to affect the reliability of the type of multiplier forecast procedures employed here. In a recent paper, however, Brunner and Meltzer have shown that these assertions are highly questionable. For alternative views, see David Lindsey and others, "Monetary Control Experience Under the New Operating Procedures," in *New Monetary Control Procedures, Vol. 2*, Federal Reserve Staff Study (February 1981); and Karl Brunner and Allan H. Meltzer, "Strategies and Tactics for Monetary Control," in *Carnegie-Rochester Conference Series, Vol. 18* (1983), pp. 59–104.

Table 4
Variability of Actual and Simulated M1 Growth[1]

	Monthly			Quarterly		
		Simulated using:			Simulated using:	
Period	Actual	BJ	MSKF	Actual	BJ	MSKF
1980	12.49%	12.04%	12.90%	8.62%	5.12%	4.15%
1981	5.97	4.16	4.06	2.85	0.97	1.26
1982	6.80	7.24	7.51	4.71	2.24	1.84

[1]Variability measured by standard deviation of growth rates.

Simulated M1 based on the BJ multiplier forecasts increases at a slower 8.2 percent rate in early 1980, then declines at a 10.5 percent rate from February through April. In May, the simulated M1 figure rebounds sharply as the procedure attempts to offset the errors of the previous two months: during the period April to August, simulated M1 growth averages 16.7 percent. Finally, in contrast to the 6.25 percent rate of actual M1 growth during the final four months of 1980, simulated M1 averages only a 0.64 percent rate of growth.

The volatility of the simulated monthly growth rates continues throughout the sample. For comparison, the variability of the actual and simulated money growth series are reported in table 4. In each year, the variability of the simulated growth rate series is about the same as the actual growth rate of money.

Reducing the *monthly* variability of money growth, however, is not the goal of the procedure. One aim is a reduction in quarterly growth rate variability. Judging from the evidence in table 3, the approach used here does exactly that.[10] Note that throughout the period the swings in quarterly growth rates are reduced. For instance, actual M1 growth ranges from 16.94 percent in III/1980 to −3.84 percent in IV/1980. The corresponding figures for simulated M1 growth are less volatile, varying between 12.15 percent in III/1980 and 0.65 percent in IV/1980.

[10]It should be noted that the first-quarter growth rates of the simulated series are measured from the actual level of money in the previous quarter. This reflects the common "forgiveness principle" of adjudging money growth from its actual level as opposed to the desired level.

Table 5
Simulating M1 Growth Using MSKF Multiplier Forecast: January 1980–December 1982 (seasonally adjusted)

Period	Targeted M1[1]	Actual multiplier	Forecasted multiplier	Simulated base[1]	Simulated M1[1]	Simulated M1 growth rate	
						Monthly	Quarterly
1/1980	$390.7	2.5955	2.5889	$150.9	$391.7	8.53%	
2/1980	392.3	2.6026	2.5944	151.2	393.6	6.02	4.81%
3/1980	394.0	2.5783	2.6009	151.5	390.6	−8.74	
4/1980	395.7	2.5235	2.5796	153.4	387.1	−10.25	
5/1980	397.4	2.5266	2.5244	157.4	397.7	38.54	3.40
6/1980	399.1	2.5373	2.5260	158.0	400.9	9.87	
7/1980	400.8	2.5508	2.5345	158.1	403.4	7.74	
8/1980	402.5	2.5715	2.5475	158.0	406.3	9.06	10.59
9/1980	404.2	2.5812	2.5683	157.4	406.2	−0.14	
10/1980	406.0	2.5837	2.5799	157.4	406.5	0.86	
11/1980	407.7	2.5605	2.5834	157.8	404.1	−7.03	0.78
12/1980	409.2	2.5514	2.5626	159.8	407.6	11.14	
1/1981	416.1	2.5612	2.5524	163.0	417.5	10.44	
2/1981	418.1	2.5698	2.5605	163.3	419.6	6.24	4.62
3/1981	420.2	2.5853	2.5690	163.6	422.8	9.52	
4/1981	422.2	2.5964	2.5840	163.4	424.2	4.05	
5/1981	424.3	2.5870	2.5954	163.5	422.9	−3.74	3.87
6/1981	426.3	2.5789	2.5876	164.8	424.9	5.84	
7/1981	428.4	2.5806	2.5796	166.1	428.6	10.94	
8/1981	430.5	2.5843	2.5805	166.8	431.1	7.33	6.50
9/1981	432.6	2.5834	2.5840	167.4	432.5	3.88	
10/1981	434.7	2.5807	2.5834	168.3	434.2	4.94	
11/1981	436.8	2.5824	2.5810	169.2	437.1	8.03	6.22
12/1981	439.0	2.5918	2.5822	170.0	440.6	10.12	
1/1982	442.0	2.6096	2.5911	170.6	445.2	13.25	
2/1982	443.5	2.5866	2.6083	170.0	439.8	−13.59	6.00
3/1982	444.9	2.5826	2.5880	171.9	444.0	12.12	
4/1982	446.4	2.5689	2.5830	172.8	444.0	−0.18	
5/1982	447.9	2.5661	2.5699	174.3	447.2	9.13	2.69
6/1982	449.3	2.5515	2.5664	175.1	446.7	−1.26	
7/1982	450.8	2.5542	2.5525	176.6	451.1	12.45	
8/1982	452.3	2.5603	2.5541	177.1	453.4	6.21	6.98
9/1982	453.8	2.5733	2.5599	177.2	456.1	7.53	
10/1982	455.2	2.5881	2.5725	177.0	458.0	5.02	
11/1982	456.7	2.5987	2.5872	176.5	458.8	1.98	4.86
12/1982	458.2	2.6088	2.5981	176.4	460.1	3.64	

[1]Billions of dollars.

This reduction in quarterly money growth volatility is made clearer in table 4. There we see that the volatility of the quarterly money growth derived from the BJ multiplier forecasts is appreciably smaller than the actual. In fact, in 1981 and 1982, the volatility of simulated quarterly M1 growth is less than one-half that of actual M1 growth. Thus, in terms of reducing quarterly fluctuations in money growth, the control procedure using the BJ multiplier forecasts is quite successful.

Money Growth Simulations: MSKF Multiplier Forecasts

The outcome from using the MSKF multiplier forecasts to simulate M1 growth is reported in table 5. Similar to the results using the BJ multiplier forecasts, the simulated M1 growth rates in table 5 exhibit a large degree of monthly variation. Again, in contrast to actual M1 growth, the distribution of monthly growth rates reveals the procedure's attempt to correct deviations from the desired M1 path. As reported in table 4, the monthly money growth derived from the MSKF forecasts is more variable than either actual money growth or the BJ simulations in 1980 and again in 1982.

This monthly volatility, however, again translates into a more stable pattern of quarterly M1 growth. Recall that, during the second half of 1980, simulated M1 growth based on BJ multiplier forecasts varied from 0.65 percent to 12.15 percent. Over this period, the MSKF-based figures range from 0.78 percent to 10.59 percent. As shown in table 4, quarterly M1 simulated using the MSKF forecasts is less volatile than that using the BJ multiplier forecasts in 1980 and 1982. This suggests that the MSKF approach provides a steadier path of quarterly money growth than the BJ approach.

The evidence indicates that stable quarterly money growth can be achieved by making use of the multiplier forecasting techniques implemented here. Based on our empirical results, the simulated quarterly money growth series were, on average, about 50 percent less variable than actual M1 growth during the past few years. Moreover, the simulated series generally came quite close to hitting the desired M1 growth target. As shown in table 6, both simulated money series missed the annual growth targets by only one percentage point, on average.

MONEY GROWTH AND ECONOMIC ACTIVITY

Large fluctuations in quarterly M1 growth have led some observers to conclude that the pattern of economic activity during the 1980–82 period is attributable largely to volatile monetary policy actions. Indeed, empirical evidence for the United States and other countries suggests a close association between substantial short-run declines in money growth from its trend and the pace of economic activity.[11] During our sample, such deviations occurred in early 1980 and again in 1981. In this regard, reducing money growth fluctuations, everything else equal, should produce more stable economic growth. To examine this hypothesis, the following experiment was conducted: First, a standard, St. Louis type of reduced-form equation for nominal GNP growth was estimated over the period I/1960 to IV/1979. Then, using the estimated coefficients, GNP growth was simulated for the period I/1980 to IV/1982. Three simulation runs were made: one with actual M1 growth, one with the posited path of M1 and one based on M1 growth from the MSKF money growth simulations. (The BJ simulations are omitted because they were so similar to the MSKF.)

The simulated GNP growth rates for each experiment are reported in table 7.[12] The volatility of actual M1 growth is evident in the consequent fluctuations of GNP growth, especially in 1980 when GNP growth fluctuated from 6.81 percent to 12.69 percent. For the whole period, nominal GNP growth simulated with actual money growth averages 10.46 percent with a standard deviation of 1.94 percent.

The pattern of GNP growth simulated under the posited M1 path of 5.25 percent growth in 1980, 6.0

Table 6
Comparison of Desired and Simulated M1 Growth Rates

Period	Desired M1 growth	Simulated M1 growth using: MSKF	BJ
IV/1979–IV/1980	5.25%	4.82%	4.96%
IV/1980–IV/1981	6.00	7.69	7.67
IV/1981–IV/1982	4.00	4.96	5.10

[11]Historical evidence on this point for the United States is presented in Clark Warburton, "Bank Reserves and Business Fluctuations," *Journal of the American Statistical Association* (December 1948), pp. 547–58; Milton Friedman and Anna J. Schwartz, "Money and Business Cycles," *Review of Economics and Statistics* (Supplement: February 1963), pp. 32–78; and William Poole, "The Relationship of Monetary Decelerations to Business Cycle Peaks: Another Look at the Evidence," *Journal of Finance* (June 1975), pp. 697–712. An analysis of more recent data for the United States along with several other countries can be found in Dallas S. Batten and R. W. Hafer, "Short-Run Money Growth Fluctuations and Real Economic Activity: Some Implications for Monetary Targeting," this *Review* (May 1982), pp. 15–20.

[12]The equation used to generate the simulations is (t-statistics in parentheses):

$$\underset{}{\dot{Y}_t} = \underset{(2.14)}{2.507} + \underset{(5.34)}{1.052} \sum_{i=0}^{4} \beta_i \dot{M}_{t-i} + \underset{(0.68)}{0.068} \sum_{i=0}^{4} \delta_i \dot{E}_{t-i}$$

$$\bar{R}^2 = 0.33 \qquad SE = 3.52 \qquad DW = 1.95$$

where $\dot{Y}$ is nominal GNP growth, $\dot{M}$ is the growth of M1 and $\dot{E}$ is the growth of high-employment government expenditures. The equation is estimated for the period I/1960–IV/1979 using a fourth-order Almon polynomial lag for each of the explanatory variables with endpoints constrained. All simulations use actual $\dot{E}$.

Table 7
Simulated Quarterly GNP Growth Rates: I/1980–IV/1982

			Simulated values derived from:
Period	Actual M1	Desired M1	MSKF
I/1980	11.06%	10.50%	10.37%
II	6.81	8.98	8.24
III	9.81	9.04	9.90
IV	12.69	9.23	9.26
I/1981	12.70	9.24	8.41
II	12.12	8.89	7.13
III	10.41	9.96	8.41
IV	9.05	10.23	9.79
I/1982	9.15	8.37	8.98
II	8.47	7.23	7.69
III	10.18	8.16	9.16
IV	13.04	8.57	9.80
Mean	10.46	9.03	8.93
Standard deviation	1.94	0.92	0.98

percent growth in 1981 and 4.0 percent growth in 1982 is very different from that simulated with actual M1 growth. For one thing, the average GNP growth simulated with actual money is almost 1.5 percentage points above that simulated with the desired path. It is only in II/1980 and IV/1981 that GNP growth based on actual money is less than GNP growth based on desired money. In addition to the difference in mean growth rates, there is also a sizeable difference in the volatility of GNP growth under the alternative simulations. As measured by the standard deviation of GNP growth, the simulations with actual money show more than twice the volatility than the simulations with desired money yield.

Comparisons between simulations using actual and desired money growth presumes that the desired money growth easily can be achieved. As we have seen, however, the Fed cannot totally control money growth from one quarter to the next. How serious a problem is this? Would this lack of precise control make it difficult to achieve a less volatile GNP growth objective?

To examine this issue, the GNP equation was simulated using the M1 growth rates that resulted from the MSKF money multiplier forecasting control procedure. These simulated GNP growth rates are shown in the third column of table 7. There is surprisingly little difference between the GNP growth simulated using desired M1 growth and M1 growth resulting from the forecast/control procedure. The average level of GNP growth under the desired M1 growth scenario is 9.03 percent, compared with 9.08 percent under the MSKF procedure. The standard deviation of simulated GNP growth is less than one percent in both cases — about one-half that associated with actual M1 growth. In addition, the simulated GNP path using the quarterly growth of money derived from the MSKF forecast procedure usually is within one percentage point of the simulated GNP path using desired M1 growth.

SUMMARY AND CONCLUSION

This paper has examined two alternative procedures to forecast the M1 multiplier. The multiplier was forecast one period ahead for the 1980–82 sample period using both a Box-Jenkins and a Multi-State Kalman Filter forecast procedure. The evidence from the multiplier forecasts shows the MSKF procedure to be an improvement over the BJ procedure. For example, the MSKF yielded a root-mean-squared error about 9 percent smaller than the BJ procedure for the whole period, with even greater reduction in forecast error in 1981 and 1982.

Both forecasts of the multiplier then were used to simulate M1 growth. These simulations resulted in volatile monthly growth rates, but relatively stable quarterly growth rates. There was, in fact, little difference between the simulated M1 growth rates, suggesting that forecasting the multiplier with great accuracy may not be as important as aiming for a steady long-run growth rate.

The paper also examined the importance of money stock control by simulating GNP growth under the hypothetical desired path, as well as the M1 growth simulated under the MSKF forecast/control procedure. There was only a minor difference in these simulations; quarterly GNP growth usually did not differ by more than one percentage point. This indicates that the money multiplier forecast/control procedure used in this article could be successful in achieving more stable GNP growth.