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W. DOUGLAS McMILLIN

Money Growth Volatility and the Macroeconomy

1. INTRODUCTION

CRITICS OF ACTIVIST MONETARY POLICY designed to offset shocks to the macroeconomy frequently argue that erratic monetary policy raises the level of uncertainty and thereby affects the level of economic activity. The effects of volatile money growth (using an explicit measure of money growth variability) on variables like interest rates, output, and nominal GNP have been analyzed empirically in recent years by Mascaro and Meltzer (1983), Evans (1984), Belongia (1984), and Tatom (1984, 1985). No doubt these studies were stimulated by the dramatic increase in the variability of money growth following the October, 1979, change in operating procedures by the Federal Reserve.[1]

The aim of this study is to analyze empirically the effects of variability in money growth on the U.S. economy over the period 1961:I–1984:IV. Unlike earlier

[1] For example, the mean of an eight-quarter moving standard deviation of quarterly $M1$ growth over the period 1961:I–1979:III is 0.0044. For the period 1979:IV–1982:III (when the Federal Reserve moved to a nonborrowed reserve operating procedure), the mean of the same series is 0.0108. For the borrowed reserve operating procedure period (1982:IV–1984:IV), the mean is 0.0096, which is less than the period in which the Federal Reserve's operating procedure focused upon nonborrowed reserves in an environment of lagged reserve accounting, but is still more than twice the value over the 1961:I–1979:III period.

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studies which have focused upon one variable like the interest rate or output, this study examines the effects of variability in money growth within a vector autoregressive (VAR) model of the macroeconomy which includes output, the price level, the long-term interest rate, a supply shock variable, money, federal purchases of goods and services, a federal tax measure, and a measure of the variability in money growth. The VAR modeling technique is employed rather than a structural model, since VAR models avoid imposing potentially spurious a priori constraints (like, for example, econometric exogeneity of money in an interest rate or output equation) on the model. Fischer (1981) points out that VARs allow one to capture empirical regularities in the data and to thereby gain insight into the channels through which, in this particular instance, volatile monetary policy operates. Furthermore, Sims (1982, p. 138), in a discussion of his VAR results, argues that "careful attention to the historical data exerts an important discipline on what can be plausibly asserted about the way the economy works."

As is well known, however, the VAR method is a reduced-form technique and it is often difficult, based upon VAR results, to distinguish sharply among structural hypotheses. Some uses of VARs have been examined critically by Cooley and LeRoy (1985) and Leamer (1985). Although they are critical of many common uses of VARs, Cooley and LeRoy note, as does Eichenbaum (1985), that there are valid uses of VARs. These include forecasting, the description of the cyclical behavior of a system, the generation of stylized facts about the behavior of the elements of the system which can be compared with existing theories or can be used in formulating new theories, and the testing of theories that generate Granger-causality implications. This study can be regarded as being in the spirit of searching for empirical regularities among the system's variables. To achieve this end, variance decompositions and historical decompositions for the period 1979:IV–1984:IV are computed and analyzed.

In section 2 of the paper the theoretical linkages between variability in money growth and the macroeconomy are briefly discussed as is the available empirical evidence on the effects of money growth variability. In section 3 the specification of the VAR and the empirical results are discussed, and section 4 provides a summary and conclusions.

2. THEORY AND PREVIOUS EMPIRICAL EVIDENCE

The theoretical rationale often advanced for studying the macro effects of volatile money growth is that money growth variability increases the variability of interest rates which in turn increases the risk of holding bonds (see, for example, Mascaro and Meltzer 1983 and Evans 1984). This increased risk of holding bonds raises money demand and hence the general level of interest rates; as a result, investment and output fall.

Tatom (1984, 1985) suggests other channels through which money growth variability might affect the macroeconomy. On the demand side, Tatom notes that variability in money growth may directly reduce investment demand (i.e., shift the investment demand schedule) by reducing the predictability of income streams associated with investment projects and hence increasing their riskiness. Although this shift in investment demand tends to offset the rise in interest rates brought about by higher money demand, both effects tend to reduce aggregate demand. The reduction in aggregate demand would, other things equal, reduce prices, raise the real money supply, and put further downward pressure on the interest rate. In addition, Tatom points out that aggregate supply will be reduced since the increased risk to the firm generated by the increase in variability of returns to production can be lessened by cutting back production and the capital used in production. The decrease in aggregate supply reinforces the effects of the decrease in aggregate demand on output, and tends to raise interest rates since, other things equal, lower aggregate supply raises prices, thereby reducing the real money supply and raising interest rates. The decline in aggregate demand and supply unambiguously reduces output, but the effect on the price level depends upon the relative magnitudes of the declines in aggregate demand and supply. The effect on the level of interest rates is also ambiguous, although the presumption in most studies is that the interest rate will rise.

With the apparent exception of Evans (1984), many of the previous studies that have examined the effects of variability in money growth have found evidence of a significant effect of this variability on the performance of the macroeconomy. In the context of a portfolio-theoretic framework in which money, bonds, and capital are treated as distinct assets, Mascaro and Meltzer (1983) find that increases in unanticipated money growth variability raise both short- and long-term interest rates over the periods 1969:IV–1979:III and 1969:IV–1981:IV. Belongia (1984) finds that unanticipated money growth variability has a significant negative effect on the growth rate of nominal GNP within the context of a St. Louis-type equation.

However, Evans (1984), within the context of a Barro-type output equation, finds that interest rate variability affects output while unanticipated money growth variability does not. Tatom (1985) constructs an alternative money growth variability measure that better reflects the short-run variability of money growth than does Evans' measure. He finds that his money growth variability measure significantly and positively affects interest rate variability and that interest rate variability significantly and negatively affects output at the same time it significantly and positively affects the price level. On balance, the thrust of the available evidence is that money growth variability has significant macroeconomic effects.

3. MODEL SPECIFICATION AND EMPIRICAL RESULTS

As mentioned in section 1, the effects of variability in money growth on the macroeconomy are analyzed within the context of a VAR model which employs a common lag for all variables in all equations.[2] The model variables include real gross national product (y), which reflects the 1985 rebenchmarking of the data in the national income accounts; the gross national product deflator (P), with 1982 = 100; the narrowly defined money supply ($M1$); real federal purchases of goods and services (g); a tax variable, the ratio of real federal net taxes to real gross national product (tx); a supply shock variable (ss), which is the difference between the rate of change in the producer price index for crude oil and the rate of change in the gross national product deflator; Moody's AAA corporate bond rate (AAA); and a measure of the volatility of money growth (to be described momentarily). With the exception of the measure of variability in money growth, the model variables are those typically included in a simple macro model and were taken from Citibase.

Accumulating evidence (see, for example, Rasche and Tatom 1981, Hamilton 1983, Wilcox 1983, and Gisser and Goodwin 1986) suggests that supply shocks such as changes in the relative price of oil have significant effects on a variety of macro variables. Based upon this evidence, a supply shock variable is included in the system to avoid omitting an important determinant of macro performance. The long-term interest rate rather than a short-term rate is included since it is typically thought that investment decisions depend more closely upon the long-term rate than the short-term rate. Given the importance of investment spending in the theoretical analyses of the impact of policy variability on output and prices, it seems appropriate to focus upon the rate most relevant to investment decisions.

Based upon the recent argument of Tatom (1986), federal purchases of goods and services are adjusted for Commodity Credit Corporation (CCC) purchases of farm products. CCC purchases redistribute farm products from private inventories to government inventories. If this redistribution were done solely within the private sector, neither inventory investment nor final sales would be altered. However, these CCC purchases are treated as final sales to the federal government and hence raise federal purchases in the National Income and Product Accounts (NIPA). At the same time measured private sector inventory investment is reduced. Thus distortions are introduced into the measurement of federal purchases of goods and services and into farm inventory investment. Tatom (1986) shows that the magnitude of recent CCC purchases has materially affected growth in real federal purchases, farm inventory investment, and final sales. As a consequence, CCC purchases are subtracted from the NIPA measure of federal purchases and the resulting measure is the federal purchases series used in this paper.

Based upon the recent evidence of Nelson and Plosser (1982) and Stulz and

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[2] An alternative method of specifying the VAR model has been suggested by Hsiao (1981). This procedure is not used here since the sensitivity of the results reported in the text are checked by estimating several alternative VAR models, and use of the Hsiao technique, because of the time required to properly specify the model, would have severely limited the sensitivity analysis.

Wasserfallen (1985), y, P, $M1$, and g are transformed prior to specification and estimation of the VAR by taking the first difference of the log of these variables. AAA and tx are transformed by taking the first difference of these variables. The variability of money growth, $SDM1$, is measured as an eight-quarter moving standard deviation of the quarterly growth in $M1$. Specifically,

$$SDM1_t = [(1/8) \sum_{i=1}^{8} (DLM1_{t-i} - \overline{DLM}1_t)^2]^{1/2} \qquad (1)$$

where $SDM1_t$ = the standard deviation of the change in the log of $M1$, $DLM1_{t-i}$ = the change in the log of $M1$ in quarter $t-i$, and $\overline{DLM}1_t$ = the mean of the change in the log of $M1$ over the previous eight quarters ($\overline{DLM}1_t = (1/8) \sum_{i=1}^{8} DLM1_{t-i}$). This is similar to measures used in previous studies, and it captures much of the intrayear variation in the growth of $M1$.[3] As noted in footnote 1, $SDM1$ rises sharply for the nonborrowed reserve operating regime (1979:IV–1982:III) relative to the period 1961:I–1979:III. The value of $SDM1$ for the borrowed reserves operating regime (1982:IV–1984:IV) is less than for the nonborrowed reserves operating regime but is still more than twice the value for 1961:I–1979:III.

However, since theory predicts that a money growth variability measure like $SDM1$ should affect the level of the interest rate and since theory also predicts that changes in money growth or inflation affect the level of the interest rate, the system was also estimated with AAA in level, rather than first difference, form.[4] Results for both systems are reported.

Following Lutkepohl (1982), Akaike's AIC criterion is used to determine the lag length of the VAR model. The lag length chosen is the one that minimizes

$$AIC(k) = \ln \det \Sigma_k + (2d^2k)/T, \qquad (2)$$

$k = 1,\ldots, m$ where d = the number of variables in the system, m = maximum lag length considered (set to eight quarters[5]), $\det \Sigma_k$ = determinent of Σ_k, and Σ_k = estimated residual variance-covariance matrix for lag k. Use of the AIC criterion suggested a lag of eight quarters for the estimation period 1961:I–

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[3] In order to check the sensitivity of the results to the measure of money growth volatility, a four-quarter moving standard deviation of the quarterly growth in money ($SD4M1$) was also employed. The variance decomposition results for this measure of money growth volatility are reported briefly in footnote 10.

[4] However, tests of the hypothesis that AAA has a first-order unit root of the type described by Stulz and Wasserfallen (1985) indicated that the hypothesis could not be rejected. Details are available on request.

[5] Given the relatively large number of variables in the model (8), it was felt that considering a maximum lag of greater than eight quarters would undesirably reduce the degrees of freedom for estimation.

1984:IV for both the model with *AAA* in first difference form and the model with *AAA* in level form.[6,7]

Since the VAR model is a reduced-form model, it is very difficult to interpret the individual coefficients of the model and these coefficients are not reported here but are available upon request. However, the sums of the coefficients for each variable in each equation and their associated standard errors are presented in Table 1. For both the model with *AAA* in first difference form and the model with *AAA* in level form, the *sum* of the coefficients on *SDM*1 in the *y* equation is significantly negative, while the *sums* of coefficients on *SDM*1 in the *P* and *AAA* equations are not significantly different from zero. However, as Sims (1972) has pointed out, the absolute sizes of the coefficients on a variable like *SDM*1 are important no matter what the *F*-tests indicate. He contends that coefficients that are economically important should not be set to zero and ignored even if they are found to be statistically insignificant, and he further notes that coefficients that are statistically significant may be so small that they are not economically significant. Thus, since the variance decompositions and historical decompositions reported later are based on the moving average representation of the system, and since the moving average representation reflects the sizes of the estimated coefficients, the results of the variance decompositions and historical decompositions are used to judge the economic significance of *SDM*1. As the results reported below demonstrate, nonsignificance of the sum of coefficients does not indicate that a variable does not have important effects in the system.

In estimating the VAR, it is assumed that the macroeconomy may be treated as being stable over the period of estimation, and it is felt that the inclusion of the volatility measure for money growth makes this assumption more credible. It is further assumed that policymakers' behavior in relation to the other variables in the macro model was consistent over the estimation period. Although the Lucas critique is potentially applicable, an appeal is made to Sims' (1982, p. 138) argument that "the U.S. postwar data contain enough information to give a useful characterization of the conditional distribution of the future of major macroeconomic aggregates given the past. Although there is evidence that this structure changes over time, there is also evidence that it does not change suddenly, so that a model fit to the whole period is not badly biased because of parameter changes."[8]

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[6] *Q*-statistics for the eight-lag systems indicated the absence of serial correlation.

The eighth lag for 1961:I is 1959:I. The data published by the Federal Reserve for the current definition *M*1 begins in 1959:I. In order to obtain a growth rate measure for *M*1 for 1959:I and a value for *SDM*1 for 1959:I, data for the current definition of *M*1 for the period 1953:I–1958:IV were generated in the following manner. The current definition of *M*1 was regressed on old *M*1 (currency + demand deposits) for the period in which data on the two measures overlap. The estimated coefficients from this regression in conjunction with the values of old *M*1 for 1953:I–1958:IV were used to generate values for the current definition of *M*1 for 1953:I–1958:IV.

[7] Since the *AIC* criterion suggested the optimal lag was the maximum considered, the systems were also estimated with the lag set to nine quarters. The VDC results for *SDM*1 reported in Table 2 and 3 were not substantially altered; these results are available on request.

[8] In fact, when the system is estimated over the period 1961:I–1979:III and variance decompositions are computed, the results for *SDM*1 are quite comparable to those for the full period for

TABLE 1

Sums of Coefficients in the VAR Equations

A. Model with AAA in First-difference Form

Coefficient Sums for	Equation							
	y	*P*	*ss*	*AAA*	*M*1	*SDM*1	*g*	*tx*
y	-2.30	-0.18	3.43	-70.38	-0.26	-0.25	1.83	0.05
	(0.86)	(0.46)	(4.39)	(39.37)	(0.53)	(0.11)	(2.11)	(0.57)
P	-1.95	0.62	3.54	-48.28	0.04	-0.20	0.28	0.11
	(0.62)	(0.33)	(3.18)	(28.56)	(0.39)	(0.08)	(1.53)	(0.41)
ss	0.03	0.03	0.35	3.54	-0.06	0.01	0.12	-0.01
	(0.08)	(0.04)	(0.43)	(3.81)	(0.05)	(0.01)	(0.20)	(0.05)
AAA	-0.03	0.0003	-0.03	-0.21	-0.008	-0.0002	0.02	-0.0006
	(0.01)	(0.01)	(0.06)	(0.55)	(0.01)	(0.002)	(0.03)	(0.01)
*M*1	1.50	0.34	-1.09	46.60	1.00	0.20	-0.42	-0.02
	(0.56)	(0.30)	(2.87)	(25.32)	(0.35)	(0.07)	(1.38)	(0.37)
*SDM*1	-3.42	-0.60	1.79	-91.24	-0.94	0.54	2.26	-0.33
	(1.18)	(0.63)	(6.02)	(53.97)	(0.73)	(0.15)	(2.90)	(0.78)
g	0.04	-0.004	0.09	3.88	0.10	0.03	0.50	0.11
	(0.11)	(0.06)	(0.57)	(5.16)	(0.07)	(0.01)	(0.28)	(0.07)
tx	0.75	0.35	0.20	104.98	0.28	0.04	-3.69	-0.66
	(1.02)	(0.54)	(5.21)	(46.70)	(0.63)	(0.13)	(2.51)	(0.67)

B. Model with AAA in Level Form

Coefficient Sums for	Equation							
	y	*P*	*ss*	*AAA*	*M*1	*SDM*1	*g*	*tx*
y	-3.03	0.15	3.21	-66.36	-0.34	-0.30	0.34	-0.04
	(0.87)	(0.45)	(4.75)	(41.24)	(0.55)	(0.11)	(2.12)	(0.60)
P	-3.03	1.12	3.07	-42.60	-0.07	-0.29	-1.93	-0.02
	(0.71)	(0.37)	(3.90)	(33.81)	(0.45)	(0.09)	(1.74)	(0.49)
ss	-0.06	0.07	0.29	4.02	-0.07	0.002	-0.08	-0.02
	(0.09)	(0.05)	(0.48)	(4.17)	(0.06)	(0.01)	(0.21)	(0.06)
AAA	-0.004	-0.002	0.004	0.98	0.0005	-0.0004	0.009	-0.0004
	(0.002)	(0.001)	(0.009)	(0.08)	(0.001)	(0.0002)	(0.004)	(0.001)
*M*1	0.94	0.62	-2.25	47.85	0.92	0.14	-1.63	-0.05
	(0.60)	(0.32)	(3.32)	(28.77)	(0.38)	(0.08)	(1.48)	(0.42)
*SDM*1	-6.81	0.91	1.50	-71.28	-1.27	0.27	-4.58	-0.81
	(1.56)	(0.81)	(8.53)	(74.04)	(0.99)	(.20)	(3.80)	(1.07)
g	0.08	-0.01	-0.22	3.07	0.10	0.03	0.56	0.13
	(0.10)	(0.05)	(0.57)	(4.98)	(0.07)	(0.01)	(0.26)	(0.07)
tx	1.72	-0.09	0.66	99.92	0.39	0.12	-1.69	-0.53
	(1.04)	(0.54)	(5.72)	(49.67)	(0.66)	(0.13)	(2.55)	(0.72)

Note: Standard errors are in parentheses.

The effects of variability in money growth are evaluated by examining variance decompositions (VDCs) and historical decompositions (HDs). VDCs show the proportion of forecast error variance for each variable that is attributable to its own innovations and to shocks to the other system variables. VDCs capture both direct and indirect effects. Sims (1982) has argued that the strength of Granger-causal relations can be measured by VDCs. Sims (1982, p. 131) pointed

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ordering (1) (defined later in the text). For ordering (2), the effects of *SDM*1 on *AAA*, *y*, and *P* are often stronger than for the full period. These results are available on request.

out that "a variable that is optimally forecast from its own lagged values will have all its forecast error variance accounted for by its own innovations." For example, if *SDM*1 explains only a small portion of the forecast error variance of y, this could be interpreted as a weak Granger-causal relation.

HDs are used to assess the impact of the monetary and fiscal variables on output, the price level, and the interest rate over the period 1979:IV–1984:IV. The beginning of this period coincides with the introduction of the nonborrowed reserve operating regime and the subsequent sharp rise in money growth volatility. As noted by Burbidge and Harrison (1985), the HD assigns credit for the difference between what can be called the base projection for a series and the actual series to the shocks to the system's variables. The extent to which the shocks to a particular variable or a particular set of variables close the gap between the base projection and the actual series is a measure of the importance of that variable or that set of variables.

Like VDCs, HDs are based upon the moving average representation of the VAR. The moving average representation of the VAR can be written as

$$\mathbf{x}_t = \sum_{i=0}^{\infty} \mathbf{M}_i \mathbf{u}_{t-i} \tag{3}$$

where $\mathbf{x}_t$ = column vector of the variables in the system, $\mathbf{u}_{t-i}$ = column vector of shocks to the elements of x in period $t-i$, and $\mathbf{M}_i$ = matrix of impulse response weights conformible to the dimensions of x and u. Consider now a base period which runs from observation 1 to observation T. The value of x in periods subsequent to T can be written as

$$\mathbf{x}_{T+j} = \sum_{i=j}^{\infty} \mathbf{M}_i \mathbf{u}_{T+j-i} + \sum_{i=0}^{j-1} \mathbf{M}_i \mathbf{u}_{T+j-i} \tag{4}$$

where $\sum_{i=j}^{\infty} \mathbf{M}_i \mathbf{u}_{T+j-i}$ = base projection or forecast of $\mathbf{x}_{T+j}$ based only upon information available at time T, and $\sum_{i=0}^{j-1} \mathbf{M}_i \mathbf{u}_{T+j-i}$ = the part of x accounted for by shocks since T. The elements of the second term are used to determine the extent to which shocks to a particular variable(s) close(s) the gap between $\mathbf{x}_{t+j}$ and the first term.

Since no contemporaneous terms enter the equations of the VAR, any contemporaneous relations among the variables are reflected in the correlation of residuals across equations. In calculating the VDCs and HDs, the variables are ordered in a particular fashion, and the variance-covariance matrix is orthogonalized by the Choleski decomposition. Because of the cross-equation residual correlation, when a variable higher in the order changes, variables lower in the order are assumed to change. The extent of the change depends upon the covariance of the variables higher in the order with those lower in the order. The orderings considered are (1) *ss*, *g*, *tx*, *M*1, *SDM*1, *AAA*, *y*, *P*; (2) *ss*, *M*1, *SDM*1, *g*, *tx*, *AAA*, *y*, *P*; (3) *ss*, *g*, *tx*, *M*1, *SDM*1, *y*, *P*, *AAA*; (4) *ss*, *M*1, *SDM*1, *g*, *tx*, *y*, *P*, and *AAA*; (5) *ss*, *y*, *P*, *g*, *tx*, *M*1, *SDM*1, *AAA*; and (6) *ss*, *y*, *P*, *M*1, *SDM*1, *g*, *tx*, *AAA*.

The rationale for these orderings is based upon the following considerations. The supply shock variable, *ss*, is placed first based upon the assumption that contemporaneous shocks to the relative price of oil stem more from developments in world oil markets than from shocks to policy variables, the interest rate, domestic output, or the aggregate price level. In orderings (1) and (2) the goods market variables—output and the aggregate price level—are placed last in the ordering, with the interest rate preceding the goods market variables. The monetary and fiscal policy variables—including the volatility measure—precede the interest rate. This allows innovations in *ss* and the policy variables to contemporaneously alter the interest rate and it allows shocks to *ss*, the policy variables, and the interest rate to alter the goods market variables. In terms of the policy variables, the appropriate order is more difficult to determine. In ordering (1), the fiscal variables precede the monetary policy variables. This allows the monetary authorities to be affected by or to respond to fiscal policy developments, which does not seem unreasonable in light of the relative flexibility of implementation of monetary policy as compared to fiscal policy. However, in ordering (2), the monetary policy variables precede the fiscal variables. Similar theoretic and institutional considerations guide the selection of orderings (3) and (4) except that the interest rate is placed last based upon the efficient markets argument of Gordon and Veitch (1984). They suggest putting the interest rate last since this allows all other variables in the system to contemporaneously affect the interest rate.[9] In orderings (5) and (6), the goods market variables precede the monetary and fiscal policy variables which allows the policy variables to contemporaneously respond to the goods market variables.

The VDCs for ordering (1) for the system with the first difference of *AAA* are presented in Table 2. Since the ordering does not have substantial effects on the results for *SDM*1, only results for ordering (1) are discussed. Results for other orderings are available on request. The biggest effects of *SDM*1 are on *AAA*; *SDM*1 explains 22 percent of the first-quarter variation in *AAA*, and the effect tapers off to 15 percent at the end of twenty quarters. The effects of *SDM*1 on *y* and *P* build up over time. About 5 percent of the first-quarter variation in *y* is explained by *SDM*1; the percentage of variation in *y* explained by *SDM*1 rises to approximately 12 percent in quarter twelve and drops slightly to 11 percent at the end of twenty quarters. The first-quarter effect on *P* (1.3 percent) is small, but this rises over time to 15 percent at the end of twenty quarters. It thus appears that the macroeconomic effects of *SDM*1 are substantial. In fact, the effects of

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[9] Bernanke (1986) has also argued that theoretical considerations should be employed in computing the VDCs. However, he has suggested an alternative method of orthogonalizing the residuals to the Choleski decomposition.

TABLE 2

VARIANCE DECOMPOSITIONS FOR SYSTEM WITH *AAA* IN FIRST-DIFFERENCE FORM

Relative Variation in	Horizon (Quarters)	Explained by Innovations in							
		ss	*g*	*tx*	*M*1	*SDM*1	*AAA*	*y*	*P*
ss	1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	77.3	2.3	0.4	7.2	0.9	9.8	0.6	1.5
	8	61.6	6.8	4.8	9.2	2.3	9.3	4.2	1.8
	12	54.9	5.4	7.5	9.2	8.8	7.7	3.8	2.7
	20	46.4	9.2	7.3	8.8	10.7	9.5	4.0	3.9
g	1	3.2	96.8	0.0	0.0	0.0	0.0	0.0	0.0
	4	7.9	77.2	0.5	2.2	2.8	7.9	1.4	0.1
	8	8.2	69.4	3.5	2.0	6.9	6.5	2.5	1.0
	12	9.4	59.1	3.7	3.8	8.9	7.0	4.5	3.7
	20	10.7	54.0	3.9	4.0	8.7	8.0	5.2	5.6
tx	1	8.2	0.4	91.5	0.0	0.0	0.0	0.0	0.0
	4	9.8	0.7	61.7	14.1	4.9	2.9	2.6	3.3
	8	34.7	9.7	35.3	8.2	3.2	4.1	1.8	3.0
	12	31.2	10.4	31.2	10.6	5.2	4.7	1.9	4.7
	20	27.0	11.9	26.3	11.3	8.3	7.0	3.7	4.5
*M*1	1	4.9	1.8	2.7	90.6	0.0	0.0	0.0	0.0
	4	17.7	6.8	1.4	38.0	7.3	21.9	1.7	5.3
	8	16.4	6.1	3.7	33.2	9.7	19.0	5.6	6.3
	12	14.9	5.8	5.9	30.1	10.8	17.6	7.4	7.6
	20	16.0	6.6	6.7	25.8	12.3	16.9	8.6	7.0
*SDM*1	1	4.0	0.0	15.1	5.4	75.5	0.0	0.0	0.0
	4	24.6	4.3	5.3	2.6	52.7	3.4	6.0	1.0
	8	27.0	17.2	3.6	1.8	37.1	2.6	4.9	5.8
	12	21.8	26.0	4.1	5.8	27.6	3.9	3.6	7.1
	20	16.9	35.2	4.0	7.7	19.1	3.1	2.7	11.3
AAA	1	0.3	0.0	0.3	0.1	22.0	77.3	0.0	0.0
	4	17.5	2.0	6.9	9.7	14.0	46.4	1.6	2.0
	8	15.7	3.4	7.5	15.4	18.0	36.5	1.5	1.9
	12	16.2	5.6	6.7	13.1	14.6	31.7	6.6	5.5
	20	15.8	7.0	8.8	12.9	14.6	27.7	7.1	6.0
y	1	7.3	16.8	6.1	4.7	5.2	0.1	59.8	0.0
	4	18.5	9.4	8.2	5.9	5.9	6.0	40.3	5.8
	8	23.6	9.9	9.4	9.9	7.1	6.4	27.6	6.0
	12	24.2	8.1	7.6	11.4	11.5	7.9	23.4	6.1
	20	22.1	11.0	8.4	9.5	10.7	12.9	19.5	6.0
P	1	0.3	15.3	0.6	25.5	1.3	1.2	0.0	55.8
	4	12.1	10.0	1.3	26.1	6.9	3.3	7.4	32.9
	8	12.7	11.8	3.0	26.0	7.1	5.8	6.3	27.3
	12	16.6	11.7	3.3	22.9	14.3	4.4	5.8	20.9
	20	23.4	11.8	3.0	18.3	15.0	4.5	4.9	19.1

*SDM*1 on *AAA* are larger than are the separate effects of *M*1, *g*, or *tx*. In the case of *y*, the effects of *M*1 and *SDM*1 are roughly equal, and, with the exception of the first-quarter effect of *g*, *SDM*1's effects on *y* are comparable to those of *g* and *tx*. *M*1, as might be expected, explains more of the variation in *P* than does *SDM*1. *SDM*1's effects on *P* exceed those of *tx*, and, after quarter eight, are larger than the effects of *g*. Together, *SDM*1 and *M*1 explain substantial fractions of the variation in *AAA*, *y*, and *P*, considering the size of the system.[10]

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[10] The system was also estimated and the VDCs computed for *SD*4*M*1, the four-quarter moving standard deviation of quarterly money growth. Again the optimal lag was eight quarters. The effects of money growth variability are more modest when *SD*4*M*1 is employed. For ordering (1) the maxi-

The VDCs for ordering (1) for the system with the level of AAA are presented in Table 3. The results are comparable to those in Table 2. The effects of $SDM1$ on AAA are larger for the first year, but the effects after that fall off more sharply than they do in Table 2. The initial effects of $SDM1$ on y are somewhat weaker than before, but the twenty-quarter effect is essentially the same. In the case of P, the effects of $SDM1$ are approximately half what they were in Table 2. Again, though, considering the size of the system, $SDM1$ appears to have nontrivial macroeconomic effects.

The HDs computed over the period 1979:IV–1984:IV shed further light on the macroeconomic effects of $SDM1$. For the system with the first difference of AAA, the results of these HDs [for ordering (1)] are presented in Figures 1–3. In order to save space, comparable figures for the system with the level of AAA are not presented but are available on request. In examining these figures, it should be kept in mind that y and P refer to the first differences of logs of these variables. In each figure the actual series is plotted, as are the base projection for that series and the base projection plus the contribution of $SDM1$. As noted earlier, if $SDM1$ is important in explaining the behavior of, for example, AAA, the base projection for AAA plus the contribution of $SDM1$ should be closer to the actual AAA series than the base projection alone.

Figure 1 contains the results for AAA. We see that the base projection plus $SDM1$ ($BPSDM1$) line is generally closer to the actual series than is the base projection (BP) line alone. This appears to be particularly true when there is a sharp change in AAA, although the magnitude of the change is often underestimated by both BP and $BPSDM1$. In order to more precisely determine how $SDM1$ contributes to closing the gap between the base projection and the actual series, Theil's U statistic and the root-mean-square error ($RMSE$) were computed for BP and $BPSDM1$. The precise definitions of the U statistic and the $RMSE$ are given in Table 4. The U statistic lies between 0 and 1 with a value of 0 indicating perfect forecasts and a value of 1 indicating the worst possible forecasts.

The results of this exercise for the first difference of AAA are reported in Table 4, A. The numbers in parentheses are the ratios of the $RMSE$s of $BPSDM1$ to those of BP. We note that the U statistic for $BPSDM1$ is 0.33 while that for BP is 0.43. We also see that the addition of $SDM1$ to the base projection reduces the $RMSE$ of the base projection alone by about 21 percent. Similar results for the system with the level of AAA are reported in Table 4, B. The U statistic is much lower, as would be expected, but again we see a reduction from 0.03 to 0.02 when

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mum effect on AAA is 12 percent in quarter eight, and the twenty-quarter effect is 9 percent. For y, 7–9 percent of the variation is explained by $SD4M1$, and 4–5 precent of the variation in P is explained by $SD4M1$. Moving to ordering (2) made more difference for the $SD4M1$ system than for the $SDM1$. When $M1$ and $SD4M1$ precede g and tx, $SD4M1$ explains a maximum of 18 percent of the variation in AAA at quarter eight and explains 15 percent at quarter twenty. For y approximately 11 percent of the variation is explained for the first twelve quarters; this rises to 14 percent at the end of twenty quarters. Again the effect on P is weak; only 4 percent of the twenty-quarter variation in P is explained by $SD4M1$. These results are available on request.

TABLE 3

Variance Decompositions for System with *AAA* in Level Form

Relative Variation in	Horizon (Quarters)	Explained by Innovations in							
		ss	*g*	*tx*	*M*1	*SDM*1	*AAA*	*y*	*P*
ss	1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4	78.5	3.4	1.4	7.8	1.2	6.3	0.9	0.6
	8	62.9	6.3	5.4	9.9	2.0	7.3	5.2	1.0
	12	54.6	5.3	9.2	10.2	6.6	6.3	4.6	3.2
	20	46.0	6.5	9.4	8.9	9.4	10.8	5.3	3.8
g	1	0.5	99.5	0.0	0.0	0.0	0.0	0.0	0.0
	4	3.8	73.3	0.5	0.3	1.7	18.3	1.3	0.9
	8	3.7	62.4	1.5	2.7	3.9	22.6	2.6	0.6
	12	6.7	51.5	1.8	6.3	4.6	21.5	5.3	2.4
	20	9.0	46.9	3.1	6.2	5.4	20.7	5.6	3.1
tx	1	4.5	1.5	94.0	0.0	0.0	0.0	0.0	0.0
	4	9.6	2.0	62.5	12.1	5.7	1.3	3.1	3.7
	8	35.2	8.2	36.4	7.3	3.4	3.8	2.0	3.6
	12	31.7	9.9	31.6	11.0	4.0	5.4	2.4	4.0
	20	28.6	11.2	27.5	11.5	5.3	7.6	4.2	4.0
*M*1	1	4.3	2.1	3.4	90.2	0.0	0.0	0.0	0.0
	4	20.0	4.6	1.3	38.9	10.7	20.7	1.4	2.4
	8	18.0	5.2	3.3	34.7	10.9	18.4	5.5	4.0
	12	16.4	5.0	5.6	31.2	11.5	17.1	7.5	5.7
	20	17.1	5.9	6.1	26.4	12.8	17.2	9.0	5.4
*SDM*1	1	2.5	0.4	17.8	4.3	75.0	0.0	0.0	0.0
	4	19.1	0.6	7.5	4.8	54.5	1.4	10.5	1.6
	8	19.0	6.2	3.9	3.8	37.1	14.2	10.7	5.0
	12	13.0	9.5	3.8	4.0	23.0	36.3	6.8	3.5
	20	9.9	12.9	6.5	3.7	17.7	41.7	4.9	2.8
AAA	1	0.0	0.1	0.6	0.1	25.1	74.1	0.0	0.0
	4	27.5	2.0	6.7	6.6	25.1	30.1	1.2	0.6
	8	37.5	1.4	9.3	18.3	12.7	16.2	4.2	0.3
	12	24.9	4.5	7.0	24.1	8.9	25.6	3.8	1.3
	20	14.6	11.7	7.9	26.5	9.4	24.8	2.3	2.8
y	1	1.6	16.0	10.1	4.2	2.7	0.3	65.1	0.0
	4	18.2	11.8	9.9	5.6	7.1	2.7	40.9	3.8
	8	23.6	10.2	9.8	12.0	8.8	4.4	27.6	3.5
	12	25.5	8.4	8.0	14.4	11.2	5.6	23.5	3.4
	20	23.3	10.4	8.9	11.7	10.2	10.5	20.6	4.5
P	1	0.2	11.5	0.3	31.6	0.0	0.5	0.1	55.8
	4	16.1	6.5	0.7	35.1	2.2	7.0	5.8	26.5
	8	15.7	8.7	1.8	34.0	2.3	12.1	5.1	20.4
	12	16.4	8.2	2.7	32.9	6.8	10.7	5.9	16.5
	20	20.0	6.3	4.7	26.4	7.2	17.2	4.6	13.7

*SDM*1 is added to the base projection. The *RMSE* for *BPSDM*1 is approximately 20 percent less than for *BP* alone.

The results for *y* are presented in Figure 2. Again the *BPSDM*1 line is generally closer to the *y* line than is the *BP* line. From Table 4, A, we see that the *U* statistic is lower for *BPSDM*1 (0.32) than for *BP* (0.41). The *RMSE* for *BPSDM*1 is approximately 19 percent lower than the *RMSE* for *BP*. Similar results are obtained for the system with the level of *AAA* (Table 4, B).

Figure 3 reports the results for *P*. The *BPSDM*1 line, in general, appears somewhat closer to the actual series than the *BP* line, especially from 1982:I to

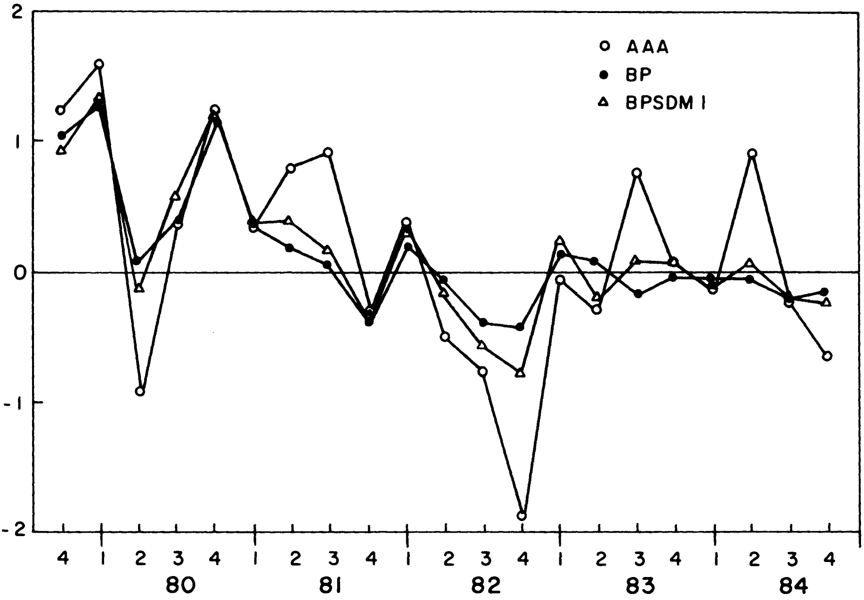

FIG. 1. Historical Decomposition for *AAA*.

TABLE 4

SUMMARY OF HISTORICAL DECOMPOSITION RESULTS

A. System with *AAA* in First-difference Form

Variable	Base Projection		Base Projection + *SDM*1	
	RMSE	*U*-Statistic	*RMSE*	*U*-Statistic
AAA	.5783	.43	.4596 (.79)	.33
y	.0087	.41	.0071 (.81)	.32
P	.0042	.12	.0038 (.92)	.11

B. System with *AAA* in Level Form

Variable	Base Projection		Base Projection + *SDM*1	
	RMSE	*U*-Statistic	*RMSE*	*U*-Statistic
AAA	.7206	.03	.5745 (.80)	.02
y	.0085	.39	.0068 (.81)	.31
P	.0033	.09	.0033 (1.0)	.09

NOTES: (a) *RMSE* = root-mean-square error rounded to the fourth decimal place $(1/\sqrt{T})\ \sum_{i=1}^{T} (F_i - A_i)^2$ where F_i = forecast value of *AAA* or *y* or *P* in period *i*, A_i = actual value of *AAA* or *y* or *P* in period *i*, and T = number of forecast periods.

(b) The numbers in parentheses are the ratios of the *RMSE* for the base projection + *SDM*1 series to the *RMSE* for the base projection series, and were calculated from unrounded *RMSE* series that contained 7 places to the right of the decimal.

(c) Following Pindyck and Rubinfeld (1981, p. 364), Theil's *U* statistic is measured as

$$U = (1/\sqrt{T})\ \sum_{i=1}^{T} (F_i - A_i)^2)/((1/\sqrt{T})\ \sum_{i=1}^{T} (F_i^2) + (1/\sqrt{T})\ \sum_{i=1}^{T} (A_i^2))$$ where F_i, A_i, and T are as defined in note (a).

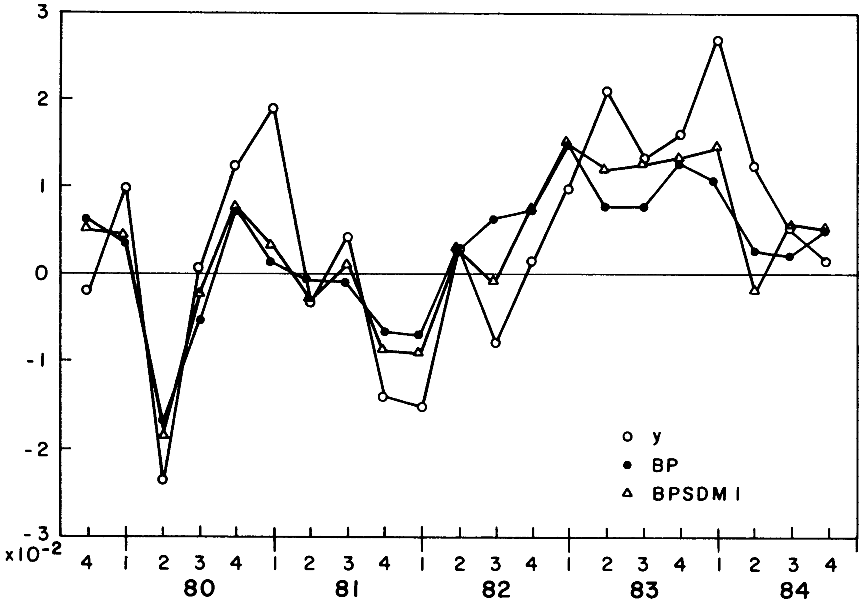

FIG. 2. Historical Decomposition for y.

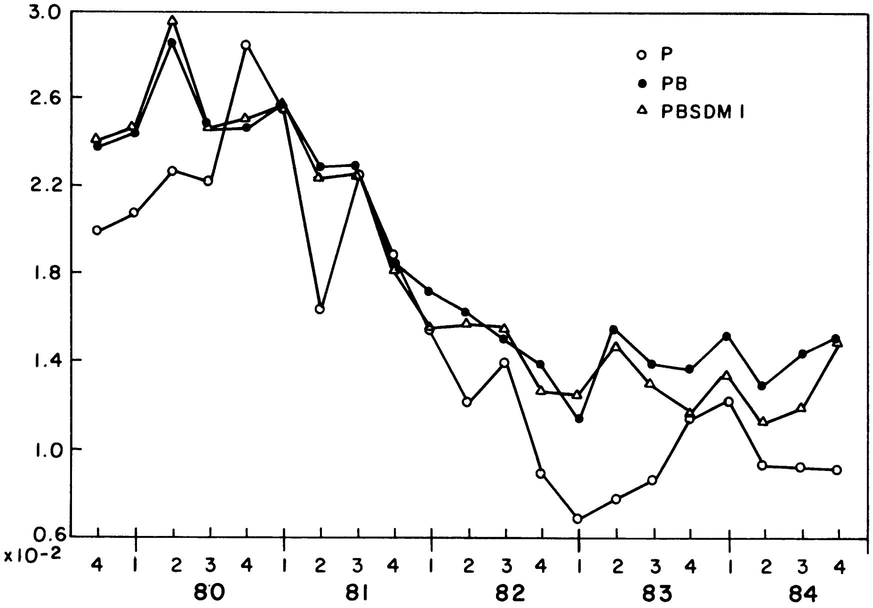

FIG. 3. Historical Decomposition for P.

1984:IV. However, the *U* statistic for *BPSDM*1 (0.11) is only slightly less than for *BP* (0.12), and the *RMSE* for *BPSDM*1 is only 8 percent less than for *BP* (Table 4, A). For the system with the level of *AAA*, we observe no change in the *U* statistic or the *RMSE* (Table 4, B).

4. CONCLUSION

This study analyzes the effects of variability in money growth on the macroeconomy for the period 1961:I–1984:IV. Unlike earlier studies that focused upon the effects of money growth variability on a single variable like the interest rate or output, this study investigates the impact of money growth variability upon the variables typically included in a small macro model. The analysis is performed within the context of a vector autoregressive model that includes output, the price level, the long-term interest rate, a supply shock variable, money, federal purchases of goods and services, a federal tax variable, and a measure of variability in money growth.

Variance decompositions and historical decompositions are used to assess the impact of money growth variability, and the results of this study are consistent with earlier studies that found substantial effects of money growth variability on the macroeconomy. The variance decompositions indicate that, considering all time horizons, money growth variability has the largest effects on the interest rate, although the long-run effects on output and price are quite similar to those for the interest rate. The effects of monetary policy are estimated by adding the variance decomposition results for the money growth variability measure to those for *M*1. This exercise indicates that monetary policy is quite important in explaining the behavior of the interest rate, output, and price, and that money growth variability's contribution to these effects is substantial.[11] It thus appears that omission of a money growth variability measure leads to an understatement of the effects of monetary policy on the macroeconomy. The effects of money growth variability are more pronounced in the system with the first difference of the interest rate, but even in the system with the level of the interest rate the effects are certainly nontrivial.

Historical decompositions for the 1979:IV–1984:IV period reveal that money growth variability had important effects on the interest rate and output but that the effect on price was weak. The results for the interest rate and output are consistent with the variance decompositions; the biggest surprise compared to the variance decompositions is the weak effect on price. However, taken to-

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[11] In the case of *AAA*, *SDM*1 contributes 59 percent of monetary policy effects in quarter four and 53 percent in quarter twenty. For *y*, *SDM*1 contributes 50 percent of monetary policy effects in quarter four and 53 percent in quarter twenty. *SDM*1 is responsible for 21 percent of the total monetary policy effect on *P* in quarter four, and this rises to 45 percent in quarter twenty.

gether, the variance decomposition and historical decomposition results imply that money growth variability has substantial effects on the interest rate, output, and price.

Data for this paper are available from the JMCB *editorial office.*

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