M2 and Monetary Policy: A Critical Review of the Recent Debate

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Recently the question of whether a monetary aggregate, and in particular M2, is a useful intermediate target for monetary policy has been the subject of intense debate. The most striking feature of this debate, which has been largely empirical, is that the central issues that are relevant for analyzing M2's usefulness in the conduct of monetary policy have been neglected. Issues involving the controllability of M2 and the structural relationship between M2 and economic activity have not been adequately addressed. Rather, much of the debate has focused on the notion of predictive content.

The argument expressed in much of the literature is that if money lacks predictive content, then it has no useful role as either an information variable, an intermediate target, or, when possible, an instrument of monetary policy.[1] This argument basically misses the point. In this article we argue that Granger-causality tests generally are not a proper test of the usefulness of money as an intermediate target. We also argue that evaluating the usefulness of any monetary aggregate in the conduct of monetary policy requires a structural model.

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[1] This view is expressed rather strongly in Friedman and Kuttner (1992) and seems at least to be implicit in most of the literature cited in this article. In what follows we use the terms *information variable, intermediate target,* and *instrument* in standard ways. An information variable is one that provides information about future economic activity and in particular about variables in the Fed's objective function. An intermediate target is a variable that the Fed explicitly tries to hit by altering its monetary instrument, which is a variable under direct control. That is, an instrument is either the federal funds rate or an element of the Fed's balance sheet.

The first section of this article reviews the empirical debate concerning M2's usefulness as an intermediate target. In particular we look at the result of Friedman and Kuttner (1992, 1993) which indicates that in the presence of financial market variables, M2 contains no predictive content for real income. We find that this result is fragile and that M2 does have significant predictive content for both real and nominal GDP when the statistical tests are properly specified. This agrees with similar evidence presented in Feldstein and Stock (1993), Hess and Porter (1992), Becketti and Morris (1992), and Konishi, Ramey, and Granger (1992). Thus under current operating procedures M2 provides useful information about the economy.

In Section 2 we take a deeper look at the notion of predictive content and its limitations in designing monetary policy. In particular, we show that a failure to find predictive content says very little about the potential usefulness of a monetary aggregate as an intermediate target. The lack of predictive content can arise as a result of operating procedures. It is entirely possible that the same monetary aggregate could serve as a reliable intermediate target or information variable under alternative operating procedures. Thus merely analyzing reduced-form relationships for the purpose of making theoretical arguments about the potential usefulness of M2, or any other measure of money, in formulating policy can be misleading.

Also, the presence of predictive content does not necessarily imply that M2 would make a good intermediate target. For that to be the case, M2 must be controllable and must have an effect on economic variables that the Fed ultimately wishes to influence. Feldstein and Stock (1993) realize that M2's usefulness as an intermediate target hinges on its controllability and assume that the Fed can perfectly control M2. In Section 3 we analyze the effects of relaxing this assumption and show that allowing for imperfect control weakens their argument substantially.

In Section 4 we look at another assumption that is crucial to the Feldstein and Stock analysis and to the entire recent empirical debate. That assumption involves the invariance of the estimated reduced-form structures to changes in Federal Reserve operating procedures. Here we show that the changes in operating procedures advocated by Feldstein and Stock should have substantial effects on the economy's reduced form. Thus, issues related to the Lucas critique cannot easily be dismissed and there is reason to question the validity of their policy experiments.

The combined analysis presented in Sections 2 and 4 indicates that the lines of research evaluated in this article are not likely to be productive from the standpoint of understanding and designing monetary policy. Granger-causality tests say very little about the usefulness of a variable as a monetary instrument or intermediate target. Further, the assumption that the Lucas critique is not measurably important in discussions concerning alternative operating procedures is rather heroic.

1. A REVIEW OF THE STATISTICAL EVIDENCE

In this section we look at the statistical evidence regarding the ability of M2 to help predict future movements in either real or nominal income. The key issue here is the treatment of cointegration. Engle and Granger (1987) show that proper estimation of a nonstationary system must explicitly account for any cointegrating relationships. Merely differencing nonstationary data and then performing statistical analysis does not properly account for long-run relationships, while leaving the data in levels omits relevant parameter restrictions. To highlight the differences that can occur with alternative specifications, we present Granger-causality tests results using differenced data with and without the inclusion of a cointegrating vector. The finding of Friedman and Kuttner that M2 has no predictive content is shown to be in part a result of an improper statistical representation.

Specifically we analyze equations of the following form:

$$\Delta y_t = \sum_{i=1}^{n} \alpha_{yi} \Delta y_{t-i} + \sum_{i=1}^{n} \alpha_{mi} \Delta M_{t-i} + \sum_{i=1}^{n} \alpha_{pi} \Delta p_{t-i} + \sum_{i=1}^{n} \alpha_{ri} \Delta r_{t-i} + \sum_{i=1}^{n} \alpha_{si} s_{t-i} + \sum_{i=1}^{n} \alpha_{\tau i} \tau_{t-i} + \beta z_{t-1} + \varepsilon_t \qquad (1)$$

$$\Delta Y_t = \sum_{i=1}^{n} a_{yi} \Delta Y_{t-i} + \sum_{i=1}^{n} a_{mi} \Delta M_{t-i} + \sum_{i=1}^{n} a_{ri} \Delta r_{t-i} + \sum_{i=1}^{n} a_{si} s_{t-i} + \sum_{i=1}^{n} a_{ti} \tau_{t-i} + b z_{t-1} + e_t, \qquad (2)$$

where the symbol "Δ" indicates first differencing, y (Y) is the log of real (nominal) GDP, M is the log of nominal M2, p is the log of deflator on GDP, r is either the three-month federal funds rate or the six-month commercial paper rate,[2] s is the spread between the six-month commercial paper rate and the three-month Treasury bill rate, τ is a term structure variable measuring the yield difference between the ten-year Treasury bond and the three-month funds rate, and z is the cointegrated vector between M2, the price level, income, and nominal interest rates implied by a stable money demand function.

The spread is included to take account of the financial effects emphasized by Friedman and Kuttner (1992), namely, that this spread reflects a risk premium that can vary cyclically. It is also influenced by changing liquidity needs since Treasury bills are more liquid than commercial paper. Thus the spread variable is a stand-in both for changes in the demand for financial liquidity

[2] We also experimented with the Treasury bill rate. The major difference is that the spread and the term structure are less significant (sometimes very much so) when the Treasury bill rate is employed.

and for changes in risk. Increases in risk or liquidity demands should have a negative effect on economic activity.

The term structure variable is included to portray the stance of monetary policy (see Bernanke and Blinder [1992]). An upward slope in the term structure indicates expectations of rising inflation and loose monetary policy. Thus the coefficients on this variable should be positive in the nominal GDP regressions and positive in the real GDP regressions if there are significant nominal rigidities in the economy. Alternatively, an upward-sloping yield curve could be associated with an upward-sloping term structure of real interest rates signaling expected consumption growth and thus has a positive association with future real output. If the term structure variable is largely reflecting the expected behavior of future real rates, then the effect on nominal GDP could be ambiguous since real output growth could result in lower inflation.

The regressions depicted in equations (1) and (2) are run in two different ways. One way is that of Friedman and Kuttner in which the cointegrating relationship is ignored (i.e., the constraints $\beta = b = 0$ are incorrectly imposed). The alternative methodology includes the cointegrating relationship among M2, the price level, real income, and nominal interest rates.[3]

The importance of including cointegration can be examined within the confines of a simple linear rational expectation model. Suppose the real part of the economy was exogenous and the nominal side could be depicted as

$$r_t = E_t p_{t+1} - p_t + w_t \tag{3}$$

$$M_t = p_t - cr_t + v_t \tag{4}$$

$$M_t = \mu + M_{t-1} + x_t, \tag{5}$$

where w_t, v_t, and x_t are white-noise disturbances to the nominal interest rate, money demand, and money supply, respectively. Equation (3) is the Fisher relationship relating nominal interest rates to expected inflation and a stochastic real rate of interest. The money demand disturbance, v_t, incorporates changes in real income and transactions costs, while x_t is a money control error. The model displays a cointegrating relationship between money and prices, with $M_t - p_t$ being stationary.

The reduced form for money and prices is

$$M_t = \mu + M_{t-1} + x_t \tag{6}$$

[3] We use a cointegrating vector similar to Feldstein and Stock (1993) in which $y_t + P_t - M_t - \alpha r_t$ is stationary. With interest rates multiplied by 100, α, the interest semi-elasticity of money demand, is equal to .0052 for commercial paper regressions and .0041 for regressions using the federal funds rate.

$$p_t = (1 + c)\mu + M_{t-1} + x_t + \frac{c}{1 + c}w_t - \frac{1}{1 + c}v_t. \qquad (7)$$

Using equations (6) and (7) we can examine the importance of including cointegrating terms when testing if money growth helps predict future inflation. From the structure, it is obvious that money does help predict the future price level, but statistical tests will generally fail to confirm this feature of the model if the cointegrating relationship is ignored. To illustrate this point, we generated 2,000 samples of 100 observations each and tested for Granger-causality.[4] Without cointegration the lagged money growth was only significant at the 5 percent significance level 4.5 percent of the time, while with cointegration money Granger-caused prices 95 percent of the time.

Having illustrated the potential importance of including cointegrating vectors, we reinvestigate the Friedman-Kuttner results that M2 does not Granger-cause real output. The results are depicted in Table 1, where we report p-values or significance levels on Granger-causality tests. The sample period is 1960:1 through 1993:1 and four lags of each variable are included (i.e., $n = 4$ in equation [1]). Column 1 of Panel (a) basically replicates Friedman and Kuttner's result that the spread has significant predictive content while M2 does not. Replacing the commercial paper rate by the funds rate implies that M2 is significant at the 10 percent level, while adding a term structure term implies that M2 is significant at the 5 percent level. Like Feldstein and Stock (1993) we find that including a cointegrating term yields the result that M2 is highly significant in all specifications, even the one favored by Friedman and Kuttner, as is the spread and the term structure.[5]

Since the monetary authority may also be interested in the forecasts of nominal magnitudes when making policy decisions, we also look at the predictive content of M2 growth and the spread in regressions where nominal GDP is the dependent variable. The results are depicted in Table 2. Here both the spread and M2 are found to be highly significant predictors of nominal output.

Granger-causality tests are not the only way of examining predictive content. One may also wish to know if the effects of certain variables are long-lived or if they die out quickly over time. To address these issues, we look at impulse

[4] In the simulations both w and v are independently drawn from an N (0,1) distribution while $x_t \sim$ N (0, .1). The parameter $\mu = .05$ and $c = 2$ reflect an interest elasticity of approximately .10. The VARs were run with five lags of money growth and inflation.

[5] Friedman and Kuttner's results have been attacked on other grounds. Becketti and Morris (1992) find that eliminating the period October 1979–October 1982 when the Fed altered its operating procedures implies that M2 Granger-causes real output, while Konishi, Ramey, and Granger (1992) attribute most of the spread's predictive power to the inclusion of the 1971–1975 period. We were able to replicate the Becketti and Morris result but did not find the Konishi, Ramey, and Granger result to be robust to alternative specifications. Using equation (1) with $\beta \neq 0$, we still find the spread has predictive content for real GDP when using the funds rate, the commercial paper rate, or both the funds rate and the term structure.

Table 1 p-Values for Variables in Real Income Equations 1960:1–1993:1

Panel (a): No Cointegration

Independent Variable				
Δy	.5273	.6551	.5429	.6942
Δm	.1520	.0912	.0348	.0364
Δp	.0217	.0301	.0196	.0096
Δr_{ff}	na	.0264	na	.0095
Δr_{cp}	.0593	na	.0816	na
s	.0155	.0147	.0063	.0054
τ	na	na	.0650	.0167

Panel (b): With Cointegration

Independent Variable				
y	.0291	.0355	.0246	.0122
m	.0070	.0037	.0012	.0004
p	.0009	.0012	.0007	.0001
r_{ff}	na	.0010	na	.0001
r_{cp}	.0026	na	.0029	na
s	.0031	.0026	.0012	.0008
τ	na	na	.0476	.0044
zmd	.0025	.0022	.0019	.0005

Definition of variables: y = ln(real GDP), m = ln(nominal M2), p = ln(implicit price deflator for GDP), r_{ff} = quarterly average federal funds rate, r_{cp} = six-month commercial paper rate, s = six-month commercial paper rate minus the three-month Treasury bill rate, τ = ten-year Treasury bond rate minus the federal funds rate.

response functions. These results are displayed in Figures 1 and 2. Here we only use the specification that includes cointegration. The impulse response functions and the dashed lines that depict their 95 percent confidence band are displayed in Figure 1 and indicate that M2 has a short-lived effect on real output growth when ordered second in the orthogonalization procedure (panel A) but not much effect when ordered third (panel B). The spread, however, has a significant negative effect on real growth independent of ordering (panels C and D). The results for nominal income are depicted in Figure 2. Here a shock to M2 has a significant effect on nominal GDP that is quite long-lived (panels A and B), while the spread's effect is significant and surprisingly positive at business cycle frequencies.[6]

[6] We also tested if the sum of coefficients on the spread variable were significant and found that we could not reject this sum being equal to zero in either the real or nominal GDP regressions.

Table 2 p-Values for Variables in Nominal Income Equations 1960:1–1993:1

Panel (a): No Cointegration

Independent Variable				
Δy	.7074	.6172	.8817	.8975
Δm	.0261	.0204	.0065	.0053
Δr_{ff}	na	.0109	na	.0067
Δr_{cp}	.0313	na	.0756	na
s	.0803	.1046	.0390	.0309
τ	na	na	.2649	.0731

Panel (b): With Cointegration

Independent Variable				
y	.0739	.0520	.1048	.0416
m	.0020	.0013	.0005	.0001
r_{ff}	na	.0007	na	.0002
r_{cp}	.0024	na	.0059	na
s	.0402	.0490	.0246	.0152
τ	na	na	.2411	.0277
zmd	.0053	.0042	.0052	.0013

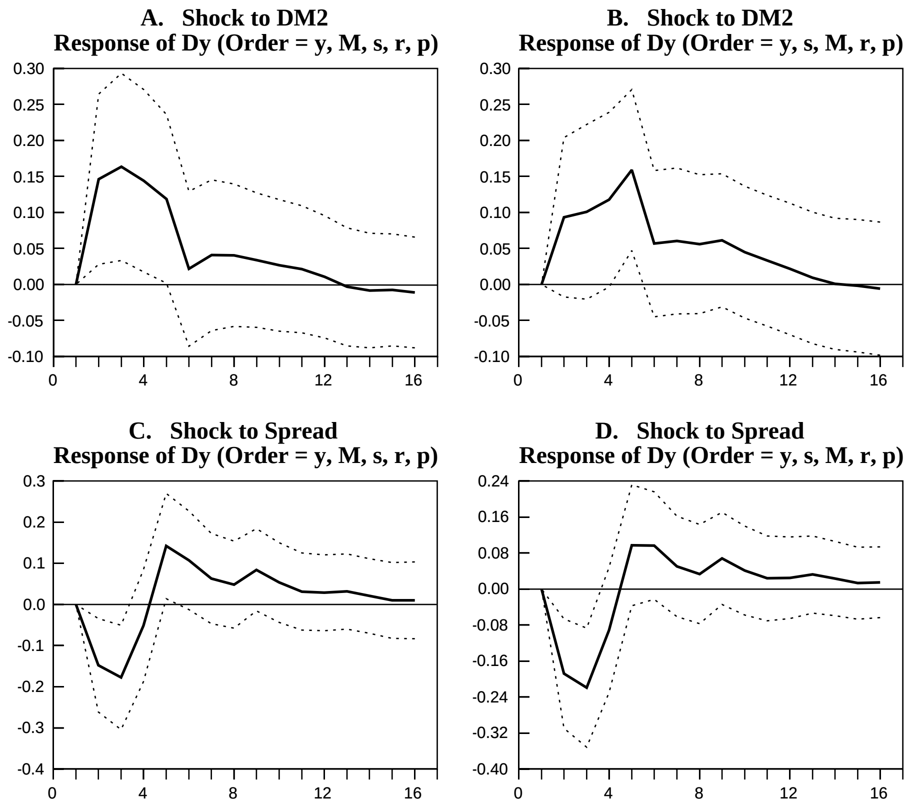
Definition of variables: y = ln(nominal GDP), m = ln(nominal M2), r_{ff} = quarterly average federal funds rate, r_{cp} = six-month commercial paper rate, s = six-month commercial paper rate minus the three-month Treasury bill rate, τ = ten-year Treasury bond rate minus the federal funds rate.

2. A DEEPER LOOK AT GRANGER-CAUSALITY

The analysis conducted in the previous section supports the results of a number of other studies that M2 has significant predictive content for future movements in both real and nominal GDP. Given the tremendous amount of effort exerted in analyzing this issue, it is important to ask whether Granger-causality is a relevant and essential property of a variable if that variable is to be useful in conducting monetary policy. In particular, does the absence of Granger-causality imply that a variable cannot be used as an intermediate target or instrument? The somewhat counterintuitive answer is no. Thus, for example, the fact that some studies show that the monetary base does not Granger-cause real economic activity provides little guidance concerning the potential role of the base in conducting monetary policy.[7]

[7] Examples depicting the usefulness of the base as an instrument of policy can be found in McCallum (1988), Judd and Motley (1991), and Hess, Small, and Brayton (1993).

Figure 1 Impulse Response Functions for Real Income



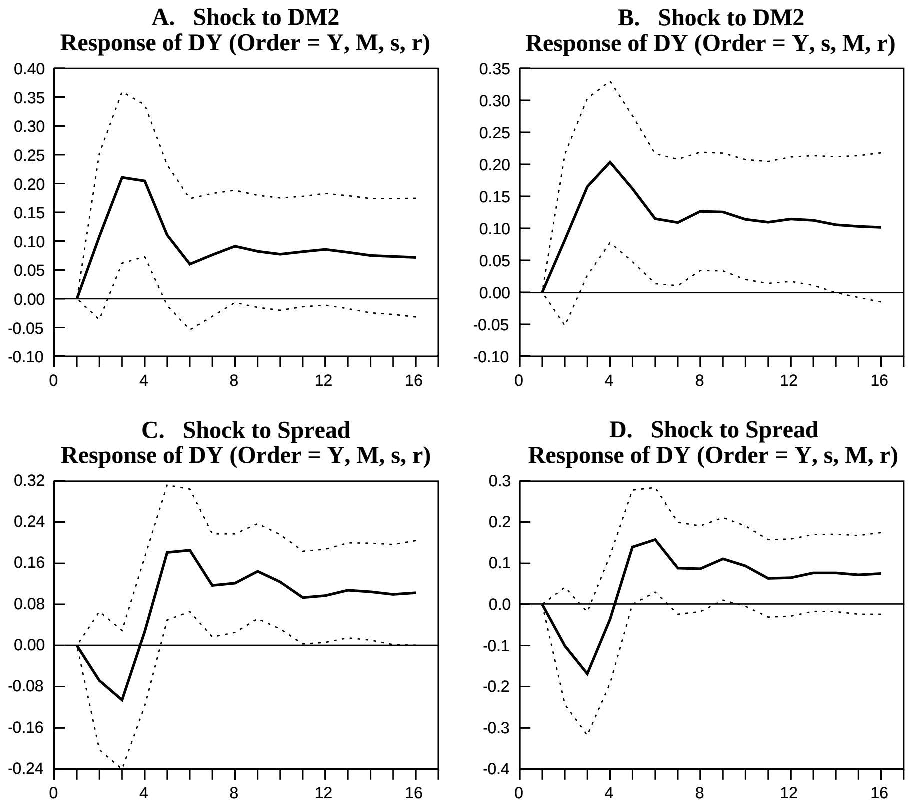
Symmetrically the observation of Granger-causality does not necessarily imply that a variable will be useful as an intermediate target or instrument. Issues of controllability and the ability of a variable to causally influence economic variables of primary concern must be addressed as well. Granger-causality, therefore, merely indicates that under existing policy a variable provides useful information about future economic activity.

In this section we examine by way of an illustration why the lack of Granger-causality may not be particularly relevant. In the next two sections we look at the other side of the coin and show that Granger-causality does not necessarily imply that a variable will be useful as an intermediate target.

To illustrate our point, we use the simple economic framework in the preceding example. Instead of using money as an instrument, the Fed uses an interest rate instrument whose behavior is given by

$$r_t = \mu_r r_{t-1} + \mu_p p_{t-1}. \tag{5'}$$

Figure 2 Impulse Response Functions for Nominal Income



Thus the economy is depicted by equations (3), (4), and (5′). The reduced form for this economy has the following ARMA (1, 1) representation:[8]

$$\begin{bmatrix} p_t \\ M_t \end{bmatrix} = \delta_1 \begin{bmatrix} 1 & 0 \\ 1 + c - c\delta_1 & 0 \end{bmatrix} \begin{bmatrix} p_{t-1} \\ M_{t-1} \end{bmatrix} + \begin{bmatrix} 1/\delta_2 & 0 \\ 1/\delta_2 & 1 \end{bmatrix} \begin{bmatrix} r_t \\ v_t \end{bmatrix}$$

$$+ \begin{bmatrix} \mu_r/\delta_2 & 0 \\ (1 + c - c\delta_1)\mu_r/\delta_2 & 0 \end{bmatrix} \begin{bmatrix} r_{t-1} \\ v_{t-1} \end{bmatrix}. \tag{8}$$

[8] As shown in Boyd and Dotsey (1993), equation (8) is the unique nonexplosive solution to this economic system. δ_1 and δ_2 are the eigenvalues of the matrix $\begin{bmatrix} 0 & 1 \\ -\mu_r+\mu_p & 1+\mu_r \end{bmatrix}$ with $|\ \delta_1\ | \leq 1$ and $|\ \delta_2\ | \geq 1$ for appropriate choices of μ_r and μ_p.

The reduced form of equation (8) can be written as an infinite order AR process

$$\begin{bmatrix} p_t \\ M_t \end{bmatrix} = \sum_{i=1}^{\infty} \Pi_i \begin{bmatrix} p_{t-i} \\ M_{t-i} \end{bmatrix} + \begin{bmatrix} 1/\delta_2 & 0 \\ 1/\delta_2 & 1 \end{bmatrix} \begin{bmatrix} r_t \\ v_t \end{bmatrix}, \tag{9}$$

where each upper right-hand element of each Π_i matrix is zero. Thus money will fail to Granger-cause prices. This failure says nothing about money's usefulness as a monetary instrument or intermediate target, since it is obvious that in this simple model economy controlling money will control prices.[9,10]

3. M2 AS AN INTERMEDIATE TARGET AND THE FELDSTEIN-STOCK ANALYSIS

As mentioned, the other side of this last result, that a lack of predictive content does not rule out the usefulness of a monetary aggregate in formulating monetary policy, is that predictive content does not necessarily imply that an aggregate should be an instrument or an intermediate target. Predictive content merely indicates that under current operating procedures a variable provides some useful information for forecasting future economic activity. In order to make the case that a variable would be a good instrument or intermediate target, one must show that a policy that incorporates the variable in either role improves economic performance in a welfare-enhancing way. Feldstein and Stock (1993) undertake such an exercise for M2.

They perform this exercise by estimating equations of the form (2), with a cointegrating vector included showing that M2 has significant predictive content for future nominal GDP. They also perform very sophisticated tests of the stability of the M2-nominal GDP relationship and find that it is indeed stable. The conclusion drawn from these results is that the reduced-form relationship they have estimated is likely to be invariant to changes in operating procedures, since the Fed changed operating procedures over their sample. The Fed, therefore, can profitably exploit the relationship between M2 and nominal GDP to reduce the variability of nominal GDP growth.

To see to what extent this variability can be reduced, they calculate the optimal M2 supply function, treating their reduced form as a structural relationship and assuming that M2 is perfectly controllable. They use the non-cointegrated system for this purpose. They find that optimally controlling M2 would result

[9] In particular, studies that show that the monetary base has little predictive content for future economic activity do not imply that the base would be an ineffective monetary instrument or intermediate target. McCallum (1993b) makes a similar argument with respect to stability of the base nominal GDP relationship.

[10] We also looked at some alternative policies. It appears that money's failure to Granger-cause output occurs whenever the Fed insulates the economy from money demand disturbances.

in quarterly growth rates of nominal GDP that are 88 percent as variable as they are now.[11] They then show that a simple feedback rule

$$M_t = -\lambda Y_{t-1} + (1 - \lambda)M_{t-1} \tag{10}$$

performs almost as well.

One of the critical assumptions in their analysis is that M2 is perfectly controllable. Taking for the moment the assumption that their reduced form is invariant to the change in operating procedures that they propose, we wish to see how their simple rule (for optimally chosen λ) would perform if M2 were not perfectly controllable. We use the cointegrated specification of equation (2) since our earlier results indicate that this is the preferred specification. Like Feldstein and Stock we drop the term structure and spread variable.

To see what the effect of using rule (10) has on the variance of nominal GDP, we conduct the same Monte-Carlo experiment that they do. First we generate 2,000 simulations of 40 quarters each using a four-variable vector autoregression that includes a cointegrating vector. The variables are nominal GDP, the price deflator on GDP, the three-month Treasury bill rate, and M2. More precisely, the first equation of this system looks like (2) with the term structure and spread terms omitted. In performing the simulations the random disturbances and coefficients are drawn from the appropriate distributions. We then replace the estimated M2 equation with (10) and perform the same exercise. Using the simulated data, ratios of the variances of nominal GDP growth can be constructed and analyzed. The results of the analysis are presented in Table 3.

For the case $\lambda = 0.3$ and perfect controllability, the mean of these ratios is .948, indicating that under the rule (10) nominal GDP's variance could be reduced to roughly 95 percent of its current value. Also 68 percent of the ratios are less than one, indicating that following (10) reduced variability most of the time. As the assumption of controllability is relaxed by adding to (10) a control error scaled by the percentage of M2's actual variance, the performance of the rule deteriorates. For example, if an attempt to control M2 as an intermediate target resulted in half the quarterly variability we now see, nominal output variance would only be reduced to .985 of its value under current procedures. Variability also only declines in 55 percent of the simulations. Thus the strength of the argument for using M2 as an intermediate target is intimately related to the issue of controllability. But the potential controllability of M2 cannot be answered by this exercise. In order to answer that question, one needs a

[11] They report a good deal more information. For example, they find that in 90 percent of their simulated decades, simulated GDP is less variable than actual GDP. Had they used the cointegrated system for this exercise, they would have found even greater improvement since including the cointegrating vector improves the R^2 of the model. (We thank Jim Stock for pointing this out to us.)

Table 3 The Predicted Reduction in the Variance of Nominal GDP Growth from Following a Simple Monetary Rule, $-\lambda Y_{t-1} + (1-\lambda)M_{t-1}$

Variance of M2	Value of λ	Mean	Standard Deviation	Median	Fraction <1
0	0	.913	.115	.914	.81
0	.1	.941	.121	.938	.72
0	.3	.948	.120	.954	.68
25% of actual	0	1.153	.268	1.085	.31
25% of actual	.1	.998	.119	.992	.51
25% of actual	.3	.965	.103	.972	.64
50% of actual	.3	.985	.098	.989	.55
75% of actual	.3	.999	.098	1.004	.48
100% of actual	.3	1.015	.101	1.015	.42

Note: These results were constructed by a Monte Carlo procedure that produced 2,000 draws of 40 quarters of predicted nominal GDP growth using the proposed money rule and random draws from the distribution of the reduced-form parameters and the reduced-form disturbances.

structural model since there is no period in which the Fed actually tried to control M2.

4. A DEEPER LOOK AT REDUCED-FORM INVARIANCE

Of equal if not greater importance than the issue of controllability is the assumption of reduced-form invariance to the change in operating procedures proposed by Feldstein and Stock. In this section we investigate the likely effects on reduced-form parameters if the Fed were to change its operating procedures from an interest rate feedback rule that responds to economic performance to a rule that targets M2. We do this for both an interest rate instrument and a total reserves instrument.

We use a simple log-linear rational expectations model for our investigation. Since monetary economics lacks an acceptable model, we choose to examine the issue of reduced-form invariance by examining a calibrated linear rational expectations model. While this model falls short of representing reality, it contains a number of key features found in many macroeconomic models and is useful for broadly illustrating the points we wish to make. The model is given by

$$y_t^s = y_{t-1} + a^s(p_t - E_{t-1}p_t) + u_t \tag{11}$$

$$y_t^d = a_0 + y_{t-1} - a^d(p_t + r_t - E_t p_{t+1}) + w_t \tag{12}$$

$$m_t^d = p_t - c_r r_t + c_y y_t + v_t \tag{13}$$

$$r_t = b_0 + b_p \Delta p_t + b_y \Delta y_t + b_r r_{t-1} + b_m m_{t-1} + x_t. \tag{14}$$

All variables with the exception of the nominal interest rate are in logs. Equation (11) is the standard Lucas supply curve relating real output to unexpected price-level movements, while (12) is an IS curve in which aggregate demand responds negatively to increases in the real rate of interest. Equation (13) is the demand function for M2 and (14) is the Fed's interest rate rule.[12] The Fed is modeled as responding to inflation, ΔP_t, and real output growth, Δy_t, while maintaining concern for some degree of interest rate smoothing. The Fed also responds to past M2 behavior using M2 as an information variable as opposed to using it as an intermediate target. (For a more complete discussion of models of this kind, see McCallum [1980].)

We can illustrate the extent to which the reduced form of this hypothetical economy is invariant to changes in operating procedures by examining how endogenous variables fluctuate around their expected value. A more complete analysis would present the entire reduced form, but the anticipated parts of the solution do not yield a simple analytical representation. We therefore present only the unanticipated portion of the reduced-form solution. For the system (11)–(14) these fluctuations are

$$\tilde{y}_t = (1/D)\{a^d(1 + b_p)u_t + a^s w_t + x_t\} \tag{15}$$

$$\tilde{p}_t = (1/D)\{-(1 + a^d b_y)u_t + w_t + x_t\} \tag{16}$$

$$\tilde{r}_t = (1/D)\{(a^d b_y - b_p)u_t + (a^s b_y + b_p)w_t + a x_t\} \tag{17}$$

$$\begin{aligned}\tilde{m}_t = (1/D)\{&[-(1 + a^d b_y) - c_r(a^d b_y - b_p) + c_y(a^d(1 + b_p))]u_t + v_t \\ &+ [1 - c_r(a^s b_y + b_p) + c_y a^s]w_t + [1 - c_r(a^s + a^d) + c_y]x_t\},\end{aligned} \tag{18}$$

where the "˜" notation indicates unexpected deviations (e.g., $\tilde{y}_t = y_t - E_{t-1}y_t$) and $D = a^s + a^d + a^d(b_p + a^s b_y)$.

If the Fed were to alter its policy rule (14) and use a noisy interest rate instrument, such as borrowed reserves, instead of directly controlling the funds rate, then the basic change in the economic system would be captured by an increased variance in x_t (the unexplainable part of policy). The solutions for the reduced-form parameters in terms of the structural parameters would be largely unchanged.[13]

[12] Fuhrer and Moore (1993) find a similar rule helps fit the data quite well when included in their contracting model.

[13] Dotsey (1989) shows that allowing banks to have private information does affect the reduced-form coefficients. For reasonable parameters, however, this effect is very small.

The changes in operating procedures over the period of the Feldstein and Stock analysis—the announced move to nonborrowed reserve targeting under lagged reserve requirements and the gradual emphasis placed on a borrowed reserve target later on—amounted to a noisy interest rate instrument. Also, as long as the Fed is using an interest rate instrument changes in reserve requirements, or the move from lagged reserve to contemporaneous reserve requirements, are largely inconsequential. Finally, the removal of Regulation Q ceilings should have very little impact on the interest elasticity of money demand if banks face fairly constant marginal costs of providing transactions services and if they price deposits competitively.[14] The stability that Feldstein and Stock find in their reduced-form estimates is, therefore, not surprising.

The change in operating procedures they contemplate, namely, directly targeting M2, may be an entirely different matter. To investigate the effect on the economies reduced form, we replace equation (14) by an equation that describes the Fed as targeting M2 with an interest rate instrument. This equation is given by

$$r_t = (1/c_r)[E_{t-1}p_t + c_y E_{t-1}y_t - m_t^*], \tag{14$'$}$$

where m_t^* is the target level of M2. Equations (15)–(18) would become

$$\tilde{y}_t = (a^d/a)u_t + (a^s/a)w_t \tag{15$'$}$$

$$\tilde{p}_t = (-1/a)u_t + (1/a)w_t \tag{16$'$}$$

$$\tilde{r}_t = 0 \tag{17$'$}$$

$$\tilde{m}_t = [(a^d - 1)/a]w_t + [(1 + a^s)/a]w_t + v_t, \tag{18$'$}$$

where $a = a^s + a^d$. This reduced-form system is quite different from the one shown previously, implying that the assumption of structural invariance is somewhat tenuous.

Alternatively, the Fed could attempt to control M2 by placing a uniform reserve requirement, η , on M2 balances and controlling M2 through the supply of total reserves. Under this policy, required reserves, *RR*, would then be equal to $\eta(\text{M2}-C)$, where C is currency, and total reserve demand would equal *RR*

[14] If one thinks of the demand for money as responding to opportunity costs, then prior to the removal of Regulation Q money demand was influenced by the nominal rate, r. After removal of rate Q it was influenced by $r - r_M$, where r_M is the own rate. If marginal costs are fairly constant and the banking system is competitive, then $r_M = (1 - \lambda)r$ and the opportunity cost of holding money will be λr. One sees that $d \log M/d \log r$ is invariant to this regulatory change when money demand is of the constant elasticity form. If the demand for money is semi-logarithmic, then its interest elasticity would be scaled by λ. Since the elasticity is very small to begin with, stability tests may not be very sensitive to the removal of Regulation Q.

plus excess reserve demand, *ER*. A log-linear representation of total reserve demand would be

$$tr_t^d = \log \eta + m_t - \zeta_t + \varepsilon_t, \tag{13''}$$

where *tr* is the log of total reserves, m_t is the log of M2 balances, $\zeta_t = (c_t/\text{M2}_t)$ and $\varepsilon_t = ER_t/[\eta(\text{M2}_t - C_t)]$.[15] If the Fed supplied total reserves in an attempt to hit an M2 target, it could do so by setting $tr_t^s = \log \eta + m_t^*$. If total reserve control was exact then $m_t = m_t^* + \zeta_t - \varepsilon_t$ and M2 will vary with movements in currency and excess reserves. If the Fed instead controlled the monetary base, then movements between currency and deposits would generally change M2. Only if $\eta = 1$ and excess reserves were unimportant would strict M2 control be achievable. In this case M2 would equal the monetary base. Note, however, that although M2 is controllable, there is no longer a banking system since without fractional reserves banks have no assets with which to make loans. One suspects that such a policy would lead to financial changes that would considerably affect the correlation of nominal output and M2.

Again if we replace (13) with equation (13″) and (14) with

$$tr_t^s = tr_t^* + x_t, \tag{14''}$$

where $tr_t^* = \log \eta + m_t^*$ and x_t represents reserve control errors, then the reduced-form representation for unexpected changes in economic activity are

$$\tilde{y}_t = (1/DD)\{-(a^d c_y + c_r)u_t + c_r w_t - a^d(v_t - x_t - \zeta_t + \varepsilon_t)\} \tag{15''}$$

$$\tilde{p}_t = (1/DD)\{-(a^d/a)(a^d c_y - 1)u_t - (a^d/a)(1 + a^s c_y)w_t \\ - a^d(v_t - x_t - \zeta_t + \varepsilon_t)\} \tag{16''}$$

$$\tilde{r}_t = (1/DD)\{(a^d c_y - 1)u_t + (1 + a^s c_y)w_t + a(v_t - x_t - \zeta_t + \varepsilon_t)\} \tag{17''}$$

$$\tilde{m}_t = x_t + \zeta_t - \varepsilon_t, \tag{18''}$$

where $DD = (a^s + a^d)c_r + a^d(1 + a^s c_y)$. Again, the reduced form is not invariant to this proposed change in operating procedures.

To investigate the extent of the reduced-form invariance, we calibrate the three distinct structural models and examine the implied variance-covariance matrices. In doing so, we set $a^s = 1.0$ and $a^d = .7$. The first value is taken from King and Plosser (1986) while the second comes from Fuhrer and Moore (1993).[16] We assume M2 has a unitary income elasticity, $c_y = 1$, and $c_r = 2$

[15] $tr = \log(RR + ER) = \log[RR(1 + \frac{ER}{RR})] = \log RR + \log(1 + \frac{ER}{RR}) \approx \log \eta + \log(\text{M2}-C) + \varepsilon_t = \log \eta + \log[M(\frac{1-C}{M})] + \varepsilon_t \approx \log \eta + m - \zeta + \varepsilon$.

[16] Fuhrer and Moore's coefficient is actually the impact effect of aggregate demand to a change in lagged value of the long-term real interest rate.

implies an interest elasticity of approximately $-.10$. Again following Fuhrer and Moore, the coefficients b_p and b_y are assumed to be .1 and we set $b_r = b_m = .1$ as well.

To produce numerical results, we also need to say something about the variances of the structural disturbances. We assume that the variance of the shocks to aggregate supply, aggregate demand, money demand, and Fed behavior are all of the same magnitude σ^2. The variances for the currency/M2 ratio, ζ, and the excess reserve/M2 ratio, ε, are assumed to be somewhat smaller. These are $(1/16)\sigma^2$ and $(1/1000)\sigma^2$, respectively. For example, a value of $\sigma^2 = .0001$ would imply that 95 percent of the shocks to quarterly output supply growth or output demand growth are ± 2 percent. The $(1/16)\sigma^2$ value for the variance of $\pm C$/M2 then implies that fluctuations in this ratio are generally no larger than .005 and the $(1/1000)\sigma^2$ value implies that fluctuations in ER/M2 seldom exceed .0006.

Under this parameterization the variance-covariance matrices for the three models are

$$\begin{bmatrix} .77 & & & \\ .35 & .93 & & \\ .55 & .57 & .87 & \\ .005 & .13 & -.60 & 1.54 \end{bmatrix} \sigma^2, \quad \begin{bmatrix} .52 & & & \\ .10 & .69 & & \\ 0.0 & 0.0 & 0.0 & \\ .61 & .80 & 0.0 & 2.42 \end{bmatrix} \sigma^2, \text{ and}$$

$$\begin{bmatrix} .51 & & & \\ -.04 & .07 & & \\ .10 & -.18 & .43 & \\ .15 & .15 & -.35 & 1.06 \end{bmatrix} \sigma^2,$$

respectively. The differences are noticeable, indicating that it is inappropriate to use a reduced-form structure from one type of policy rule to make inferences about the effects of an alternative policy rule. Of interest, however, is the fact that using a total reserves instrument to target M2 produces the lowest variance in prices and real output. Whether this result would carry over to more detailed structural models is unknown. Also, other types of rules, for example, those advocated by McCallum (1988, 1993a), may be better still. It is obvious that before jumping on an M2 bandwagon a lot of work remains to be done.

4. CONCLUSION

In this article we have critically examined the debate over using M2 as an intermediate target of monetary policy. We have done this by focusing on two largely empirical studies. We found that Friedman and Kuttner's central result that money does not Granger-cause real or nominal output is due to a model misspecification. When the cointegrating relationship among money, income, prices, and interest rates is accounted for, money does indeed Granger-cause output. We also found that Feldstein and Stock's main result, that a monetary policy that uses M2 as an intermediate target can substantially reduce the variance of nominal GDP growth, depends critically on their assumption that M2 is perfectly controllable. When this assumption is realistically relaxed, the ability of their policy to reduce the variance of nominal income growth is seriously diminished.

More generally, our results cast doubt on the idea that either empirical exercise is useful in analyzing alternative monetary policies. Studies, such as Friedman and Kuttner's, that base their conclusions solely on the use of Granger-causality and reduced-form models do not provide a firm basis for making a decision about the usefulness of a monetary aggregate under some alternative operating procedure. The absence of Granger-causality may provide little guidance for evaluating the usefulness of M2 or any other aggregate for monetary policy. All that the absence of Granger-causality tells us is that under current operating procedures some variable does not help forecast future economic activity.

Further, the presence of Granger-causality does not in and of itself imply that targeting the aggregate in question would be good monetary policy. In order to undertake that exercise, one needs a theory and the corresponding structural model. Simply using a reduced-form model as Feldstein and Stock do is inappropriate when that reduced form will not remain invariant to the contemplated changes in policy. There does not seem to us any shortcuts that will substitute for the hard and necessary work of building and analyzing structural models.

REFERENCES

Becketti, Sean, and Charles Morris. "Does Money Still Forecast Economic Activity?" Federal Reserve Bank of Kansas City *Economic Review,* vol. 77 (4th Quarter 1992), pp. 65–78.

Bernanke, Ben S., and Alan S. Blinder. "The Federal Funds Rate and the Channels of Monetary Transmission," *American Economic Review,* vol. 82 (September 1992), pp. 901–21.

Boyd, John H., III, and Michael Dotsey. "Interest Rate Rules and Nominal Determinancy." Manuscript. April 1993.

Dotsey, Michael. "Monetary Control Under Alternative Operating Procedures," *Journal of Money, Credit, and Banking,* vol. 21 (August 1989), pp. 273–90.

Engle, Robert F., and C. W. J. Granger. "Cointegration and Error Correction: Representation, Estimation, and Testing," *Econometrica,* vol. 55 (March 1987), pp. 251–76.

Feldstein, Martin. "The Recent Failure of U.S. Monetary Policy," Working Paper 4236. Cambridge, Mass.: National Bureau of Economic Research, December 1992.

__________, and James H. Stock. "The Use of Monetary Aggregate to Target Nominal GDP," Working Paper 4304. Cambridge, Mass.: National Bureau of Economic Research, March 1993.

Friedman, Benjamin M., and Kenneth K. Kuttner. "Another Look at the Evidence on Money-Income Causality," *Journal of Econometrics*, vol. 57 (June 1993), pp. 189–203.

__________. "Money, Income, Prices, and Interest Rates," *American Economic Review,* vol. 82 (June 1992), pp. 472–92.

Fuhrer, Jeff, and George Moore. "Monetary Policy and the Behavior of Long-Term Real Interest Rates," Finance and Economic Discussion Series No. 93-16. Washington: Board of Governors of the Federal Reserve System, May 1993.

Hess, Gregory D., and Richard D. Porter. "Comparing Interest-Rate Spreads and Money Growth as Predictors of Output Growth: Granger Causality in the Sense Granger Intended." Manuscript. Board of Governors of the Federal Reserve System, September 1992.

Hess, Gregory D., David H. Small, and Flint Brayton. "Nominal Income Targeting with the Monetary Base as Instrument: An Evaluation of McCallum's Rule," in Marvin Goodfriend and David H. Small, special issue eds., *Operating Procedures and the Conduct of Monetary Policy: Conference Proceedings.* Finance and Economics Discussion Series, Working Studies 1: Part 2. Washington: Board of Governors of the Federal Reserve System, 1993.

Judd, John P., and Brian Motley. "Nominal Feedback Rules for Monetary Policy," Federal Reserve Bank of San Francisco *Economic Review,* Summer 1991, pp. 3–17.

King, Robert G., and Charles I. Plosser. "Nominal Surprises, Real Factors and Propagation Mechanisms," Working Paper 50. University of Rochester, Center for Economic Research, July 1986.

Konishi, Toru, Valerie A. Ramey, and Clive W. J. Granger. "Stochastic Trends and Short-Run Relationships Between Financial Variables and Real Activity." Manuscript. University of California, San Diego, December 1992.

McCallum, Bennett T. "Monetary Policy Rules and Financial Stability." Manuscript. August 1993a.

__________. "Comment on Feldstein and Stock's 'The Use of a Monetary Aggregate to Target Nominal GDP.' " Manuscript. April 1993b.

———. “Robustness Properties of a Rule for Monetary Policy,” *Carnegie-Rochester Conference Series on Public Policy,* vol. 29 (Autumn 1988), pp. 173–203.

———. “Rational Expectations and Macroeconomic Stabilization Policy,” *Journal of Money, Credit, and Banking,* vol. 12 (November 1980, Part 2), pp. 716–46.

Stock, James, and Mark W. Watson. “A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems,” Working Paper WP-91-3. Federal Reserve Bank of Chicago, February 1991.

———. “New Indexes of Coincident and Leading Indicators,” in O. Blanchard and S. Fischer, eds., *NBER Macroeconomic Annual*. Cambridge, Mass.: MIT Press, 1989, pp. 351–93.