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2 Unanticipated Money and Economic Activity

Robert J. Barro and Mark Rush

This paper discusses ongoing research on the relation of money to economic activity in the post–World War II United States. As in previous work (Barro 1977, 1978), the stress is on the distinction between anticipated and unanticipated movements of money.

The first portion deals with annual data. Aside from updating and refinements of earlier analysis, the principal new results concern joint, cross-equation estimation and testing of the money growth, unemployment, output, and price level equations. The present findings raise doubts about the specification of the price equation, although the other relations receive further statistical support.

The second part applies the analysis to quarterly data. Despite the necessity of dealing with pronounced serial correlation of residuals in the equations for unemployment, output, and the price level, the main results are consistent with those obtained from annual data. Further, the quarterly estimates allow a detailed description of the lagged response of unemployment and output to money shocks. The estimates reveal some lack of robustness in the price equation, which again suggests some misspecification of this relation.

Results from Annual U.S. Data

Robert J. Barro

The first section of this paper summarizes and extends the results for annual U.S. data on money growth, unemployment, output, and the

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price level (Barro 1977, 1978). The estimated money growth equation, which is used to divide observed growth rates into anticipated and unanticipated components, is

1941–77 sample (observations from 1941 to 1945 multiplied by 0.36):

$$
\begin{aligned}
(1)\qquad DM_t = & \underset{(.024)}{.085} + \underset{(.14)}{.44DM_{t-1}} + \underset{(.12)}{.18DM_{t-2}} + \\
& + \underset{(.015)}{.073FEDV_t} + \underset{(.008)}{.027} \cdot \log(U/1 - U)_{t-1},
\end{aligned}
$$

$\hat{\sigma}$ (for post–World War II sample) $= .0141$,

$D\text{-}W = 1.9$,[1]

where the money growth rate is $DM_t \equiv \log(M_t/M_{t-1})$, M_t is the annual average of the $M1$ concept of money,[2] real federal expenditure relative to "normal" is $FEDV_t \equiv \log(FED_t) - [\log(FED)]^*_t$, FED_t is total nominal federal expenditure divided by the GNP deflator, $[\log(FED)]^*_t$ is an exponentially declining distributed lag of $\log(FED)$ with current weight of 0.2, U is the unemployment rate in the total labor force, $\hat{\sigma}$ is the standard error of estimate, and $D\text{-}W$ is the Durbin-Watson statistic.

Using the residuals, DMR, from equation (1) to measure "unanticipated money growth," the estimated equations for the unemployment rate and output (real GNP) turn out to be

1949–77 sample:

$$
\begin{aligned}
(2)\qquad \log(U/1 - U)_t = & -\underset{(.04)}{2.68} - \underset{(1.6)}{4.6DMR_t} \\
& -\underset{(1.6)}{10.9}\ DMR_{t-1} \\
& - \underset{(1.6)}{5.5DMR_{t-2}} - \underset{(0.6)}{5.3MIL_t},
\end{aligned}
$$

$R^2 = .87$, $\hat{\sigma} = .113$, $D\text{-}W = 2.4$

1. The Durbin h-statistic also shows no serial correlation of residuals for this equation. The weighting pattern accounts for a higher variance of the error term for observations prior to 1946. The value of 0.36 is determined from a maximum likelihood criterion (assuming normality for the errors).

2. A change from the previous money data involves an adjustment to the level of the money stock prior to 1947 by a factor of 1.013. See the notes to table 2.3.

1946–77 sample:

$$\log(y_t) = \underset{(.04)}{2.93} + \underset{(.22)}{0.99}DMR_t + \underset{(.22)}{1.18}DMR_{t-1} + \underset{(.19)}{0.37}DMR_{t-2} + \underset{(.0004)}{.0357} \cdot t + \underset{(.09)}{0.54}MIL_t, \tag{3}$$

$$R^2 = .998,\ \hat{\sigma} = .0159,\ D\text{-}W = 1.8,$$

where y is GNP in 1972 dollars, MIL is the military personnel/conscription variable that is discussed in Barro (1977), and t is a time trend.[3]

The unemployment rate equation (2) has been altered from that in my 1977 paper by dropping a minimum wage rate variable and omitting the 1946–48 observations. As discussed earlier (Barro 1979*a*), the estimated positive influence of the minimum wage variable turns out to be merely an imperfect attempt to account for the otherwise unexplained low values of the unemployment rate from 1946 to 1948. The variable is insignificant over the post-1949 sample (estimated coefficient of —0.1, standard error = 0.6 when added to equation (2)). Aside from a higher standard error of estimate, an unemployment rate equation estimated over a 1946–77 sample (with the minimum wage rate variable excluded) appears similar to that shown in equation (2).[4]

The estimated equation for the price level (GNP deflator), based on my previous analysis (Barro 1978) is

3. Estimation of equation (3) in first-difference form yields

$$D\log y_t = \underset{(.0038)}{.0350} + \underset{(.25)}{.80}DDMR_t + \underset{(.27)}{.98}DDMR_{t-1} + \underset{(.24)}{.19}DDMR_{t-2} + \underset{(.18)}{.41}DMIL_t,$$

$$R^2 = .52,\ \hat{\sigma} = .0208,\ D\text{-}W = 2.6,$$

where D is the difference operator. The robustness of the coefficient estimates to differencing—which turns out to apply here—is a useful check on the specification of the model. See Plosser and Schwert 1979.

4. The estimated equation over 1946–77 is

$$\log(U/1 - U)_t = \underset{(.05)}{-2.75} - \underset{(2.1)}{4.3}DMR_t - \underset{(2.1)}{11.5}DMR_{t-1} - \underset{(1.8)}{5.3}DMR_{t-2} - \underset{(0.7)}{4.6}MIL_t,$$

$$R^2 = .76,\ \hat{\sigma} = .150,\ D\text{-}W = 1.7.$$

1948–77 sample:

(4)
$$\begin{aligned}\log(P_t) = \log(M_t) - \underset{(0.2)}{4.4} - \underset{(.20)}{0.64}DMR_t \\ - \underset{(.23)}{1.52}DMR_{t-1} - \underset{(.28)}{1.80}DMR_{t-2} \\ - \underset{(.26)}{1.42}DMR_{t-3} - \underset{(.19)}{.73}DMR_{t-4} \\ - \underset{(.16)}{.37}DMR_{t-5} - \underset{(.0021)}{.0120} \cdot t \\ + \underset{(.16)}{.59}(G/y)_t + \underset{(1.1)}{4.3}R_t, \\ \hat{\sigma} = .0130,\ D\text{-}W = 1.6,\end{aligned}$$

where G is real federal purchase of goods and services and R is the long-term interest rate (Aaa corporate bond rate). The inclusion of the G/y and R variables has been rationalized from their inverse influences on money demand (Barro 1978). Equation (4) is estimated using the lagged value R_{t-1} as an instrument for R_t. The coefficient of $log(M_t)$ in equation (4) is constrained to be unity (tests of this proposition are discussed in Barro 1978).[5]

Observations for 1946–47 are excluded from equation (4) because of the apparently strong persisting influence on reported prices of the World War II controls. The estimated negative effects of the DMR variables on the price level, as shown in equation (4), are substantially drawn out relative to the pattern of positive output effects shown in equation (3). An attempt to account for this discrepancy in terms of the dynamics of money demand has already been described (Barro 1978). It is worth stressing that this appearance of sluggish price adjustment does not correspond to the pattern of output and unemploy-

5. In an unconstrained regression the coefficient estimate for $\log(M_t)$ is 1.01, *s.e.* = .06. The results with the $\log(M_t)$ coefficient restricted or unrestricted are altered negligibly if $(G/\hat{y})_t$ is used as an instrument for $(G/y)_t$, where $\hat{y}_t$ is an estimated value of real GNP based on equation (3). OLS estimates differ from equation (4) mostly in the estimated coefficient of R_t, which becomes 3.1, *s.e.* = 0.6. OLS estimates of the price equation in first-difference form are

$$\begin{aligned}D\log P_t = \underset{(.0031)}{-.0082} + D\log M_t - \underset{(.20)}{.81}DDMR_t - \underset{(.28)}{1.30}DDMR_{t-1} \\ - \underset{(.32)}{1.43}DDMR_{t-2} - \underset{(.29)}{1.06}DDMR_{t-3} - \underset{(.25)}{.57}DDMR_{t-4} \\ - \underset{(.16)}{.21}DDMR_{t-5} + \underset{(.21)}{.38}D(G/y)_t + \underset{(0.8)}{2.5}DR_t, \\ \hat{\sigma} = .0143,\ D\text{-}W = 2.1.\end{aligned}$$

Despite some reduction in the magnitude of the lagged *DMR* coefficients, the general results are robust to differencing; see n. 3, above.

ment persistence that appears in equations (2) and (3). Accordingly, explanations for price stickiness of the "disequilibrium" (Barro and Grossman 1976, chap. 2) or contracting variety (as in Taylor 1978) would not explain the results. These theories seem to account only for a pattern of price stickiness that corresponds to the patterns of output and unemployment stickiness.

The estimated elasticity of response of the price level to a contemporaneous money shock can be ascertained from equation (4) to be 1.00 (from $\log(M_t)$) plus -0.64 (from DMR_t) to be 0.36. The corresponding effect of this year's money shock on $\log(P_{t+1})$ can also be calculated, making use of equations (1) and (2) to determine the movement in $\log(M_{t+1})$, to be $-.020$. Therefore, the type of relative price variable stressed by Lucas and others, $\log(P_t) - \log(P_{t+1})^e$ (where the expectation of $\log(P_{t+1})$ includes all data generated up to date t), is estimated to respond with an elasticity of 0.56 to a contemporaneous money shock. Accordingly, the contemporaneous output response coefficient of 0.99 shown in equation (3) would require an elasticity of output supply with respect to this relative price variable of about 1.8.[6] Since this elasticity is of "plausible" size in the context of response to a temporary opportunity for high prices, it may be that this channel of effect from money shocks to contemporaneous output responses is more important empirically than I once thought (Barro 1978, p. 579). The earlier calculations neglected the effect of DMR_t on $\log(P_{t+1})^e$ and were also based on a larger magnitude coefficient estimate for DMR_t in the price equation.

My previous analyses involved a number of tests of the proposition that monetary influences on unemployment and output operate only in the form of unanticipated movements, $DMR \equiv DM - \widehat{DM}$, where $\widehat{DM}$ is estimated money growth from a relation of the form of equation (1). Tests were also carried out for the hypothesis that fully perceived changes in the level of money (shifts in M with the DMR's and R held fixed) imply a one-to-one, contemporaneous effect on the price level. The best way to test these hypotheses involves joint estimation of the money growth, unemployment, output, and price level equations. In particular, this joint estimation appropriately allows the estimation of coefficients in the money growth equation to take account of the effect on the fit of the other equations through the calculation of DMR values. In the two-part estimation procedure described in equations (1)–(4), the coefficient estimates reported in equation (1) consider only the fit of the money growth equation.[7]

Write the money growth equation as $DM_t = F(X_t) + DMR_t$, where X_t is a set of money growth predictors—in the present case, $F(X_t) =$

6. This calculation assumes no monetary wealth effect on supply.

7. *See Leiderman 1979 for a discussion of this matter.*

$\alpha_0 + \alpha_1 DM_{t-1} + \alpha_2 DM_{t-2} + \alpha_3 FEDV_t + \alpha_4 \log(U/1-U)_{t-1}$. The condition, $DMR_t \equiv DM_t - F(X_t)$, with corresponding substitutions for DMR_{t-1}, etc., can then be applied to the unemployment, output, and price level equations. The system can be estimated in an unrestricted manner by allowing separate coefficients on the variables—DM_{t-1}, DM_{t-2}, . . . —contained in $F(X_t)$, $F(X_{t-1})$, etc., in each of the equations. The underlying unanticipated money growth hypothesis, which amounts to a set of nonlinear coefficient restrictions across the equations, is that $F(X_t)$ in the unemployment, output, and price level equations corresponds to the coefficients in the money growth equation. A likelihood ratio test can be carried out to check whether the imposition of these restrictions on the joint estimation produces a statistically significant deterioration of the fit—in which case the underlying hypothesis would be rejected.

The joint estimates for the money growth, unemployment, and output equations that are subject to the restrictions implied by the unanticipated money growth hypothesis and which comprise the same sample periods and weighting scheme for the DM equation as shown above are[8]

$$\text{(1')} \quad \begin{aligned} DM_t = {} & \underset{(.012)}{.074} + \underset{(.11)}{.36} DM_{t-1} + \underset{(.09)}{.18} DM_{t-2} \\ & + \underset{(.010)}{.079} FEDV_t + \underset{(.004)}{.022} \cdot \log(U/1-U)_{t-1}, \end{aligned}$$

$$\hat{\sigma} = .0133,\ D\text{-}W = 1.8,$$

$$\text{(2')} \quad \begin{aligned} \log(U/1-U)_t = {} & \underset{(.06)}{-2.65} - \underset{(1.3)}{4.7} DMR_t \\ & \underset{(1.3)}{-10.8} DMR_{t-1} - \underset{(1.6)}{5.0} DMR_{t-2} \\ & - \underset{(0.6)}{6.2} MIL_t, \end{aligned}$$

$$\hat{\sigma} = .090,\ D\text{-}W = 2.6,$$

$$\text{(3')} \quad \begin{aligned} \log(y_t) = {} & \underset{(.03)}{2.90} + \underset{(.18)}{1.00} DMR_t + \underset{(.21)}{1.09} DMR_{t-1} \\ & + \underset{(.19)}{.44} DMR_{t-2} + \underset{(.0002)}{.0358} \cdot t + \underset{(.10)}{.68} MIL_t, \end{aligned}$$

$$\hat{\sigma} = .0129,\ D\text{-}W = 1.9,$$

where asymptotic standard errors are shown in parentheses. Note that these σ values are not adjusted for degrees of freedom and are there-

8. The estimation, carried out with the TSP regression package, includes contemporaneous covariances for the error terms across the equations. But the covariance of the money growth error term with that in the other equations is zero by construction.

fore not directly comparable to those shown in equations (1)–(3).[9] As would be expected, the fit of the unemployment and output equations is improved relative to that shown in equations (2) and (3)—the worsening in fit of the *DM* equation turns out to be minor. The only notable changes in coefficient estimates are in the *DM* equation: the estimated coefficient of DM_{t-1} is reduced and the estimated standard error of the lagged unemployment rate coefficient declines sharply.

The three equations have also been fitted with the relaxation of the cross-equation restrictions implied by the unanticipated money growth hypothesis. A comparison of the unrestricted and constrained results leads to the calculation of a value for $-2 \cdot log$(likelihood ratio) for a test of the cross-equation restrictions, which would be distributed asymptotically as a χ^2 variable with 16 degrees of freedom. The actual value of 16.3 is below the 5% critical value of 26.3. Therefore, the unanticipated money growth hypothesis is accepted by this joint test on the money growth, unemployment, and output equations.

The cross-equation restrictions associated with the unanticipated money hypothesis are not accepted when the price equation is included in the joint estimation. This conclusion applies to the four-equation system for (DM,U,y,P) and also for the system that comprises only the *DM* and *P* equations. The joint estimates for this last case that embody the cross-equation restrictions of the unanticipated money hypothesis are[10]

$$(1'') \qquad \begin{aligned} DM_t = & \underset{(.011)}{.098} + \underset{(.12)}{.44}DM_{t-1} + \underset{(.09)}{.16}DM_{t-2} \\ & + \underset{(.011)}{.061}FEDV_t + \underset{(.004)}{.031} \cdot \log(U/1-U)_{t-1}, \\ & \hat{\sigma} = .0134,\ D\text{-}W = 1.8, \end{aligned}$$

$$(4'') \qquad \begin{aligned} \log P_t = & \log M_t - \underset{(.15)}{4.58} - \underset{(.12)}{.85}DMR_t - \underset{(.15)}{1.31}DMR_{t-1} \\ & - \underset{(.18)}{1.36}DMR_{t-2} - \underset{(.17)}{.94}DMR_{t-3} \\ & - \underset{(.12)}{.61}DMR_{t-4} - \underset{(.10)}{.16}DMR_{t-5} \\ & + \underset{(.15)}{.34}(G/y)_t + \underset{(0.5)}{2.9}R_t - \underset{(.0015)}{.0096} \cdot t, \\ & \hat{\sigma} = .0069,\ D\text{-}W = 2.2. \end{aligned}$$

9. There is also a minor problem in that the presently used computer program allows for different numbers of observations across equations only by introducing some extra observations (for the *U* and *y* equations) that are then set to zero on both sides of the equations. This procedure inflates the apparent degrees of freedom and thereby leads to an underestimate of standard errors of coefficient estimates and disturbances.

10. This estimation does not use R_{t-1} as an instrument for R_t in the price equation. For the case of equation (4), OLS estimates differed mainly in the estimate of the R_t coefficient.

Unrestricted estimation of the two equations leads to the calculation of a value for $-2 \cdot \log(\text{likelihood ratio})$ for a test of the cross-equation restrictions. The actual value of 66.8 is well above the 5% χ^2 value with 14 degrees of freedom of 23.7. Similar results obtain for the four-equation system, where the actual value for $-2 \cdot \log(\text{likelihood ratio})$ of 122.2 exceeds the 5% χ^2 value with 30 degrees of freedom of 43.8.

A large part of the discrepancy in results seems to involve estimation of contemporaneous effects, specifically, the response of P_t to DM_t. The estimated coefficient of DM_t in the unrestricted form comparable to equation (4″) is -1.33, $s.e. = .12$, as compared with the restricted estimate (on DMR_t) of $-.85$, $s.e. = .12$. The estimation of this contemporaneous relation could involve a simultaneity problem, for example, if there were within-period feedback from P_t to DM_t. If the DMR_t variable (which would satisfy the usual properties of an error term) is omitted from the restricted price equation, and the DM_t, $FEDV_t$, and $\log(U/1 - U)_{t-1}$ variables are deleted from the unrestricted form, the value for $-2 \cdot \log(\text{likelihood ratio})$ associated with the unanticipated money hypothesis turns out to be 31.8, as compared with a 5% χ^2 value with 12 degrees of freedom of 21.0. Although the discrepancy is substantially reduced in this case, the unanticipated money hypothesis would still be rejected. It seems clear that there are some important unresolved questions about the specification of the price equation that will require further investigation. One possible source of difficulty would be feedback to money growth from the price level or interest rates, which were not included as explanatory variables in equation (1).

A number of people have raised reasonable doubts about the meaning of the military personnel/conscription variable MIL in the unemployment and output equations. The MIL variable was viewed initially as a draft pressure influence that would increase employment and reduce labor force participation. (In this context see Small 1979 and my reply 1979*a*.) I have noted some problems with the MIL variable that concerned its surprisingly strong output effect and insignificant price level influence (1978). Although the MIL variable is highly significant in unemployment and output equations, as in equations (2), (2′), (3) and (3′) above, it should be noted that this variable (see Barro 1977, table 2) does not exhibit major variations from 1951 to 1969, especially from 1955 to 1969. Mostly, the MIL variable shows a sharp increase from its 1949–50 values at the start of the Korean war, a mild decline from 1953 to 1958, a mild increase with the Vietnam war for 1967–69, and a sharp drop (to zero with the end of the selective, nonlottery draft) in 1970.

I have considered the possibility that the MIL variable is proxying for movements in real federal purchases of goods and services. In the case of output, a substitution of log(G) for *MIL*, where G is real federal purchases and the *DMR* values are the residuals from equation (1), yields (for the 1946–77 sample)

$$\begin{aligned}(5)\qquad \log(y_t) = {} & \underset{(.05)}{2.92} + \underset{(.23)}{1.06DMR_t} + \underset{(.24)}{1.08DMR_{t-1}} \\ & + \underset{(.20)}{.07DMR_{t-2}} + \underset{(.0004)}{.0330 \cdot t} \\ & + \underset{(.013)}{.070 \cdot \log(G_t)} \\ R^2 = .998,\ \hat{\sigma} = .0169,\ & D\text{-}W = 1.5.\end{aligned}$$

For the case of the unemployment rate, I have entered the ratio of G to y as an explanatory variable to obtain the estimated equation for the 1949–77 sample,[11]

$$\begin{aligned}(6)\qquad \log(U/1-U)_t = {} & \underset{(.12)}{-2.21} - \underset{(2.0)}{6.3DMR_t} \\ & \underset{(2.0)}{-10.5DMR_{t-1}} - \underset{(2.0)}{1.9DMR_{t-2}} \\ & - \underset{(1.0)}{6.7(G/y)_t}, \\ \hat{\sigma} = .145,\ & D\text{-}W = 1.6.\end{aligned}$$

Lagged values of log(G) and G/y are insignificant when added to equations (5) and (6), respectively. The estimated equations do suggest an important expansionary effect of the contemporaneous amount of federal purchases. (Another result is the loss of significance of the DMR_{t-2} variable; that is, with log(G) or G/y substituted for *MIL*, the lagged effects from money shocks to output and unemployment are shorter than those estimated previously.) If the *MIL* variable is added to equations (5) and (6), however, its estimated coefficients are significant (0.4, *s.e.* = 0.2 for output; —5.2, *s.e.* = 1.4 for unemployment), while those on log(G) or G/y become insignificant (.01, *s.e.* = .03 for output; —0.2, *s.e.* = 1.8 for unemployment). Similar results obtain even if the samples are terminated in 1969, that is, if the period where the *MIL* variable drops to zero is omitted.

It may be worth noting that equation (2), which includes the *MIL* variable, and equation (6), which contains G/y, have similar implications for the time path of the natural unemployment rate. With all *DMR* variables and the error term set to zero, equation (2) implies an unemployment rate of 6.4% at the 1977 value of *MIL* (zero), and 4.5% for the values of *MIL* (.07 to .08) prevailing in the early 1960s. Equation (6) yields values for the unemployment rate of 6.2% at the 1977 value

11. The results differ negligibly if G/y is used as an instrument for $G/\hat{y}$, where $\hat{y}$ is an estimated value of real GNP based on equation (5).

of G/y (.076) and also about 4.5% for the values of G/y (around .125) that existed in the early 1960s. Conceivably, this pattern for the natural unemployment rate is approximately correct even if neither the *MIL* nor the G/y variables are the properly specified military/government purchases influence on unemployment.

Jointly estimated equations that include the federal purchases variables are

$$
\begin{aligned}
(1''') \quad DM_t = {} & \underset{(.015)}{.086} + \underset{(.10)}{.41}DM_{t-1} + \underset{(.08)}{.15}DM_{t-2} \\
& + \underset{(.010)}{.079}FEDV_t + \underset{(.005)}{.027} \cdot \log(U/1 - U)_{t-1},
\end{aligned}
$$

$\hat{\sigma} = .0132$, $D\text{-}W = 1.9$,

$$
\begin{aligned}
(5''') \quad \log(y_t) = {} & \underset{(.03)}{2.88} + \underset{(.19)}{1.00}DMR_t + \underset{(.22)}{1.03}DMR_{t-1} \\
& + \underset{(.17)}{.00}DMR_{t-2} + \underset{(.0005)}{.0329} \cdot t \\
& + \underset{(.015)}{.081} \cdot \log(G_t),
\end{aligned}
$$

$\hat{\sigma} = .0138$, $D\text{-}W = 1.6$,

$$
\begin{aligned}
(6''') \quad \log(U/1 - U)_t = {} & -\underset{(.13)}{2.19} - \underset{(1.7)}{6.0}DMR_t \\
& - \underset{(1.7)}{10.7}DMR_{t-1} - \underset{(1.7)}{0.6}DMR_{t-2} \\
& - \underset{(1.1)}{7.0}(G/y)_t,
\end{aligned}
$$

$\hat{\sigma} = .117$, $D\text{-}W = 1.7$.

In this case the test statistic for the cross-equation restrictions implied by the unanticipated money hypothesis turns out to be 26.0, which is slightly below the 5% χ^2 value with 16 degrees of freedom of 26.3.

Results from Quarterly U.S. Data

Robert J. Barro and Mark Rush

The second portion of this paper describes results from applying the preceding analysis to quarterly U.S. data.

Money Growth

An estimated equation for money growth, based on quarterly, seasonally adjusted observations, for the period 1941:I to 1978:I, and following the general form of equation (1) is

$$\begin{aligned}
(7) \qquad DM_t = {} & \underset{(.0048)}{.0149} + \underset{(.08)}{.54DM_{t-1}} - \underset{(.09)}{.05DM_{t-2}} \\
& + \underset{(.09)}{.03DM_{t-3}} + \underset{(.08)}{.09DM_{t-4}} - \underset{(.08)}{.01DM_{t-5}} \\
& + \underset{(.07)}{.13DM_{t-6}} + \underset{(.0030)}{.0104FEDV_t} \\
& - \underset{(.005)}{.003} \cdot \log(U/1 - U)_{t-1} \\
& + \underset{(.007)}{.015} \cdot \log(U/1 - U)_{t-2} \\
& - \underset{(.005)}{.007} \cdot \log(U/1 - U)_{t-3}, \\
\hat{\sigma} = {} & .0049, \quad D\text{-}W = 2.0,
\end{aligned}$$

where DM is measured at quarterly rates (see the notes to table 2.3 for data definitions), $FEDV$ is comparable to the annual variable discussed above but with an adjustment coefficient of .05 per quarter, and observations from 1941–46 have been weighted by 0.25. This weight was determined from a maximum likelihood criterion (under normally distributed errors).

The principal explanatory power from the past history of the money growth series appears in the first quarterly lag value, DM_{t-1}. Lags from quarters two through six are of marginal joint significance (the F-value for joint significance is 2.0, which is actually just below the 5% critical value of 2.3). The pattern of DM effects after the first lag is difficult to interpret and may well reflect some persistence that is induced by inappropriate seasonal adjustment procedures (which one would wish to filter out for the present analysis).

The reaction of money growth to lagged unemployment is primarily with a two-quarter lag; the first lag value is insignificant. There is some indication from the negative coefficient on the third lag that DM_t reacts positively to the change in unemployment from period t-3 to t-2 as well as to the level of unemployment at date t-2. Lagged values of the $FEDV$ variable (with $FEDV_t$ included) and additional lag values of the DM and $\log(U/1 - U)$ variables are insignificant when added to equation (7). A comparison of the quarterly and annual money growth equations is carried out in a later section.

Actual values of DM are shown in table 2.3 along with estimated values, $\widehat{DM}$, and residuals, DMR, from equation (7).

Output and Unemployment

The quarterly analysis of output, unemployment, and the price level uses the residuals from equation (7) to measure "unanticipated money growth," *DMR*. Since anticipated money growth is then conditioned on values of *DM* and *U* up to a one-quarter lag, the assumption is that the relevant information lag on these variables is no more than one quarter. We continue to use the contemporaneous value of the *FEDV* variable to generate anticipated money growth (see Barro 1977, p. 106), although a substitution of $FEDV_{t-1}$ has a negligible effect on the results.[12]

A quarterly ordinary least squares equation for output is shown in table 2.1, column 2. This equation includes as explanatory variables a contemporaneous and 10 quarterly lag values of the *DMR* variable, the contemporaneous *MIL* variable, and a time trend. Additional lag values of *DMR* are insignificant. The most interesting result is the precision in the estimates of the quarterly lag pattern for *DMR*, which involves a strong contemporaneous response, a peak effect with a 3–4 quarter lag, a strong persisting effect through two years, and no significant remaining effect after 10 quarters.

The *MIL* variable has a highly significant, positive effect. Lag values over 4 quarters are insignificant. The substitution of the $\log(G_t)$ variable for MIL_t (col. 3) produces only minor changes in the fit or in the estimated pattern of *DMR* coefficients; principally, there is some shortening in the lagged *DMR* effect, which is now significant for only 8 quarters. Lagged values of the $\log(G)$ variable are unimportant, although there is some indication of a negative effect for the first lag.

The estimated output equations show strong positive serial correlation of residuals with *D-W* values of 0.4 and 0.3 in columns 2 and 3, respectively. Estimation of the pattern of residual serial correlation turned out to require a second-order autoregressive form: $u_t = \rho_1 u_{t-1} + \rho_2 u_{t-2} + \epsilon_t$, where ϵ_t is serially independent. The estimated values (based on a maximum likelihood criterion under normally distributed errors) for ρ_1, ρ_2, as shown in column 4 of table 2.1 (which uses the *MIL* variable), are 1.20, *s.e.* = .09 and −0.37, *s.e.* = .09.[13] Similar results appear in column 5, which uses the $\log(G)$ variable. This pattern of

12. With $FEDV_{t-1}$ substituted for $FEDV_t$, the σ value for the *DM* equation rises from .00490 to .00496. The estimated coefficient of $FEDV_{t-1}$ is .0089, *s.e.* = .0031, as compared with .0104, *s.e.* = .0030 for $FEDV_t$ in equation (7). The other coefficient estimates and standard errors are changed negligibly from those shown in equation (7). The substitution of $FEDV_{t-1}$ for $FEDV_t$ in the *DM* equation is also inconsequential for the analysis of output, unemployment, and the price level.

13. The 95% confidence interval for the sum of the two residual serial correlation coefficient estimates, $(\widehat{\rho_1 + \rho_2})$, which was constructed by finding the restricted value for the sum that yielded the 5% critical value of the likelihood ratio, turns out to have an upper limit of .92, which is below the nonstationary region. In particular, the value of $-2 \cdot \log(\text{likehood ratio})$ corresponding to the restriction $\rho_1 + \rho_2 = 1.0$ is 14.6, which exceeds the 5% critical value for the χ^2 distribution with 1 degree of freedom of 3.8. A difficulty with this test, however, is that the usual desirable asymptotic properties of the estimators do not hold in the region where $\rho_1 + \rho_2 \geq 1$. For the case of the unemployment rate

persistence for the error term implies strong positive serial correlation of residuals from quarter to quarter, but much weaker association from year to year.

The main impact of the residual serial correlation correction on the coefficient estimates of the output equations are, first, a reduction in the contemporaneous *DMR* effect, and second, a shortening of the overall lag response, which is now significant (in cols. 4 and 5 of table 2.1) for only 7 quarters. The pattern of output response to monetary shocks is now concentrated in the 1–5 quarter range. The coefficient estimates of the *MIL* or $\log(G)$ variables (and the time trend) are not materially altered from those in the *OLS* regressions. If the *MIL* and $\log(G)$ variables are entered simultaneously in the case where estimation of a second-order pattern of residual serial correlation is also carried out, the coefficient estimates are .16, *s.e.* = .16 for *MIL* and .060, *s.e.* = .027 for $\log(G)$. But the "relative significance" of these two variables is reversed in the unemployment rate equation (below).

Actual values of output growth, $DY_t \equiv \log(y_t/y_{t-1})$, are shown along with estimated values, $\widehat{DY}_t \equiv \widehat{\log(y_t)} - \log(y_{t-1})$, and residuals in table 2.3, where $\widehat{\log(y_t)}$ is calculated from the equation in table 2.1, column 4.

Results for the unemployment rate, shown in columns 6–9 of table 2.1, are basically similar to those for output. These equations involve a starting date in 1949 (corresponding to that for the annual data discussed above), although a shift to samples that begin in 1947 does not substantially alter the estimates. There is again a precisely estimated pattern of lag response to *DMR* values, with a shortened lag appearing in the equations (cols. 8 and 9) that contain a correction for second-order residual serial correlation. The peak response of the unemployment rate to *DMR* values in columns 8 and 9 of table 2.1 is at 2–5 quarter lag, which is slightly delayed relative to the response of output.

The unemployment rate equations shown in columns 6 and 8 use the *MIL* variable, while those in columns 7 and 9 use the variable $(G/y)_t$. (The use of $(G/\hat{y})_t$ as an instrument, where $\hat{y}_t$ is an estimated value for output calculated from the equations shown in cols. 2–5, produces a negligible change in results.) The estimated coefficients of the *MIL* or G/y variables are not sensitive to the correction for serial correlation of residuals. If the *MIL* and G/y variables are entered simultaneously in an equation that also includes correction for residual serial correlation,

equation (table 2.1, col. 8), a similar procedure yields a 95% confidence interval for $(\widehat{\rho_1 + \rho_2})$ with an upper limit of .85. The value of $-2 \cdot \log(\text{likelihood ratio})$ corresponding to $\rho_1 + \rho_2 = 1$ is 23.0 in this case. Finally, for the price level equation (table 2.2, col. 5), the upper limit of the 95% confidence interval for $(\widehat{\rho_1 + \rho_2})$ is .97 and the value of $-2 \cdot \log(\text{likelihood ratio})$ corresponding to $\rho_1 + \rho_2 = 1$ is 10.8.

Table 2.1 **Quarterly Output and Unemployment Rate Equations**

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dep. Var.	$\log(y_t)$	$\log(y_t)$	$\log(y_t)$	$\log(y_t)$	$\log(U/1-U)_t$	$\log(U/1-U)_t$	$\log(U/1-U)_t$	$\log(U/1-U)_t$
Sample	47:I–78:I	47:I–78:I	47:III–78:I	47:III–78:I	49:I–78:I	49:I–78:I	49:III–78:I	49:III–78:I
Constant	5.79(.01)	5.59(.03)	5.78(.03)	5.56(.07)	−2.70(.02)	−2.28(.06)	−2.69(.06)	−2.48(.17)
DMR_t	1.01(.35)	1.03(.36)	0.52(.18)	0.55(.18)	−3.7(2.8)	−4.4(3.3)	−4.1(1.7)	−4.0(1.9)
DMR_{t-1}	1.50(.35)	1.40(.36)	1.13(.27)	1.22(.27)	−6.2(2.8)	−6.5(3.3)	−7.2(2.5)	−7.1(2.7)
DMR_{t-2}	1.47(.34)	1.34(.35)	1.25(.32)	1.40(.32)	−11.3(2.8)	−11.7(3.3)	−12.2(2.9)	−11.8(3.2)
DMR_{t-3}	1.79(.32)	1.94(.33)	1.53(.34)	1.64(.34)	−11.9(2.7)	−12.8(3.3)	−13.6(2.9)	−13.0(3.3)
DMR_{t-4}	1.73(.31)	1.67(.32)	1.60(.34)	1.64(.34)	−14.6(2.7)	−16.3(3.3)	−15.2(2.9)	−14.7(3.3)
DMR_{t-5}	1.51(.31)	1.43(.32)	1.13(.31)	1.18(.31)	−14.5(2.7)	−14.6(3.3)	−12.2(2.8)	−11.6(3.2)
DMR_{t-6}	1.33(.30)	1.27(.32)	0.75(.25)	0.80(.25)	−14.6(2.7)	−14.0(3.3)	−8.4(2.5)	−8.1(2.7)
DMR_{t-7}	1.11(.30)	0.88(.32)	0.28(.16)	0.33(.15)	−13.3(2.7)	−11.2(3.2)	−4.0(1.7)	−4.0(1.8)
DMR_{t-8}	0.98(.30)	0.54(.32)			−10.3(2.7)	−7.5(3.2)		
DMR_{t-9}	0.82(.29)				−6.6(2.7)			
DMR_{t-10}	0.43(.29)				−5.4(2.7)			
MIL_t	0.35(.04)		0.36(.11)		−3.3(0.2)		−3.4(0.5)	
$\log(G_t)$		.066(.007)		.072(.017)				
$(G/y)_t$						−6.2(0.5)		−4.5(1.4)
t	.00897(.00006)	.00828(.00006)	.00897(.00019)	.00828(.00014)				
u_{t-1}			1.20(.09)	1.22(.09)			1.16(.09)	1.19(.09)
u_{t-2}			−0.37(.09)	−0.42(.09)			−0.41(.09)	−0.39(.09)
R^2	.997	.997	—	—	.82	.74	—	—
σ	.0179	.0187	.0092	.0090	.135	.161	.083	.089
$D\text{-}W$	0.4	0.3	2.1	2.1	0.5	0.4	2.2	2.1

the coefficient estimates are for MIL_t: -4.0, $s.e. = 1.1$, and for $(G/y)_t$: 1.4, $s.e. = 2.1$.

The pattern of serial correlation of residuals, $\rho_1 = 1.16$, $s.e. = .09$ and $\hat{\rho}_2 = -0.41$, $s.e. = .09$ in column 8, is similar to that found for output. Actual values of U are shown with estimated values and residuals from the column 8 equation in table 2.3.

Price Level

Quarterly price level estimates are shown in table 2.2. The *OLS* regression in column 2 of the table includes an unrestricted coefficient estimate for the $\log(M_t)$ variable, while the column 3 regression restricts this coefficient to equal unity. (Inclusion of R_{t-4} as an instrument for R_t affects principally the estimates of the R_t coefficient, which increase from those shown in cols. 2 and 3 of table 2.2.)

The estimated *DMR* coefficients in the equations shown in columns 2 and 3 are negative and individually significantly different from zero over a lag of 24 quarters. For example, in column 3, which sets the coefficient of $\log(M_t)$ to 1, the *DMR* pattern is remarkably flat and strongly negative for lags between 1 and 18–20 quarters. As with the annual data, the elongation of the *DMR* pattern relative to that revealed by the output equation is evident from these results.

Similar to the output and unemployment results, the quarterly price equation estimated by *OLS* exhibits strong positive serial correlation of residuals. Reestimation subject to a second-order autoregressive process for the error term is carried out in columns 4 and 5 of table 2.2. The estimated pattern: $\hat{\rho}_1 = 1.60$, $s.e. = .08$; $\hat{\rho}_2 = -0.67$, $s.e. = .07$, indicates that the serial correlation of residuals is even more pronounced than that found for the output and unemployment equations.

The estimated coefficient of $\log(M_t)$ in column 4, .93, $s.e. = .09$, differs insignificantly from 1. The pattern of *DMR* coefficients in this equation and in the column 5 equation that constrains the $\log(M_t)$ coefficient to equal 1 are substantially less drawn out than those shown in columns 2 and 3. Lagged values over 14 quarters are now significant, with the principal effects occurring in the 1–12 quarter range.

NOTES TO TABLE 2.1

The variables U, y, M, and G are seasonally adjusted. The dependent variable for cols. 2–5 is $\log(GNP)$, where GNP is in 1972 dollars. The dependent variable for cols. 6–9 is $\log(U/1 - U)$, where U is the unemployment rate in the total labor force. G is real federal purchases of goods and services, and t is a time trend. *MIL* is the military personnel variable discussed in the text. DMR_t is the residual from the money growth equation (7).

Cols. 4, 5, 8, and 9 involve estimation of a second-order autoregressive process for the error term, as described by the coefficients on u_{t-1} and u_{t-2}. Standard errors of coefficient estimates are shown in parentheses. $\hat{\sigma}$ is the standard error of estimate. *D-W* is the Durbin-Watson statistic.

Table 2.2 **Quarterly Price Level Equations**

(1)	(2)	(3)	(4)	(5)
Sample	48:I–78:I	48:I–78:I	48:III–78:I	48:III–78:I
Constant	−1.13(.10)	−0.79(.01)	−0.36(.40)	−0.64(.03)
$\log(M_t)$	1.08(.02)	1	0.93(.09)	1
DMR_t	−.42(.28)	−0.37(.30)	−0.64(.14)	−0.70(.11)
DMR_{t-1}	−1.02(.27)	−0.98(.28)	−1.04(.24)	−1.13(.20)
DMR_{t-2}	−1.25(.27)	−1.21(.28)	−1.08(.31)	−1.18(.28)
DMR_{t-3}	−1.38(.27)	−1.36(.28)	−0.96(.37)	−1.05(.33)
DMR_{t-4}	−1.47(.26)	−1.46(.28)	−0.92(.40)	−1.01(.37)
DMR_{t-5}	−1.68(.27)	−1.66(.28)	−0.88(.42)	−0.97(.39)
DMR_{t-6}	−1.87(.26)	−1.89(.28)	−1.08(.43)	−1.16(.40)
DMR_{t-7}	−2.06(.25)	−2.07(.27)	−1.03(.43)	−1.10(.40)
DMR_{t-8}	−2.16(.26)	−2.20(.27)	−1.01(.42)	−1.07(.40)
DMR_{t-9}	−2.09(.26)	−2.09(.27)	−0.97(.41)	−1.02(.39)
DMR_{t-10}	−1.88(.26)	−1.83(.27)	−0.78(.37)	−0.83(.36)
DMR_{t-11}	−1.85(.25)	−1.81(.26)	−0.90(.33)	−0.93(.32)
DMR_{t-12}	−1.79(.25)	−1.77(.26)	−0.84(.26)	−0.86(.26)
DMR_{t-13}	−1.58(.24)	−1.55(.25)	−0.51(.18)	−0.52(.18)
DMR_{t-14}	−1.50(.23)	−1.39(.24)	−0.31(.10)	−0.32(.09)
DMR_{t-15}	−1.09(.23)	−0.96(.24)		
DMR_{t-16}	−1.23(.23)	−1.05(.24)		
DMR_{t-17}	−1.13(.21)	−0.93(.21)		
DMR_{t-18}	−1.28(.21)	−1.08(.21)		
DMR_{t-19}	−1.12(.21)	−0.88(.21)		
DMR_{t-20}	−1.02(.20)	−0.82(.20)		
DMR_{t-21}	−0.90(.17)	−0.75(.18)		
DMR_{t-22}	−0.73(.17)	−0.61(.18)		
DMR_{t-23}	−0.57(.17)	−0.43(.18)		
DMR_{t-24}	−0.43(.17)	−0.32(.18)		
$(G/y)_t$	.62(.07)	.58(.07)	−0.32(.14)	−0.30(.15)
R_t	2.7(0.3)	3.0(0.3)	−0.2(0.3)	−0.2(0.3)
t	−.0028(.0002)	−.0023(.0002)	−.0005(.0009)	−.0011(.0003)
u_{t-1}			1.60(.08)	1.60(.08)
u_{t-2}			−0.67(.07)	−0.67(.07)
R^2	.999	.998	—	—
σ	.0123	.0130	.0052	.0051
D-W	0.4	0.4	2.2	2.2

NOTES

The dependent variable is $\log(P_t)$, where P is the seasonally adjusted *GNP* deflator (1972 = 1). M is the level of the seasonally adjusted *M*1 concept of the money stock. R is the Aaa corporate bond rate. See the notes to table 2.1 for other definitions.

The coefficient of $\log(M_t)$ is constrained to equal 1 in cols. 3 and 5. Estimation of a second-order autoregressive process for the error term is carried out in cols. 4 and 5.

The coefficients of the G/y, R, and t variables are not robust to the correction for serial correlation of residuals. In particular, the coefficient estimate for G/y changes sign, while that for R becomes insignificant. These results are indicative of some specification error in the price equation—a conclusion that also emerged from some hypothesis tests that were carried out above with the annual data.

We have not yet obtained any jointly estimated equations from quarterly data for systems involving the money growth and other equations.

Comparison of Annual and Quarterly Results

Correspondence between the annual and quarterly results constitutes an additional check on the statistical properties of a "dynamic" model. There does turn out to be a close correspondence in the results for the money growth, unemployment, and output equations, but not for the price equation.

Consider first the annual unemployment equation (2) (equation (2′) is similar) and the quarterly equation in column 8 of table 2.1, which includes the *MIL* variable and adjustment for serial correlation of residuals. The constant terms are virtually identical, so that both equations generate a "natural" unemployment rate of .064 at $MIL = 0$ and with all values of the *DMR* variables set to zero. Since the money growth rates are measured at quarterly rates in the quarterly equation, the overall level of estimated *DMR* coefficients in this equation should be roughly 4 times those shown in the annual equation. In fact, the sum of the magnitude of the *DMR* coefficients from the quarterly regression (table 2.1, col. 8) is 76.9, which is 3.7 times the sum (21.0) from the annual equation (2). Therefore, the two equations generate approximately the same response of the unemployment rate to a sustained *DMR* stimulus (which would, since *DMR* is constructed to be serially independent, be an unusual event). The quarterly estimates provide a much finer description of the dynamic response, although the peak effect at a four-quarter lag is consistent with the peak at a one-year lag in the annual data.

A discrepancy arises in the estimated *MIL* coefficients, which are -5.3, $s.e. = 0.6$ in the annual equation and -3.4, $s.e. = 0.5$ in the quarterly case. Similarly, when the G/y variable is substituted for *MIL*, the annual coefficient estimate in equation (6) is -6.7, $s.e. = 1.0$, while the quarterly estimate (table 2.1, col. 9) is -4.5, $s.e. = 1.4$.

The comparison of annual and quarterly results for output is basically similar. The sum of *DMR* coefficient magnitudes in the quarterly equation from table 2.1, column 4 is 8.2, which is 3.3 times the annual sum (3.5) from equation (3). The quarterly *MIL* coefficient is .33, $s.e. = .15$, which is below the annual estimate of .54, $s.e. = .09$. In

Table 2.3 Quarterly Values of Money Growth, Output Growth, and Unemployment

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	DM	$\widehat{DM}$	DMR	Dy	$\widehat{Dy}$	DyR	U	$\hat{U}$	UR
1941:I	.0553	.0452	.0101						
41:II	.0348	.0506	−.0158						
41:III	.0345	.0348	−.0003						
41:IV	.0168	.0396	−.0228						
42:I	.0470	.0339	.0131						
42:II	.0500	.0446	.0054						
42:III	.0693	.0584	.0109						
42:IV	.0774	.0543	.0231						
43:I	.0866	.0622	.0244						
43:II	.0457	.0640	−.0183						
43:III	.0752	.0431	.0321						
43:IV	.0108	.0649	−.0541						
44:I	.0373	.0337	.0036						
44:II	.0476	.0426	.0050						
44:III	.0345	.0458	−.0113						
44:IV	.0591	.0323	.0268						
1945:I	.0404	.0522	−.0118						
45:II	.0269	.0302	−.0033						
45:III	.0236	.0234	.0002						
45:IV	.0227	.0223	.0004						
46:I	−.0002	.0196	−.0198						
46:II	.0325	.0128	.0197						

Notes to table 2.3 are on p. 47.

Table 2.3 (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	DM	$\widehat{DM}$	DMR	Dy	$\widehat{Dy}$	DyR	U	$\widehat{U}$	UR
46:III	.0140	.0242	—.0102						
46:IV	.0036	.0098	—.0062						
47:I	—.0017	.0009	—.0026						
47:II	.0163	.0031	.0132						
47:III	.0089	.0061	.0028	.0011	.0070	—.0059			
47:IV	.0044	.0053	—.0009	.0121	.0128	—.0007			
48:I	.0000	.0019	—.0019	.0076	.0134	—.0058			
48:II	—.0089	—.0024	—.0065	.0181	.0094	.0087			
48:III	.0009	—.0054	.0063	.0098	.0144	—.0046			
48:IV	—.0036	.0021	—.0057	.0103	.0077	.0026			
49:I	—.0054	—.0014	—.0040	—.0101	—.0011	—.0090			
49:II	.0018	—.0037	.0055	—.0041	.0050	—.0091			
49:III	—.0036	.0034	—.0070	.0092	.0098	—.0006	.065	.061	.004
49:IV	.0000	—.0005	.0005	—.0085	.0076	—.0161	.068	.065	.003
1950:I	.0090	.0047	.0043	.0446	.0158	.0288	.062	.066	—.004
50:II	.0151	.0072	.0079	.0262	.0279	—.0017	.055	.054	.001
50:III	.0105	.0069	.0036	.0324	.0194	.0130	.045	.050	—.005
50:IV	.0087	.0062	.0025	.0222	.0309	—.0087	.040	.036	.004
51:I	.0103	.0051	.0052	.0140	.0211	—.0071	.033	.035	—.002
51:II	.0093	.0084	.0009	.0190	.0162	.0028	.029	.030	—.001
51:III	.0126	.0079	.0047	.0199	.0131	.0068	.030	.027	.003
51:IV	.0182	.0105	.0077	.0017	.0134	—.0117	.032	.031	.001

Table 2.3 (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	DM	$\widehat{DM}$	DMR	Dy	$\widehat{Dy}$	DyR	U	$\widehat{U}$	UR
52:I	.0130	.0137	—.0007	.0095	.0061	.0034	.029	.032	—.003
52:II	.0081	.0119	—.0038	.0014	.0042	—.0028	.028	.028	.000
52:III	.0104	.0086	.0018	.0104	.0049	.0055	.030	.029	.001
52:IV	.0103	.0098	.0004	.0235	.0057	.0178	.026	.032	—.006
53:I	.0039	.0114	—.0075	.0157	.0012	.0145	.026	.028	—.002
53:II	.0063	.0057	.0006	.0064	.0003	.0061	.025	.029	—.004
53:III	.0016	.0076	—.0060	—.0061	—.0017	—.0044	.026	.029	—.003
53:IV	.0008	.0033	—.0025	—.0097	—.0100	.0003	.035	.030	.005
54:I	.0031	.0021	.0010	—.0136	—.0016	—.0120	.050	.043	.007
54:II	.0023	.0060	—.0037	—.0041	—.0003	—.0038	.055	.056	—.001
54:III	.0092	.0070	.0022	.0144	.0047	.0097	.057	.055	.002
54:IV	.0107	.0095	.0012	.0189	.0184	.0005	.050	.053	—.003
1955:I	.0113	.0096	.0017	.0237	.0143	.0094	.045	.044	.001
55:II	.0060	.0075	—.0015	.0150	.0122	.0028	.042	.043	—.001
55:III	.0045	.0054	—.0009	.0145	.0095	.0050	.039	.040	—.001
55:IV	.0015	.0047	—.0032	.0101	.0053	.0048	.040	.039	.001
1956:I	.0037	.0032	.0005	—.0044	.0030	—.0074	.038	.041	—.003
56:II	.0022	.0056	—.0034	.0051	—.0013	.0064	.040	.039	.001
56:III	.0007	.0033	—.0026	.0006	.0009	—.0003	.039	.043	—.004
56:IV	.0044	.0031	.0013	.0116	.0046	.0070	.039	.040	—.001
57:I	.0022	.0046	—.0024	.0069	.0083	—.0014	.037	.041	—.004
57:II	.0000	.0031	—.0031	.0007	.0040	—.0033	.039	.038	.001

Table 2.3 (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	DM	$\widehat{DM}$	DMR	Dy	$\widehat{Dy}$	DyR	U	$\widehat{U}$	UR
57:III	.0007	.0011	−.0004	.0069	.0066	.0003	.040	.042	−.002
57:IV	−.0059	.0029	−.0088	−.0132	.0030	−.0162	.047	.044	.003
58:I	−.0015	−.0015	.0000	−.0197	−.0015	−.0182	.061	.052	.009
58:II	.0117	.0034	.0083	.0072	.0124	−.0052	.071	.063	.008
58:III	.0101	.0125	−.0024	.0240	.0172	.0068	.070	.068	.002
58:IV	.0122	.0107	.0015	.0255	.0201	.0054	.062	.062	.000
59:I	.0134	.0113	.0021	.0122	.0275	−.0153	.056	.053	.003
59:II	.0084	.0104	−.0020	.0217	.0145	.0072	.049	.049	.000
59:III	.0049	.0078	−.0029	−.0107	.0126	−.0233	.051	.046	.005
59:IV	−.0062	.0067	−.0129	.0105	.0002	.0103	.054	.052	.002
1960:I	−.0042	.0017	−.0059	.0198	.0008	.0190	.049	.057	−.008
60:II	−.0014	.0042	−.0056	−.0024	.0062	−.0086	.050	.052	−.002
60:III	.0077	.0032	.0044	−.0043	.0028	−.0071	.053	.052	.001
60:IV	.0021	.0073	−.0052	−.0052	.0047	−.0099	.061	.058	.003
61:I	.0041	.0042	−.0001	.0064	.0097	−.0033	.066	.062	.004
61:II	.0083	.0063	.0020	.0167	.0211	−.0044	.068	.064	.004
61:III	.0061	.0094	−.0033	.0129	.0222	−.0093	.066	.062	.004
61:IV	.0095	.0079	.0016	.0237	.0199	.0038	.060	.058	.002
62:I	.0061	.0112	−.0051	.0143	.0213	−.0070	.054	.055	−.001
62:II	.0040	.0077	−.0037	.0129	.0086	.0043	.053	.050	.003
62:III	−.0020	.0060	−.0080	.0075	.0072	.0003	.054	.055	−.001
62:IV	.0060	.0041	.0019	.0019	.0080	−.0061	.053	.053	.000

Table 2.3 (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	DM	$\widehat{DM}$	DMR	Dy	$\widehat{Dy}$	DyR	U	$\hat{U}$	UR
63:I	.0093	.0085	.0008	.0095	.0083	.0012	.056	.054	.002
63:II	.0098	.0091	.0007	.0125	.0126	—.0001	.055	.055	.000
63:III	.0097	.0096	.0001	.0182	.0154	.0028	.053	.053	.000
63:IV	.0103	.0096	.0007	.0096	.0188	—.0092	.054	.049	.005
64:I	.0057	.0088	—.0031	.0166	.0121	.0045	.053	.052	.001
64:II	.0095	.0080	.0015	.0126	.0140	—.0014	.050	.050	.000
64:III	.0162	.0102	.0060	.0097	.0145	—.0048	.048	.047	.001
64:IV	.0123	.0129	—.0006	.0038	.0101	—.0063	.048	.046	.002
1965:I	.0067	.0098	—.0031	.0214	.0065	.0149	.047	.047	.000
65:II	.0079	.0081	—.0002	.0147	.0146	.0001	.044	.046	—.002
65:III	.0114	.0090	.0024	.0172	.0112	.0060	.042	.042	.000
65:IV	.0166	.0103	.0063	.0209	.0122	.0087	.039	.041	—.002
66:I	.0157	.0135	.0022	.0183	.0133	.0050	.037	.038	—.001
66:II	.0121	.0120	.0001	.0069	.0088	—.0019	.036	.036	.000
66:III	—.0017	.0098	—.0115	.0093	.0011	.0082	.036	.037	—.001
66:IV	.0011	.0033	—.0022	.0075	.0009	.0066	.035	.037	—.002
67:I	.0102	.0064	.0038	.0016	.0029	—.0013	.036	.038	—.002
67:II	.0146	.0105	.0041	.0069	—.0002	.0071	.036	.038	—.002
67:III	.0220	.0118	.0102	.0122	.0074	.0048	.036	.037	—.001
67:IV	.0146	.0154	—.0008	.0078	.0146	—.0068	.037	.036	.001
68:I	.0128	.0100	.0028	.0096	.0104	—.0008	.035	.035	.000
68:II	.0189	.0111	.0078	.0173	.0188	—.0015	.034	.033	.001

Table 2.3 (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	DM	$\widehat{DM}$	DMR	Dy	$\widehat{Dy}$	DyR	U	$\hat{U}$	UR
68:III	.0206	.0150	.0056	.0117	.0162	—.0045	.033	.032	.001
68:IV	.0197	.0153	.0044	.0027	.0060	—.0033	.033	.033	.000
69:I	.0183	.0153	.0030	.0094	.0084	.0010	.033	.033	.000
69:II	.0107	.0143	—.0036	.0045	.0065	—.0020	.034	.033	.001
69:III	.0058	.0099	—.0041	.0035	.0006	.0029	.035	.036	—.001
69:IV	.0058	.0087	—.0029	—.0055	.0005	—.0060	.035	.037	—.002
1970:I	.0091	.0089	.0002	—.0036	—.0047	.0011	.039	.039	.000
70:II	.0128	.0096	.0032	.0005	—.0053	.0058	.046	.048	—.002
70:III	.0126	.0117	.0009	.0073	.0010	.0063	.050	.054	—.004
70:IV	.0133	.0120	.0013	—.0098	.0052	—.0150	.056	.054	.002
71:I	.0168	.0117	.0051	.0221	.0070	.0150	.063	.058	.005
71:II	.0249	.0147	.0102	.0073	.0206	—.0133	.056	.061	—.005
71:III	.0165	.0206	—.0041	.0070	.0090	—.0020	.058	.053	.005
71:IV	.0065	.0134	—.0069	.0085	.0023	.0062	.053	.058	—.005
72:I	.0178	.0109	.0069	.0183	.0100	.0083	.061	.052	.009
72:II	.0200	.0161	.0039	.0189	.0118	.0071	.054	.064	.010
72:III	.0208	.0190	.0018	.0128	.0036	.0092	.054	.052	.002
72:IV	.0220	.0175	.0045	.0203	.0084	.0119	.048	.055	—.007
73:I	.0184	.0192	—.0008	.0227	.0091	.0136	.053	.047	.006
73:II	.0158	.0137	.0021	.0011	.0051	—.0040	.047	.055	—.008
73:III	.0137	.0166	—.0029	.0042	—.0002	.0044	.047	.047	.000
73:IV	.0127	.0132	—.0005	.0051	—.0047	.0098	.043	.050	—.007

Table 2.3 (Continued)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	DM	$\widehat{DM}$	DMR	Dy	$\widehat{Dy}$	DyR	U	$\widehat{U}$	UR
74:I	.0148	.0138	.0010	−.0100	−.0029	−.0071	.054	.047	.007
74:II	.0138	.0127	.0011	−.0046	−.0029	−.0017	.056	.061	−.005
74:III	.0104	.0156	−.0052	−.0062	−.0029	−.0033	.054	.060	−.006
74:IV	.0100	.0124	−.0024	−.0142	.0002	−.0144	.060	.056	.004
1975:I	.0014	.0112	−.0098	−.0252	−.0019	−.0234	.080	.067	.013
75:II	.0182	.0077	.0105	.0156	.0040	.0116	.085	.085	.000
75:III	.0176	.0207	−.0031	.0270	.0208	.0062	.084	.086	−.002
75:IV	.0058	.0179	−.0121	.0074	.0095	−.0021	.083	.081	.002
76:I	.0071	.0101	−.0030	.0211	.0089	.0122	.074	.083	−.009
76:II	.0204	.0129	.0075	.0123	.0225	−.0102	.073	.068	.005
76:III	.0108	.0167	−.0058	.0096	.0063	.0033	.077	.074	.003
76:IV	.0162	.0127	.0035	.0029	.0095	−.0066	.077	.076	.001
77:I	.0178	.0173	.0005	.0182	.0157	.0025	.074	.075	−.001
77:II	.0194	.0169	.0025	.0149	.0153	−.0004	.067	.069	−.002
77:III	.0199	.0170	.0029	.0125	.0178	−.0053	.065	.062	.003
77:IV	.0178	.0184	−.0006	.0095	.0154	−.0059	.060	.061	−.001
78:I	.0124	.0165	−.0041	−.0010	.0055	−.0065	.061	.060	.001

contrast, the quarterly estimate of the $\log(G_t)$ coefficient is .072, *s.e.* = .017 (table 2.1, col. 5), which corresponds to the annual estimate from equation (5) of .070, *s.e.* = .013.

In the case of the money growth equations, it is possible to compare the pattern of effects from the past history of the series that is shown over 6 lags for the quarterly equation (7) with that estimated from two annual lag values in equation (1). The autoregressive form of the quarterly equation (7) can be expressed as a moving average of independent shocks to money growth.[14] Four adjacent quarterly values can then be added to get an implied moving average representation for annual money growth rates.[15] It is then possible to determine the implied coefficients for a second-order autoregression on annual data. (There is an approximation here in that the annual data are actually log differences of annual average money stocks, rather than log differences of quarterly average money stocks separated by 4 quarters.) The coefficients for the annual equation that correspond to the 6 quarterly lag coefficients shown in equation (7) turn out to be .45 on DM_{t-1} and .11 on DM_{t-2}, which correspond closely to the estimates shown in equation (1). Therefore, the quarterly and annual forms of the money growth equation display similar patterns of persistence. It also turns out

14. The sequence of coefficients turns out to be: 1, .54, .24, .13, .17, .13, .21, .19, .14, .10, .09, .08, ...

15. The sequence of coefficients is: 1, 1.54, 1.78, 1.92, 1.08, .67, .64, .70, .68, .65, .53, .42, .36, .33, .30, ...

NOTES TO TABLE 2.3

$DM_t \equiv \log(M_t/M_{t-1})$ where M_t is the quarterly average value of $M1$ as adjusted for seasonality by the Federal Reserve and by Friedman and Schwartz before 1946. Data since 1947 are from the *Federal Reserve Bulletin*, incorporating revisions through April 1978. Data before 1947 are from Friedman and Schwartz 1970, table 2. These values have been multiplied by 1.013 as an approximate correction for the omission of deposits due to foreign banks. These deposits were included in $M1$ retroactively to 1947 with the revision in the October 1960 *Federal Reserve Bulletin*.

$\widehat{DM}_t$ is the estimated value from equation (7).

$DMR_t \equiv DM_t - \widehat{DM}_t$.

y_t is the Commerce Department seasonally adjusted GNP in 1972 dollars.

$Dy_t \equiv \log(y_t/y_{t-1})$

$\widehat{Dy}_t \equiv \widehat{\log y}_t - \log y_{t-1}$, where $\widehat{\log y}_t$ is the estimated value from the equation in table 2.1, col. 4.

$DyR_t \equiv Dy_t - \widehat{Dy}_t$.

U is the seasonally adjusted unemployment rate in the total labor force, calculated from standard Bureau of Labor Statistics figures on numbers of unemployed and the total labor force.

$\hat{U}$ is the estimated value based on the equation in table 2.2, col. 8.

$UR \equiv U - \hat{U}$.

that the σ value shown in the quarterly equation (7) is consistent with that estimated for the annual equation (1).

With respect to the lagged unemployment effect on money growth, consider an increase in the $\log(U/1 - U)$ variable that persists over a full year. The effect on next year's money growth rate can be determined from the quarterly equation (7) by taking account of the direct effect of the lagged U variables and also of the persisting effect from the presence of past values of the DM series. The impact on the sum of the four quarterly DM values for the next year turns out to involve a response coefficient of .028, which corresponds to the coefficient estimate of .027 that was estimated from annual data in equation (1).

A similar calculation for the $FEDV$ variable indicates that a sustained, uniform increase in this variable would, according to the quarterly equation (7), affect contemporaneous annual money growth with a coefficient of .065. This effect compares with an estimated coefficient of .073 in the annual equation (1).[16]

Correspondence between annual and quarterly estimates does not hold in the case of the price equation. The sum of the magnitude of the DMR coefficients from the quarterly price equation in table 2.2, column 5 (with the coefficient of $\log(M_t)$ constrained to 1 and with adjustment for second-order residual serial correlation) is only 2.1 times that shown in the annual equation (4), as compared with a theoretical value of 4. Interestingly, the quarterly price equation without serial correlation correction (table 2.2, col. 3) displays a sum of DMR coefficient magnitudes that is 4.8 times that in equation (4). The sensitivity of the estimated coefficients in quarterly price level equations to serial correlation adjustment and the discrepancy between quarterly and annual coefficient estimates probably reflect a common source of misspecification.

The volatility of the coefficient estimates of the G/y, R, and t variables in quarterly price equations has already been noted. The estimated coefficients of these variables in a price equation that is estimated without serial correlation adjustment (table 2.2, col. 3) actually correspond well to those found in an annual price equation (under OLS estimation; see n. 5, above). However, the introduction of residual serial correlation adjustment (table 2.2, col. 5) drastically alters the quarterly coefficient estimates of these variables and thereby produces a discrepancy between the quarterly and annual estimates.

16. The calculated value of .065 is an underestimate of the annual effect because of the larger adjustment of "normal" federal expenditure to the contemporaneous value of federal spending in the annual equation. With this effect considered, the quarterly and annual estimates would correspond more closely.

Comment Alan Blinder

Through the night of doubt and sorrow
Onward goes the pilgrim band,
Singing songs of expectation,
Marching to the promised land.
—B. S. Ingemann, 1825

Preliminaries

One need only look around this room to realize that the only way to have any real effect at this conference is to say something unanticipated. Hence, I want to begin by heaping praise upon Robert Barro for his imaginative and important empirical work. Along with Robert Lucas's justly acclaimed critique of econometric policy evaluation (Lucas 1976), Barro's well-known paper in the 1977 *American Economic Review,* of which the paper under discussion is a direct descendant, is in my view one of the two truly indispensable pieces in the rational expectations literature.

Needless to say, ever since Barro's work began circulating in draft form, Keynesians have been searching for an obvious flaw in his methodology. That one has not been found suggests that the basic flaw, if indeed there is one, is far from obvious. One result of this fruitless search has been that Barro's work has moved our priors somewhat. A priori assertions that one finds implausible and uncongenial are always easy to rebut by other a priori assertions. Empirical results cannot be dismissed so cavalierly.

Still, like most Keynesians, I am not yet ready to throw in the towel. One regression is not enough to destroy impressions built up over many years and buttressed by theoretical, statistical, and casual empirical evidence. And there do seem to be a few flies in the Barro ointment. This comment is mainly about the flies. But before going into them in detail, I want to stress that each of the criticisms provides no more than a reason why Barro's crucial result—that only unanticipated money matters—*might* be wrong; nothing here purports to show that he is in fact wrong. Barro's results are impressive and provocative, and the joint estimates presented here make them all the more so, despite some nagging worries about the price equation.

Theoretical Matters

One thing that makes many people uneasy with Barro's results is that the "second generation" of macroeconomic models incorporating rational expectations has shown that the conclusion that only unanticipated changes in the money supply have real effects is *not* generally true under rational expectations. I am referring here to such papers as Phelps and Taylor (1977), Fischer (1977, 1979), Blinder and Fischer (1978), Taylor (1979), Blanchard (chap. 3 below); and I apologize to other authors whom I have omitted from this list.

In contrast to the original series of papers by Lucas (1973, 1976), Sargent and Wallace (1975), and Barro (1976), these more recent explorations of the implications of rational expectations generally find that even anticipated changes in the money supply (or, perhaps, in its growth rate) have real (albeit transitory) effects through one of two mechanisms: either there are elements of fixity in wages or prices so that not all markets clear instantly, or anticipated money affects the real interest rate through its effect on the expected rate of inflation. I am confident that both of these factors are operative in the real world. How important they are empirically is another question, however, and this is why we need empirical work like Barro's.

There is an irony here that must be pointed out, lest we think there is anything new under the sun. In the old "Keynes versus the classics" debate over the neutrality of money, much ink was spilled before it was realized that the real effects of monetary policy rested on two main pillars: interest rate effects on some component of aggregate demand (at the time, distinctions were not usually made between real and nominal interest rates), and nominal wage-price rigidities.[17] This was true long before rational expectations, even adaptive expectations, become popular. It now seems that we have come full circle. As we start to digest the meaning of the rational expectations revolution, we come once again to realize that the nonneutrality of money rests on one of these two foundations.

All of this is relevant to Barro's work because his equations explaining unemployment and output are reduced forms that leave us relatively uninformed about the structure from which they are derived. Barro suggests that a Lucas-Sargent-Wallace type model lies behind the results; but, as just noted, embellishments to these models generally lead to the conclusion that anticipated money does matter.[18]

An obvious question thus comes to mind: Why didn't Barro try to estimate the structure of one of these models, or more specifically, the Lucas supply function, which is at their heart? This seems quite feasible since the type of analysis he conducts could be used to generate a series on unanticipated inflation, which is the principal (only?) dependent

17. There was also a strain of thought, embodied in many textbooks and countless lectures to students, based on money illusion. This was always a bit of an embarrassment and has been effectively demolished by search-theoretic approaches to the Phillips curve in conjunction with rational expectations.

18. But not always; see McCallum 1977. Barro 1979*a* is also relevant.

variable in the Lucas supply function. There is at least one example of an estimated structural model based on the ideas of the rational expectations school—Sargent's "classical" econometric model (1976*a*). In some tests of its predictive ability, Ray Fair (1978, 1979) has found it wanting.

Robustness

Barro and Rush use what I will call a reaction function of the Federal Reserve to generate predictions of the growth rate of the money supply (called *DM*) and then use the residuals from this reaction function (called *DMR*) as empirical representations of the theoretical notion of "unanticipated money growth." Skeptics—a set which includes all but the true believers—will want to know if the finding that anticipated money doesn't matter is robust to different specifications of the money reaction function, which would lead to different *DMR* series.

While Barro's original specification looks pretty good by conventional criteria (standard error, Durbin-Watson, etc.), I can't help wondering why there is no apparent reaction of monetary policy to interest rates and inflation. We know, or at least I always thought we knew, that Federal Reserve policy was dominated by a desire to limit interest rate fluctuations during much of the postwar period. Yet no interest rate term appears in Barro's reaction function. Similarly, many economists have thought that the Fed is relatively more "inflation averse" than "unemployment averse"; yet, according to the estimated equation, the Fed fights unemployment, but not inflation. This is doubly puzzling since, as we know, if the Lucas-Sargent-Wallace-Barro view of the world is correct, any monetary *rule* (i.e., the anticipated part of monetary policy) can only be effective against inflation, not against unemployment. Doesn't the Fed have rational expectations?

I gather from some remarks made by Barro about problems with his price equation (p. 30) that he is somewhat sympathetic to the inclusion of interest rate and price targets in the reaction function. My guess is that the most important unanswered question for Barro-type tests of the rational expectationists' hypothesis is how they will stand up to alternative specifications of *DM* and *DMR*.[19]

Contemporaneous Feedback

The principal stabilization activity in Barro's reaction function has the Fed raising this period's money growth rate (DM_t) whenever last

19. Barro (private communication) reports no success with interest rates or inflation in his reaction function and little effect on the equations for output and unemployment.

period's unemployment rate (U_{t-1}) goes up. This is quite reasonable when the period of observation is very short (say, a month) but to deny contemporaneous feedback from U_t to DM_t when the period of observation is a year strains credulity. In fact, we need not rely on credulity at all. The Barro and Rush results on *quarterly* data imply a clear reaction of *annual DM* to unemployment in the *same* year. If I do my calculations correctly, a sustained increase in Barro's variable $\log(U/1 - U)$ of 1.0 beginning in the first quarter of a year (which is, to be sure, a huge change in unemployment) would raise the money growth rates for the four quarters of that year by 0, 0.3%, 1.0% and 1.1%, respectively, which translates to a 0.8% increase in the annual money growth rate.

Furthermore, this probably underestimates the degree of contemporaneous feedback because monetary policy can, and apparently does, react to economic events within the quarter. In a paper published several years ago, Richard Froyen (1974) tested for such a within-quarter feedback by using monthly data and found it to be present.

I want to stress that this is not a nitpicking point. Ordinary least squares estimation forces the residuals in the reaction function (*DMR*'s) to be orthogonal to the regressors in that equation. Were $\log(U_t/1 - U_t)$ included in addition to (or instead of) $\log(U_{t-1}/1 - U_{t-1})$, the resulting *DMR* series would have been orthogonal to $\log(U_t/1 - U_t)$. This makes me wonder how good a job *DMR* would have done in explaining $\log(U_t/1 - U_t)$.

Observational Equivalence and Identification

In an important paper, Sargent (1976*b*) pointed out the "observational equivalence" of Keynesian and new classical macroeconomic models. Barro acknowledged this point in an earlier paper (1977) and pointed out that a Keynesian model could fit the data equally well, albeit with a few odd-looking coefficients. At the conference, much attention was paid to the point that Barro must impose a priori identifying restrictions in order to reach his conclusion that only unanticipated money matters. This is true, and a little bit worrisome since a priori restrictions, by definition, are not tested. Yet I think this reed is too slim for a Keynesian to hide behind comfortably. *Any* estimation requires some identifying restrictions, some maintained hypothesis.

A related point that might be called "observational near-equivalence" was brought up by Stanley Fischer in his paper for this volume. Let M_t be the money supply (or its log) and ${}_{t-s}M_t$ be the (rational) expectation of M_t formulated at time $t - s$. To a computer asked to estimate regression coefficients, a time series on $M_t - {}_{t-1}M_t$ will look very much like a time series on $M_t - {}_{t-2}M_t$—so much alike that it will be virtually impossible to discriminate between the two variables. While very close empirically, these alternatives are miles apart theoretically; for the former implies the strong conclusions associated with the rational expectations school, whereas the latter implies that even anticipated policy has real effects (see, for example, Fischer 1977).

Why the Long Lags?

As already noted, Barro and Rush estimate only reduced forms, but interpret them as coming from a Lucas-Sargent-Wallace type of structural model in which monetary policy has real effects only to the extent that it confuses producers and/or workers between relative and absolute price movements.

If this is the underlying model, it is difficult to understand why the lag of output behind an unanticipated change in the money growth rate should last two years in the annual regression or 10 quarters in the quarterly regression. Certainly the information necessary to know the general price level or the money supply cannot spread that slowly. Lucas (1975) has presented an equilibrium model of the business cycle in which the misinformation gets embodied in the capital stock and hence, while the misinformation disappears quickly, its real effects do not. But Lucas himself is skeptical that variations in the capital stock take us very far in understanding cyclical fluctuations of short duration.

I would like to suggest an alternative explanation of persistence that seems capable of explaining these short-term fluctuations and also seems to be empirically important.[20] Fischer and I (1978) have argued on theoretical grounds that, when output is storable, the Lucas supply function should be amended to read:

$$\log y_t = k_t + \gamma(p_t - {}_{t-1}p_t) + \theta(N^*_t - N_{t-1}),$$

where ${}_{t-1}p_t$ is the (rational) expectation of the price level, N_{t-1} is the stock of inventories at the end of period $t - 1$, and N^*_t is the desired stock of inventories. In such a case, since optimal behavior will imply that $0 < \theta < 1$, the partial adjustment of production decisions to inventory imbalances will make shocks persist despite rational expectations. I note in passing that if N^* is sensitive to the real interest rate, then anticipated money will also have effects on real output.

Treatment of the Natural Rate

Barro's equation for the unemployment rate can be used to generate annual (or even quarterly) estimates of the natural rate of unemploy-

20. Taylor (1979) has suggested that staggered wage contracts can serve the same purpose.

ment by setting all the *DMR*'s equal to zero. Given the slightly modified specification used in this paper (which drops the minimum wage variable), Barro's natural rate depends *only* on the military personnel/conscription variable. I find this a somewhat astounding theory of the natural rate. At the very least, one would like to see some attention paid to the well-known shifts in labor force composition, which are generally agreed to have added about ½ to 1 percentage point to the natural rate.

It is also a bit curious that the concept of the natural rate plays no role in Barro's reaction function. If the Fed really cared about stabilizing employment, I assume it would have reacted to a 5% unemployment rate differently in the 1950s (when the natural rate was perhaps 4%) and in the 1970s (when the natural rate was perhaps 6%). Barro's form of the reaction function denies this and, as a consequence, seems to embody a "natural rate of inflation." Specifically, any time the natural rate of unemployment increases, Barro's money growth equation implies that the long-run money growth rate, and hence the steady state rate of inflation, increases as well. It is hard to understand why the Fed should want to do this.

Conclusion

To summarize briefly, I have two principal questions about Barro's work. First, as is always true of the reduced form approach, one is left uneasy (and uninformed) about the theoretical model that is supposed to be supported by the empirical evidence. The remedy for this is, as always, to spell out the structural model and try to estimate it. Second, one wonders about the robustness of the results to alternative specifications of the money reaction function. This is a straightforward question that can be answered by some further empirical work.

I will conclude by reiterating that we all should thank Robert Barro for starting to put some empirical content into a debate that had previously been based on competing a priori assertions. I hope the empirical debate that he started will continue, for the history of economic thought shows that empirical debates, unlike a priori theoretical debates, sometimes do get resolved.

Comment Robert J. Gordon

Introduction

The point of departure for this empirical paper by Robert Barro and Mark Rush (and earlier papers by Barro) is the proposition, associated with the names of Lucas, Sargent, and Wallace (LSW), that real output is independent of predictable movements in the money supply.[21] The innovative and controversial feature of this hypothesis is *not* that money is neutral in the long run, for this proposition—"the natural rate" hypothesis (NRH)—was accepted by a substantial majority of economists by the time the LSW hypothesis was advanced. Instead, if it is to have any independent content, the LSW hypothesis must state that systematic monetary stabilization has no effect on output in the *short run.*

If valid, the LSW hypothesis would undermine much of the existing literature on stabilization policy. Regular countercyclical activist intervention, implemented as a predictable response to movements in output or unemployment, would be both futile and unnecessary.[22] The entire optimal control branch of the stabilization policy literature, and existing demonstrations that particular derivative or proportional feedback control formulae are more effective stabilizers than a constant growth rate rule, would be rendered irrelevant.[23] The concept of the political business cycle, and of the manipulation of the economy for electoral purposes, would be relegated to a museum for obsolete economic ideas (see Nordhaus 1975).

All formal statements of the LSW hypothesis are based on the underlying supply assumption that output deviates from its "natural" level

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21. The first half of the paper by Robert Barro and Mark Rush presents a summary and extensions of a previous paper (Barro 1978) based on annual data; the second half contains estimates of some of the same equations for quarterly data. Since the present paper does not contain an explicit statement of the hypotheses being tested, nor of the alternative hypotheses that are implicitly rejected, it is necessary to refer back to the earlier papers (Barro 1977, 1978). These comments treat together the combined results of the three papers.

22. Perfect price flexibility, necessary for the LSW hypothesis to be valid, would insulate real output from any anticipated shock. For instance, the 1974 quadrupling of the price of oil, while it would reduce the "natural" level of output, could have no effect on the gap between actual and "natural" output, once the price hike was announced.

23. This would include a series of papers by the conference organizer, e.g., Fischer and Cooper 1973.

only when economic agents are surprised. In the words of Sargent and Wallace, output depends on "productive capacity and the gap between the current price level and the public's prior expectation of the current price level" (1975, p. 243). If the Fed is to have any effect on real output, even in the short run, it cannot act in a predictable way, because to do so would fail to generate the required surprise.

Most modern economies are characterized by a continuum of markets for goods and services, ranging from the pure auction markets for wheat and pork bellies to the markets for Scripto pencils and Trident chewing gum, where retail prices are sufficiently inflexible actually to be printed on the package supplied by the manufacturer. The LSW approach would be important and valid if the entire economy behaved like the market for wheat, but in fact the presence of administered prices and "customer markets" saps the hypothesis of any relevance to most of the productive activities carried out in industrial economies of the real world.

Consider a change in nominal income, whether brought about by a change in government spending, a change in animal spirits, an anticipated change in nominal money, or an unanticipated change in nominal money. If this demand shock does not change relative prices, and if factor inputs are held constant, the economy's equilibrium or "natural" output level remains fixed, and so there is an instantaneous change in the "market-clearing" price level at which that level of output can be sold. To the extent that any significant portion of the average price level does not adjust instantly, an effective demand constraint forces agents off their notional labor and output supply curves, making totally irrelevant the level of output that agents *want* to sell at the going price.

In contrast, the LSW hypothesis requires for its validity a nation of price-taking yeoman farmers and fishermen moving along notional supply curves. The imperfect flexibility of prices invalidates (over the period of price adjustment) the LSW supply hypothesis and in its place validates the effective disequilibrium approach of Barro and Grossman (1976). In an economy with a gradual adjustment of prices (GAP), as opposed to a LSW economy, the Fed can control output even when the entire population knows *exactly* what it is doing, because it can manipulate the *effective* demand curves for labor and output. The unemployed multitudes of 1933 knew that nominal spending had fallen 50% in four years, but that knowledge didn't help a bit.

The LSW approach can be contrasted once again with the natural rate hypothesis. Let us all agree that a pure demand shock is neutral in the "long run," which might be defined in a sample survey of economists as anything between five and twenty years. To differ from NRH, the LSW proposition must claim that *anticipated* changes in money are neutral over a significantly shorter run than that. Yet knowledge about the size and growth rate of the money supply spreads rapidly, over a period of weeks or months. If we can show that the period of gradual adjustment of prices to demand shocks is *significantly longer* than the brief span needed to adjust one's estimate of the money supply to the weekly Wednesday figure, then we shall have demonstrated that, in the interim between the adjustment of anticipations about a monetary change and the full adjustment of prices to that change, output in our real economy, which combines gradual adjustment of prices with NRH (NRH-GAP), is ruled by an effective demand constraint which the Fed is fully capable of manipulating.

Basic Flaws in Barro's Empirical Tests

Because of the radical implications of the LSW hypothesis for the theory and practice of stabilization policy, it is understandable that macroeconomists should have eagerly awaited a convincing empirical verification. But it is surprising to me that the series of papers by Robert Barro would be regarded as providing any such empirical support,[24] *for the Barro papers provide no test at all of the short-run neutrality proposition of LSW that would distinguish it from the widely accepted long-run "natural rate" neutrality hypothesis.* Barro's papers fail to provide any support for the LSW hypothesis for three separate reasons:

1. There is no explicit empirical test of the leading competing NRH-GAP hypothesis upon which the orthodox stabilization literature rests its case. GAP combined with NRH implies that any permanent shift in the growth rate of nominal income is initially divided between faster growth in both output and prices, but that the inflation rate gradually but continuously accelerates whenever output exceeds its "natural" level, so that gradually the output stimulus vanishes until higher inflation has fully absorbed the entire nominal income acceleration.

2. Far from attempting to distinguish the LSW and NRH-GAP hypotheses, Barro compares as determinants of output on the one hand *unanticipated* money change and on the other hand *raw* money change. The statistical defeat of the latter appears to be the only evidence put forth to support the LSW hypothesis. But this is like setting up a

24. Thus I was startled to read in Blinder's comment, that "Keynesians have been searching for an obvious flaw in his [Barro's] methodology. That one has not been found suggests that the basic flaw, if indeed there is one, is far from obvious." The present comment argues that the flaw is patently obvious: Barro's equations are simply irrelevant in determining the role of anticipated changes in policy, because his specification cannot distingush the LSW hypothesis from the competing price inertia hypothesis on which the orthodox view of stabilization policy is based.

World Series between the Yankees and a team of geriatric invalids. The real Yankee-Dodger World Series for the output determination trophy pits unanticipated money change as one explanatory variable versus the deviation between actual money change and an adaptively adjusting expected price change as the competing variable. Barro's correlations between the output gap and *raw* money change make no contribution whatsoever to distinguishing the dubious LSW hypothesis from the widely accepted NRH, because any such long-run relation between a real variable (output) and a nominal variable (raw money change) would violate the NRH. We know that the acceleration of monetary growth between the 1950s and 1970s did not produce a "permanent economic high," but this fact does not by itself constitute evidence against the *short-run* potency of stabilization policy.

3. Not only do Barro's output and unemployment equations fail to provide any evidence *supporting* the LSW hypothesis, but, worse yet, his price equations strongly undermine the theoretical rationale of the LSW hypothesis by validating the competing NRH-GAP hypothesis. Barro estimates that the full adjustment of prices to changes in the money supply takes between four and six years, while the formation of anticipations about monetary changes takes only a single quarter.[25] For LSW to be valid, any fully anticipated monetary change that raises the anticipated level of nominal GNP must raise the price level *simultaneously* by exactly the same percentage as the increase in nominal GNP, since the hypothesis states that real output must remain unaffected.[26] Thus Barro's price equations fail to validate the one-quarter lag between *actual* money and the price level that would be necessary to confirm the required contemporaneous response of the price level to an anticipated money change. In the long interval between the single-quarter adjustment of expectations about monetary change, and the four to six years required for the full price response to occur, anticipated monetary

25. Table 2.2 of the quarterly Barro and Rush results exhibit a six-year adjustment lag in the price equation when no correction is made for serially correlated residuals and a four-year lag in the equations reestimated with an adjustment for second-order serial correlation.

26. If the influence of a monetary surprise on sales is instantaneous, but the extra sales are partly met by a temporary reduction in inventories, then the effect of the surprise on real GNP will be spread out over time. In this case, the sentence in the text should be qualified to read "any fully anticipated monetary change that raises the anticipated level of nominal GNP must raise the price level *simultaneously*, by exactly the same percentage as the increase in nominal GNP, holding constant the influence of past surprises." Thus, holding constant the effect of past surprises on current output and prices, any fully anticipated monetary change must have its entire effect on the price level and leave real output unaffected.

change can affect real output.[27] The net result of Barro's research on prices, with its finding of a 24-quarter time interval between a monetary change and the full adjustment of prices, seems to amount to little more than a reconfirmation of my earlier study (1975), which found a 28-quarter lag.[28] One comparison of the two sets of results is exhibited in table 2.4.

In order to appreciate the complete and profound contradiction between Barro's long lags and the LSW supply hypothesis, imagine an economy in an initial situation with actual and expected inflation equal and with output at its natural level. There occurs a 1% addition to the money stock. According to Barro's annual coefficients in table 2.4, after two years the price level is essentially unaffected, requiring an increase in real output equal to 1% (adjusted for any change in velocity that occurs). But this combination of a positive output change with a zero price change contradicts the LSW supply hypothesis, in which the aggregate price level must rise relative to expectations to induce the required confusion between relative and absolute prices.

The Identification Problem

Unfortunately, the entire battery of econometric tests used in the three papers is useless for the purposes of distinguishing the radical implications of the LSW model from the familiar conclusions that emerge from NRH-GAP models based on inertia in the adjustment of prices. This identification problem is pursued in table 2.5. The left-hand side displays a general money supply equation of Barro's form in equation (1), his output equation in (2), and his price equation in (3) and (4). On the right-hand side equation (1*a*) states that the expected rate of inflation depends on lagged inflation and other current and lagged variables, designated X'_L, for example, the presence of war, supply

27. Barro's text explicitly denies any connection between the long price adjustment lags and "explanations for price stickiness of the 'disequilibrium' or contracting variety." This denial appears to rest entirely on the discrepancy between the adjustment lags in the output and price equations. Yet there is another explanation of the inconsistent lags, namely, his misspecification of both the output and price equations (see below).

28. The Barro and Rush results thus provide the needed refutation of the erroneous criticism of my conclusions (1975) that appears in Barro 1978, p. 571: "The effect of anticipated money movements on the price level can be virtually instantaneous at the same time that unanticipated movements . . . affect the price level only with a long lag." Far from being instantaneous, the full response of prices to an anticipated monetary change in Barro and Rush requires a time span of 23 quarters.

Table 2.4 **Lag Distribution of Price Change behind Actual Monetary Change**

	Barro (1978*a*, p. 571)	Gordon (1975, p. 646)
Sample Period	1948–76	1954:II–1971:II
Observations	Annual	Quarterly
Lags		
t	0.17	0.18
$t-1$	−0.31	0.10
$t-2$	0.46	0.13
$t-3$	0.51	0.20
$t-4$	0.27	0.26
$t-5$	0.00	0.26
$t-6$	−0.03	0.15
$t-7$	−0.03	....
$t-8$	0.01	....
Sum of coefficients	1.05	1.28
Mean Lag	2.8	3.3

NOTE

Quarterly Gordon coefficients are obtained for the published equation 7.2 on p. 646 from unpublished printouts and are converted to an annual basis by treating quarters 0–3 as "t", 4–7 as "$t-1$," etc.

shocks, or controls. Equation (2*a*) is the familiar expectational Phillips curve, which allows the inflation rate to differ from what is expected when real output deviates from its "natural" rate (Q^*), or when there is an "s" effect from controls or supply shocks. Equation (3*a*) uses the quantity identity to replace Q, and (4*a*) expresses the reduced form.

There is simply no way of knowing whether Barro's reduced form relation between prices, lagged money, and variables related to velocity (the interest rate, real government spending, and a time trend) represents a test of the left-hand model or the right-hand model, since the same variables appear in each. The only evident difference between (4) and (4*a*) is that lagged velocity terms appear in (4*a*), but this simply points out a mistake in Barro's representation of his own model. Nominal income growth is identical on one side of the quantity equation to the sum of money growth and velocity growth and on the other side to the sum of price and output change. When there is a change in velocity, due either to a shift in the money demand function or in government spending, this must come out by definition as either a change in output or a change in prices. Barro's price equation is derived from a money demand function, and so velocity appears as a determinant of prices. But velocity does not appear in equation (2), which is simply

Table 2.5 **Identifying the LSW and NRH-GAP Approaches**

	Barro Version of LSW Approach		Alternative Approach
(1)	$m^e = \alpha(m_L, X_L)$	(1*a*)	$p^e = \beta(p_L, X'_L)$
(2)	$Q = Q^* + \phi(m - m^e)$	(2*a*)	$p = p^e + \theta(Q - Q^*) + s$
(3)	$P \equiv M + V(Z) - Q$ $= M + V(Z) - Q^* - \phi(m - \alpha(m_L, X_L))$	(3*a*)	$p = p^e + \theta(M + V(Z) - P - Q^*) + s$
(4)	$P = \gamma(M_L, Z, X_L, Q^*)$	(4*a*)	$P = \mu(M_L, Z_L, X'_L, Q^*)$, where s becomes part of X'_L

NOTES

Upper case: logs of levels; lower case: percentage growth rates.
V = velocity; Q = real output; M = money; P = price deflator; X and Z = "other variables"; s = effect of controls and supply shocks.

misspecified. It cannot be the deviation between actual and expected *money* growth, which influences real output, as long as velocity can change, but rather the deviation between actual and expected *nominal income* growth, where the latter depends on expected money, expected government spending, expected exports, and any systematic component in the private investment cycle. Stated another way, Barro's use of money surprises rather than nominal income surprises in his output and unemployment equations implies that velocity surprises are always equal to zero. Barro's agents are thus assumed to be able to predict velocity with precise accuracy, while their uncanny predictive powers do not extend to perfect foresight about the money supply.

Barro's failure to obtain consistent lags in the output and price equations is at least partly due to the inconsistent treatment of velocity. All of the ink spilled over the MIL variable also reflects this problem; instead of having anything to do with changes in the natural rate of unemployment, squeezed inside the MIL variable, velocity is struggling to get out as a determinant of output changes. In the paper presented here the shift to government spending as a determinant of output and unemployment represents a belated attempt to patch up this problem. It is ironic that the Barro and Rush results support fiscal fine-tuning, in the form of an instant effect on output and unemployment of actual (not unexpected) government spending. In contrast the Sargent and Wallace paper (1975) specified an IS curve and treated money and nonmoney exogenous variables symmetrically.

A Suggestion for Future Research

The identification problem posed in table 2.5 echoes an important theme running through recent discussions of the short-run and long-run neutrality hypotheses—the difficulty of identifying the structure of an economic model from aggregative time series data, because several models may be compatible with a time series dependence of, for instance, nominal GNP growth on lagged monetary changes (Sargent 1976*b*). More informally, "you can't get a structure out of a time series."

Nevertheless, neither Sargent's "observational equivalence" conundrum nor the related identification problem of table 2.5 prevents an empirical investigation of the competing LSW and NRH-GAP hypotheses. Although both hypotheses implicitly make real output and price change a function of a distributed lag of past nominal GNP or monetary change, the LSW alternative requires for its validity strong restrictions that can be statistically tested. Since output is required to depend only on nominal GNP "surprises," then any fully anticipated change in nominal GNP must leave real output unaffected and therefore have its full influence on prices. In short, the LSW hypothesis requires that the statistically estimated elasticity on anticipated nominal GNP change in an equation for price change must be unity, and in an equation for real output must be zero, holding constant other variables.[29] The opposing NRH-GAP hypothesis would predict that inertia in the price setting process would prevent price change from responding to anticipated nominal income change with a unitary elasticity.

There is no explicit test in Barro's paper of these coefficient restrictions implied by the LSW hypothesis. His output equations never test the hypothesis that the response of output to anticipated monetary change is positive during the transitional period of price adjustment (i.e., he uses raw money change as a variable rather than money change minus a distributed lag of past price changes). Further, his poorly specified price equation tests whether the price *level* is unit-elastic with respect to the *level* of the money supply over the postwar period; that is, it tests whether money is neutral in the long run, not whether the elasticity of price *change* to anticipated monetary *change* is unity in the short-run. A test of the zero-one restrictions of the LSW hypothesis should be high on the agenda for future research in empirical macroeconomics.

Comment Robert Weintraub

Barro and Rush are doing important work. Their research is truly exploratory, and, like all explorations, it creates excitement. Nonetheless, it does not succeed.

Barro and Rush are trying to make operational and test the Lucas-Sargent-Wallace hypotheses about the relationships between money supply and macroeconomic performance. In summary, they specify equations to decompose M1 growth (measured at annual and quarterly rates) into expected and unexpected components. The unexpected element is then used both in regression equations, whose purpose is to explain changes in output and unemployment, and in a regression of what appears to be a rearranged real money demand equation, which purports to explain inflation. This is a sensible methodology. Although they do not succeed, their effort is not in vain. It casts light on the pitfalls that await us when we try to put the LSW hypotheses into operational form

I am indebted to Robert Auerbach and John Hambor.

29. In the general case in which output depends not just on current nominal surprises but also on the past history of surprises, as in the recent inventory model developed by Blinder and Fischer 1978, these "other variables" include past surprises.

and test them. Future researchers who try, including, I hope, Barro and Rush, will find they have an easier job as a result.

Expected M1 Growth

Empirical decomposition of M1 growth into expected and unexpected elements is the essential first step in testing LSW propositions. If the decomposition statistics are weak, or if the logic behind the statistics is questionable, the test of the LSW propositions will be neither fair nor useful. The Barro and Rush decomposition statistics are weak, and the logic on which they base their decomposition is suspect.

The equations that were used to estimate annual M1 growth in the original version of the Barro and Rush paper generated a steady-state M1 growth/unemployment relationship substantially different from the Barro and Rush quarterly expected M1 growth equation. In the revised version, a new equation (7) is used to estimate expected quarterly M1 growth. Its steady-state properties are consistent with the annual equation, but the new quarterly equation (7) raises other questions.

Briefly, the weakness of the coefficients on the lagged DM terms (other than $t - 1$) raises doubts about using them as regressors. More important, the irregularity of the response of expected money growth to lagged unemployment, as well as the weakness of the unemployment coefficients, raises doubts about relating expected money growth to lagged unemployment to begin with.

The standard errors of the regressions of the annual expected M1 growth regressions are high. The smallest error, which is from the jointly estimated equation (1′), is .0133. The standard error of the regression of equation (1), which was estimated by OLS, is .0140. This is an improvement on the .0227 standard deviation of the mean of log (M_t/M_{t-1}) in the 1946–77 period, but, .0140 is not small. It is too large for the regression to be economically meaningful. It is 37.5% of the .0373 mean of $\log(M_t/M_{t-1})$ in the 1946–77 period. Expressed in probability terms, this error cautions us that there is a one in twenty chance that the true value of expected money growth is 2.80 percentage points above or 2.80 percentage points below the estimate generated by Barro's equation (1). Using equation (1′), the error is 35.7% of .0373, and there is a one in twenty chance that the true value of expected M1 growth is 2.66 percentage points above or below the regression estimate. Given this magnitude of potential error, it is hard to see how anyone can take seriously the decomposition of M1 growth into the expected and unexpected components implied by Barro's expected M1 growth regressions.

Those who do should ponder the fact that it is easy to conjure up other explanations of expected M1 growth that fit the annual data about as well as Barro's independently estimated equation (1). Two examples are provided below:

• A linear regression for the 1946–77 period (Barro weights 1941–45 observations) of $\log(M_t/M_{t-1})$ on the log of last year's U.S. population divided by the population the year before last has a standard error of .0146. For the record, using POP to denote population,[30] this regression, with standard errors in parentheses, is

$$\log(M_t/M_{t-1}) = \underset{(.968)}{10.020} - \underset{(.685)}{4.614} \log(POP_t/POP_{t-1})$$

• The linear regression for the 1957–77 period of $\log(M_t/M_{t-1})$ on itself lagged both one and two years plus the change in the federal funds rate last year from the year before last has a standard error of .0127. This is only 30.5% of the .0418 mean of $\log(M_t/M_{t-1})$ in the 1957–77 period.

With Ffr to denote the federal funds rate, the results of this regression are

$$\begin{aligned}\log(M_t/M_{t-1}) = {} & \underset{(.635)}{.824} + \underset{(.180)}{.599} \log(M_{t-1}/M_{t-2}) \\ & + \underset{(.181)}{.290} \log(M_{t-2}/M_{t-3}) \\ & - \underset{(.0016)}{.0054} (Ffr_{t-1} - Ffr_{t-2})\end{aligned}$$

The coefficient on the funds rate is highly significant. Its sign is negative, which indicates that contracyclical M1 growth can be expected after a year's delay.

Strictly speaking, this regression is not comparable with Barro's regressions because it was run for the subperiod 1957–77. The regression was fitted for this period because the Ffr data series dates back only to 1955. Moreover, interest rate data for the 1940s and early 1950s cannot be used to estimate how M1 growth responds to lagged interest rate changes because during those years interest rates were continuously pegged. A fair test of how well Barro's equation (1) estimates expected money growth compared with intuitive explanations that use interest rates as arguments must be made with post-Accord data. My bet is that the standard error of the mean of expected M1 growth from Barro's equation (1), estimated for the 1957–77 period, is not significantly less than .0127.

Barro's expected M1 growth equations are suspect for logical as well as statistical reasons. Specifically, the unemployment rate would not

30. The source of the population data used in this regression is the 1978 *Economic Report*, p. 287. In this regard, in computing the 1950/1949 ratio, it was necessary to adjust the reported 1950 population to exclude residents of Hawaii and Alaska because the series excludes them prior to 1950.

appear to be an appropriate variable for estimating expected M1 growth in a rational world. Here's why.

If M1 growth is expected to increase in response to an observed prior rise in unemployment, and if unexpected M1 growth is required to reduce unemployment, then, the Federal Reserve authorities cannot allow M1 growth to react to unemployment as the public expects if they want to reduce unemployment. They must target unexpected M1 growth because expected M1 growth is dissipated in inflation, and differences between actual and expected M1 growth that are due to the Federal Reserve's under- or overshooting targeted M1 growth are as likely to be minus as plus, and hence as likely to increase as to decrease unemployment. If, however, the Federal Reserve pursues M1 growth policies in response to lagged unemployment that are different from what the public expects, then Barro's method of separating unexpected and expected M1 growth is inappropriate. The historical relationship that Barro observed between lagged unemployment and M1 growth cannot be interpreted as a relationship between lagged unemployment and *expected* M1 growth. Barro's measure of the response of M1 growth to lagged unemployment would have emerged from policies designed to fool the public. In a rational world the public would know this and would not bet on the stability of the observed relationship between lagged unemployment and M1 growth. Put otherwise, if at any time after 1941 the Federal Reserve authorities had thought the public expected M1 growth to conform to Barro's regression results (which he interprets as what the public has expected all along), then, assuming the Federal Reserve authorities wanted to affect unemployment and knew that only unanticipated M1 growth would affect it, they would have made sure that those results turned out differently. Hence, Barro's results shed no light on the relationship between *expected* M1 growth and lagged unemployment.

More generally, logic would appear to rule out using unemployment in estimating expected M1 growth in the first place, except under the assumption that the Federal Reserve authorities don't know what they are doing or how the economy works. If the Federal Reserve authorities know that only unexpected M1 growth can affect the real economy, they are not likely to react to changes in real economic variables including unemployment in any systematic way, and any observed response of M1 growth to lagged unemployment rationally must be regarded as accidental.[31]

31. Stanley Fischer has pointed out to me in a letter dated 14 November 1978 that some may have difficulty seeing what I am driving at in this section. He asked whether I might put it a bit differently. Happily, in the same letter he did the job for me. He wrote: "My understanding is that you're saying the Fed must either

Inflation

Barro's inflation equations (4) and (4″) are overdrawn. Each includes the value of the long-term Aaa corporate bond index interest rate in the current year as an explanatory variable. It is used to capture inflation expectations. A rise, Barro explained in his original paper, with a caveat, "reflects a shift in anticipated inflation—but, one that is *unsatisfactorily* treated as exogenous in the present framework" (emphasis added).[32]

Nevertheless, Barro was and continues to be willing to use interest rate changes to capture shifts in inflation expectations. Apparently, he believes that such changes are not very important for explaining U.S. post–World War II inflation experience. In his original paper Barro recognized that, using the 3.8 coefficient on R_t from regression equation (4″), as originally reported, the rise in the long-term Aaa rate from .0744 to .0857 between 1973 and 1974 "accounts for .043 of the total estimated value for the 1974 inflation rate of .104." However, this did not seem to disturb him because he stated, "the interest rate change is not as important for 1975—accounting for only .010 of the total

---

itself have been irrational to have changed the money growth rate in response to unemployment (if Barro's theory is right) in a predictable way, or else that until recently Barro's theory can't have applied. The other possibility is that the Fed thought it could affect the unemployment rate and acted as the equation says it did, even though in fact it was only shadow boxing. This may be equivalent to its being irrational."

The only way I would modify Fischer's interpretation is by changing "until recently Barro's theory can't have applied" to "Barro's theory can't apply," i.e., his coefficients can't shed light on the expected M1 growth–lagged unemployment relationship if the Fed wants to affect unemployment and knows that only unexpected M1 growth will affect it.

Still another way of putting my point was suggested by Robert Solow in a letter dated 12 January 1979. He wrote: "Barro proceeds as if the Fed is a kind of passive machine-plus-random-disturbance which the public can learn about. But the whole point of view suggests that the Fed ought to be as smart as the public, in which case the situation becomes a kind of 2-person game. But then, as you point out, the Barro method is inappropriate."

Finally, Barro, in a letter dated 8 January 1979, urges that "Your discussion of the logic of the lagged unemployment rate as a DM predictor repeats a point from my 1977 paper (p. 114)." There he wrote: "'This observation raises questions concerning the rationality of the countercyclical policy response that appears in equation (2). One possibility is that the reaction of money to lagged unemployment reflects optimal public finance considerations."

It is clear that Barro knows that his approach is inappropriate. His reference to "optimal public finance considerations" does not rescue his methodology. The flaw is fatal.

32. This quotation and those that follow are taken from Barro's original paper before it was revised for publication.

1975 inflation estimate of .082." I concluded that Barro should have checked in other years. Following are the contributions to inflation as per his original equation (4″) of changes in the Aaa bond rate from the prior year in years since the Korean war when the rate rose and inflation, as measured by the log of the ratio of the value of the GNP deflator this year to last year's value, exceeded .020.

Year	Contribution	Inflation
1955	.006	.021
1956	.012	.031
1957	.020	.033
1959	.023	.022
1965	.003	.022
1966	.024	.032
1967	.014	.029
1968	.025	.044
1969	.032	.049
1970	.038	.052
1973	.009	.056
1974	.043	.096
1975	.010	.089

The record shows that in nine of the thirteen years since 1953 when the Aaa bond rate rose and inflation exceeded .020, the rise in the Aaa bond rate plays a major role in Barro's explanation of inflation.

In his letter of 8 January 1979, Barro stated that "I exaggerate the explanatory role of the interest rate variable." In this regard it should be noted that the results from equation (4″) in the current version of the Barro and Rush paper differ substantially from the equation (4″) results as they appeared in the paper delivered at the conference. The two equations are reproduced below.

$$
\begin{aligned}
(Conf.)\ \log P_t = \log(M_t) &- \underset{(0.1)}{4.5} - \underset{(.12)}{.81DMR} \\
&- \underset{(.15)}{1.40DMR_{t-1}} - \underset{(.18)}{1.45DMR_{t-2}} \\
&- \underset{(.14)}{1.08DMR_{t-3}} - \underset{(.11)}{.79DMR_{t-4}} \\
&- \underset{(.09)}{.27DMR_{t-5}} - \underset{(.0010)}{.0109 \cdot t} \\
&+ \underset{(.11)}{.45(G/y)_t} + \underset{(.4)}{3.8R_t}
\end{aligned}
$$

$$
\begin{aligned}
(\mathit{Current})\ \log P_t = \log(M_t) &- \underset{(.15)}{4.58} - \underset{(.12)}{.85DMR_t} \\
&- \underset{(.15)}{1.31DMR_{t-1}} - \underset{(.18)}{1.36DMR_{t-2}} \\
&- \underset{(.17)}{.94DMR_{t-3}} - \underset{(.12)}{.61DMR_{t-4}} \\
&- \underset{(.10)}{.16DMR_{t-5}} - \underset{(.0015)}{.0096 \cdot t} \\
&+ \underset{(.15)}{.34(G/y)} + \underset{(.5)}{2.9R_t}
\end{aligned}
$$

The conference equation was estimated jointly with the other three equations of Barro's four-equation system (DM,U,y,P). The current results were obtained from joint estimates "that embody the cross-equation restrictions of the unanticipated money hypothesis." Barro also notes that the current estimation "does not use R_{t-1} as an instrument for R_t" as did the estimation whose results were presented at the conference. This switch raises doubts about the reliability of the new coefficient on R_t (2.9) compared with the old (3.8).

Using the new coefficient on R_t requires modifying the inflation contributions of R_t tabulated above by .76. Definitely this is an improvement on the conference paper. However, the adjusted contributions are still unacceptably high. Though Barro might be appalled, the fact is that institutionalists who stress "cost-push" explanations of inflation will find his results, whether as reported at the conference or here, supportive of their arguments. As far as I am concerned, they are useless.

Another View

We advance our knowledge of the world in successive approximations. Most economists would now agree, I think, that familiar monetarist propositions approximate reality in the long run. The LSW hypotheses are intended to explain year-to-year or even shorter events. Barro and Rush have tried to test these hypotheses but what they have done is helpful only in pointing out some pitfalls that await those who attempt to make operational and test LSW hypotheses. It is not a fair test. Until they, or other researchers, do better, we will have to make do with the familiar monetarist propositions that, over the long haul, unemployment is invariant with respect to M1 growth while inflation and interest rates are closely and positively related to the rate of M1 growth. This does not mean that M1 growth changes will not temporarily affect output and unemployment, and the larger such shocks are the more lasting the real effects will be, as in the 1930s. But, with the mag-

Table 2.6 **Unemployment, Inflation, Money Growth, and Interest Rates in Nonoverlapping Three-Year Periods, 1954–77**

Period	Unemployment Rate	Inflation (CPI) Rate	Money Supply Growth Rate	Three-month T-bill rate
1954–56	4.7	0.5	2.0	1.8
1957–59	5.5	2.4	1.8	2.8
1960–62	5.9	1.3	1.4	2.7
1963–65	5.1	1.4	3.7	3.6
1966–68	3.7	3.3	5.3	4.9
1969–71	4.8	5.2	5.5	5.8
1972–74	5.3	6.9	6.7	6.3
1975–77	7.7	7.1	5.5	5.4
1955–57	4.3	1.5	1.6	2.6
1958–60	5.9	1.7	1.6	2.7
1961–63	6.0	1.2	2.4	2.8
1964–66	4.5	2.0	4.3	4.1
1967–69	3.6	4.1	5.7	5.5
1970–72	5.5	4.5	5.9	5.0
1973–75	6.3	8.8	5.7	6.9
1976–77	7.4	6.1	6.1	5.1
1956–58	5.1	2.5	1.0	2.6
1959–61	5.9	1.2	1.9	2.9
1962–64	5.5	1.3	3.0	3.2
1965–67	4.1	2.5	4.3	4.4
1968–70	4.0	5.2	5.7	6.2
1971–73	5.5	4.6	7.1	5.2
1974–76	7.3	8.6	4.9	6.2
1977	7.0	6.5	7.2	5.3

nitude of M1 growth changes that the U.S. has experienced during the post–Korean war years, it appears to take only three or at most six years for changes in M1 growth to be fully reflected (and dissipated) in changes in the rate of inflation and rates of interest. During the post–Korean war period, no relationship is observed between three year averages of M1 growth and unemployment. The relevant data are assembled for *nonoverlapping* three-year periods beginning, alternatively, 1954–56, 1955–57 and 1956–58 in table 2.6.

General Discussion

Robert Barro responded to several of the discussants' comments. He was not himself satisfied with the role of the unemployment rate in the Fed reaction function, since it implied some irrationality on the part of the

Fed. He was not sure on theoretical grounds how the interest rate should enter the reaction function but thought the issue worth further empirical exploration. He felt that the best approach to testing his hypothesis was the examination of the implied cross-equation coefficient restrictions. He agreed that increased government spending could increase output and did not see anything in natural rate theory to contradict this. Finally, he agreed that more than information confusions were needed to explain the serial correlation of output but did not see any reason to reject the role of information confusions on that account.

Robert Hall said that the novelty in Barro's work was not testable: there is no test that will distinguish the effects of anticipated from unanticipated money. If one substituted from Barro's reaction function into his output equation, one then had an equation in which current and lagged growth rates of money, and other factors, particularly a fiscal variable and lagged unemployment, affected current output. What Barro is actually testing is whether fiscal variables matter, as in the Saint Louis equation. In further discussion it was pointed out that Barro had addressed this issue (Barro 1977) and suggested that this point had also been made by Thomas Sargent (1976*b*).

Charles Nelson said that the power of Barro's test depended on how strongly the other variables—in this case the fiscal variable—entered the reaction function. In the Barro and Rush paper the *t*-statistics on the fiscal variable are reasonably high, so that the test is reasonably powerful.

Benjamin Friedman suggested that in thinking about the reaction function we should consider the Fed's operating procedures. In the short term the Fed sets interest rates, and the money stock is determined by money demand at that interest rate. Barro's reaction function looked like the reduced form resulting from that process. It would therefore be useful to view the Barro reaction function explicitly as a reduced form and try to identify the structural coefficients in the true reaction function.

Neil Wallace remarked that Barro's procedure derived identifying restrictions on the reaction function from elements that were not central to the theory that was being tested. The obvious way to test the hypothesis Barro was interested in was to look for periods in which money supply processes differed, as suggested in Sargent's observational equivalence paper.

Robert Barro thought the emphasis on the shift of regimes exaggerated. One could interpret the nonmoney variables in his supply function as representing changes in regime. He also suggested that you could achieve identification by noting the implications of the reaction function for the coefficients on other variables that would enter the reduced form. For instance, when the reaction function was substituted into the output equation in his current paper, it was implied that current and lagged values of the federal expenditure variable reduced current output. Some competing theories imply that federal spending would, if anything, enter with a positive coefficient, and they could therefore be rejected.

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