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UNANTICIPATED MONEY AND ECONOMIC ACTIVITY

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SUMMARY

Unanticipated Money and Economic Activity

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and
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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, the stress is on the distinction between anticipated and unanticipated movements of money.

Part I 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 some doubts about the specification of the price equation, although the other relations receive further statistical support.

Part II applies the analysis to quarterly data. Despite the necessity to deal 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.

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Part I: Annual Data

by Robert J. Barro

This part of the paper summarizes and extends the results for annual U.S. data from my (1977) and (1978a) papers on money growth, unemployment, output and the price level. The estimated money growth equation, which is used to divide observed growth rates into anticipated and unanticipated components, is

1941-77 sample (observations from 1941-45 multiplied by 0.36):

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

$$\hat{\sigma}\text{ (for post-World War II sample)} = .0141,\ D\text{-}W = 1.9,$$ [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-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:

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

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

1946-77 sample:

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

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

where y is GNP in 1972 dollars, MIL is the military personnel/conscription variable that is discussed in my (1977) paper, 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 in my (1978b) paper, 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 the analysis in my (1978a) paper, is

1948-77 sample:

$$(4)\quad \log(P_t) = \log(M_t) - \underset{(0.2)}{4.4} - \underset{(.20)}{0.64}DMR_t - \underset{(.23)}{1.52}DMR_{t-1} - \underset{(.28)}{1.80}DMR_{t-2} - \underset{(.26)}{1.42}DMR_{t-3}$$

$$- \underset{(.19)}{.73}DMR_{t-4} - \underset{(.16)}{.37}DMR_{t-5} - \underset{(.0021)}{.0120}\cdot t + \underset{(.16)}{.59}(G/y)_t + \underset{(1.1)}{4.3}R_t,$$

$$\hat{\sigma} = .0130, \quad D\text{-}W. = 1.6,$$

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 is rationalized in my (1978a) paper from their inverse influences on money demand. 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 the (1978a) paper.[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. As discussed in the (1978a) paper, 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 is also described in that earlier paper. It is worth stressing that this appearance of sluggish price adjustment does not correspond to the pattern of output and unemployment persistence that appears in equations (2) and (3). Accordingly, explanations for price stickiness of the "disequilibrium" (Barro and Grossman, 1976, ch. 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, et al.,

$\log(P_t) - \log(P_{t+1})^e$ (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 (1978a, 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, $F(X_t) = \alpha_0 + \alpha_1 DM_{t-1} + \alpha_2 DM_{t-2} + \alpha_3 FEDV_t + \alpha_4 \log(U/1-U)_{t-1}$. 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 non-linear 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]

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

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

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

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

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

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

where asymptotic standard errors are shown in parentheses. Note that these $\hat{\sigma}$ values are not adjusted for degrees of freedom and are therefore 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·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]

$$(1'') \quad DM_t = \underset{(.011)}{.098} + \underset{(.12)}{.44}DM_{t-1} + \underset{(.09)}{.16}DM_{t-2} + \underset{(.011)}{.061}FEDV_t + \underset{(.004)}{.031}\log(U/1-U)_{t-1},$$

$$\hat{\sigma} = .0134, \quad DW = 1.8,$$

$$(4'') \quad \log P_t = \log M_t \underset{(.15)}{-4.58} - \underset{(.12)}{.85}DMR_t - \underset{(.15)}{1.31}DMR_{t-1} - \underset{(.18)}{1.36}DMR_{t-2} - \underset{(.17)}{.94}DMR_{t-3}$$

$$- \underset{(.12)}{.61}DMR_{t-4} - \underset{(.10)}{.16}DMR_{t-5} + \underset{(.15)}{.34}(\dot{G/y})_t + \underset{(0.5)}{2.9}R_t - \underset{(.0015)}{.0096}\cdot t,$$

$$\hat{\sigma} = .0069, \quad DW = 2.2.$$

Unrestricted estimation of the two equations leads to the calculation of a value for -2·log (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·log(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 to 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·log(likelihood ratio) associated with the unanticipated money hypothesis turns out to be 31.8, as compared to 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 reasonably raised 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 (1978) and my reply (1978b). In my (1978a) paper I noted some problems with the MIL variable that concerned its surprisingly strong output effect and insignificant price level influence. 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, as shown in table 2 of the (1977) paper, 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, non-lottery 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)

$$(5)\quad \log(y_t) = \underset{(.05)}{2.92} + \underset{(.23)}{1.06}DMR_t + \underset{(.24)}{1.08}DMR_{t-1} + \underset{(.20)}{.07}DMR_{t-2} + \underset{(.0004)}{.0330}\cdot t + \underset{(.013)}{.070}\cdot\log(G_t)$$

$$R^2 = .998, \quad \hat{\sigma} = .0169, \quad D\text{-}W = 1.5.$$

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]

$$(6)\quad \log(U/1\text{-}U)_t = \underset{(.12)}{-2.21} - \underset{(2.0)}{6.3}DMR_t - \underset{(2.0)}{10.5}DMR_{t-1} - \underset{(2.0)}{1.9}DMR_{t-2} - \underset{(1.0)}{6.7}(G/y)_t,$$

$$\hat{\sigma} = .145, \qquad D\text{-}W = 1.6.$$

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.) However, if the MIL variable is added to equations (5) and (6), 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 4-1/2% for the values of MIL (.07 to .08) prevailing in the early 1960's. Equation (6) yields values for the unemployment rate of 6.2% at the 1977 value of G/y (.076) and also about 4-1/2% for the values of G/y (around .125) that existed in the early 1960's. 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

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

$$\hat{\sigma} = .0132, \qquad DW = 1.9,$$

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

$$\hat{\sigma} = .0138, \qquad DW = 1.6,$$

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

$$\hat{\sigma} = .117, \qquad DW = 1.7.$$

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

Part II: Quarterly Data

by Robert J. Barro and Mark Rush

This part of the paper describes results from applying the 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

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

where DM is measured at quarterly rates (see the notes to table 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 (9). 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 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 the 1977 paper, 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 1, col. 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 out to 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 only out to 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 cols. 2 and 3, respectively. Estimation of the pattern of residual serial correlation turned out to require a second-order autoregressive form: $u_t = \rho_1 u_{t-1} + \rho_2 u_{t-2} + \varepsilon_t$, 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 col. 4 of table 1 (which uses the MIL variable), are 1.20, s.e. = .09 and -0.37, s.e. = .09.[13] Similar results appear in col. 5, which uses the log(G) variable. This pattern of 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 1) only out to 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). However, 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, $\hat{DY}_t \equiv \widehat{\log(y_t)} - \log(y_{t-1})$, and residuals in table 3, where $\widehat{\log(y_t)}$ is calculated from the equation in table 1, col. 4.

Results for the unemployment rate, shown in cols. 6-9 of table 1, are basically similar to those for output. These equations involve a starting date in 1949--corresponding to that for the annual data as discussed in part I--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 cols. 8 and 9 of table 1 is at a 2-5 quarter lag, which is slightly delayed relative to the response of output.

The unemployment rate equations shown in cols. 6 and 8 use the MIL variable, while those in cols. 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 coefficient of the MIL or G/y variable 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, 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--$\hat{\rho}_1$ = 1.16, s.e. = .09; $\hat{\rho}_2$ = -0.41, s.e. = .09 in col. 8--is similar to that found for output. Actual values of U are shown with estimated values and residuals from the col. 8 equation in table 3.

Price Level

Quarterly price level estimates are shown in table 2. The OLS regression in col. 2 of the table includes an unrestricted coefficient estimate for the $\log(M_t)$ variable, while the col. 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.)

The estimated DMR coefficients in the equations shown in cols. 2 and 3 are negative and individually significantly different from zero out to a lag of 24 quarters. For example, in col. 3--which sets the coefficient of $\log(M_t)$ to one--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.

As with 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 cols. 4 and 5 of table 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 col. 4, .93, s.e. = .09, differs insignificantly from one. The pattern of DMR coefficients in this equation and in the col. 5 equation that constrains the log(M_t) coefficient to equal one are substantially less drawn out than those shown in cols. 2 and 3. Lagged values out to 14 quarters are now significant, with the principal effects occurring in the 1-12 quarter range.

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 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 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 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 1, col. 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. On the other hand, the quarterly estimate of the $\log(G_t)$ coefficient is .072, s.e. = .017 (table 1, col. 5), which corresponds to that, .070, s.e. = .013, from the annual equation (5).

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 out to

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 that the $\hat{\sigma}$ 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), 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, col. 5 (with the coefficient of $\log(M_t)$ constrained to one 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. On the other hand, the quarterly price equation without serial correlation correction (table 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, 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, col. 5) drastically alters the quarterly coefficient estimates of these variables and thereby produces a discrepancy between the quarterly and annual estimates.

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Table 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	47.1-78.1	47.1-78.1	47.3-78.1	47.3-78.1	49.1-78.1	49.1-78.1	49.3-78.1	49.3-78.1
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	-	-
$\hat{\sigma}$	.0179	.0187	.0092	.0090	.135	.161	.083	.089
DW	0.4	0.3	2.1	2.1	0.5	0.4	2.2	2.1

Notes to Table 1:

The variables U, y, M and G are seasonally adjusted. The dependent variable for columns 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. 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).

Columns 4, 5, 8, 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. DW is the Durbin-Watson Statistic.

Table 2

QUARTERLY PRICE LEVEL EQUATIONS

(1)	(2)	(3)	(4)	(5)
Sample	48.1-78.1	48.1-78.1	48.3-78.1	48.3-78.1
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	---	---
$\hat{\sigma}$	.0123	.0130	.0052	.0051
DW	0.4	0.4	2.2	2.2

Notes to Table 2:

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 M1 concept of the money stock. R is the Aaa corporate bond rate. See the notes to table 1 for other definitions.

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

Table 3

QUARTERLY VALUES OF MONEY GROWTH, OUTPUT GROWTH AND UNEMPLOYMENT

(1)	(2) DM	(3) $\widehat{DM}$	(4) DMR	(5) Dy	(6) $\widehat{Dy}$	(7) DyR	(8) U	(9) $\widehat{U}$	(10) UR
1941-1	.0553	.0452	.0101						
41-2	.0348	.0506	-.0158						
41-3	.0345	.0348	-.0003						
41-4	.0168	.0396	-.0228						
42-1	.0470	.0339	.0131						
42-2	.0500	.0446	.0054						
42-3	.0693	.0584	.0109						
42-4	.0774	.0543	.0231						
43-1	.0866	.0622	.0244						
43-2	.0457	.0640	-.0183						
43-3	.0752	.0431	.0321						
43-4	.0108	.0649	-.0541						
44-1	.0373	.0337	.0036						
44-2	.0476	.0426	.0050						
44-3	.0345	.0458	-.0113						
44-4	.0591	.0323	.0268						
1945-1	.0404	.0522	-.0118						
45-2	.0269	.0302	-.0033						
45-3	.0236	.0234	.0002						
45-4	.0227	.0223	.0004						
46-1	-.0002	.0196	-.0198						
46-2	.0325	.0128	.0197						
46-3	.0140	.0242	-.0102						
46-4	.0036	.0098	-.0062						
47-1	-.0017	.0009	-.0026						
47-2	.0163	.0031	.0132						
47-3	.0089	.0061	.0028	.0011	.0070	-.0059			
47-4	.0044	.0053	-.0009	.0121	.0128	-.0007			
48-1	.0000	.0019	-.0019	.0076	.0134	-.0058			
48-2	-.0089	-.0024	-.0065	.0181	.0094	.0087			
48-3	.0009	-.0054	.0063	.0098	.0144	-.0046			
48-4	-.0036	.0021	-.0057	.0103	.0077	.0026			
49-1	-.0054	-.0014	-.0040	-.0101	-.0011	-.0090			
49-2	.0018	-.0037	.0055	-.0041	.0050	-.0091			
49-3	-.0036	.0034	-.0070	.0092	.0098	-.0006	.065	.061	.004
49-4	.0000	-.0005	.0005	-.0085	.0076	-.0161	.068	.065	.003
1950-1	.0090	.0047	.0043	.0446	.0158	.0288	.062	.066	-.004
50-2	.0151	.0072	.0079	.0262	.0279	-.0017	.055	.054	.001
50-3	.0105	.0069	.0036	.0324	.0194	.0130	.045	.050	-.005
50-4	.0087	.0062	.0025	.0222	.0309	-.0087	.040	.036	.004
51-1	.0103	.0051	.0052	.0140	.0211	-.0071	.033	.035	-.002
51-2	.0093	.0084	.0009	.0190	.0162	.0028	.029	.030	-.001
51-3	.0126	.0079	.0047	.0199	.0131	.0068	.030	.027	.003
51-4	.0182	.0105	.0077	.0017	.0134	-.0117	.032	.031	.001
52-1	.0130	.0137	-.0007	.0095	.0061	.0034	.029	.032	-.003
52-2	.0081	.0119	-.0038	.0014	.0042	-.0028	.028	.028	.000
52-3	.0104	.0086	.0018	.0104	.0049	.0055	.030	.029	.001
52-4	.0103	.0098	.0004	.0235	.0057	.0178	.026	.032	-.006
53-1	.0039	.0114	-.0075	.0157	.0012	.0145	.026	.028	-.002
53-2	.0063	.0057	.0006	.0064	.0003	.0061	.025	.029	-.004
53-3	.0016	.0076	-.0060	-.0061	-.0017	-.0044	.026	.029	-.003
53-4	.0008	.0033	-.0025	-.0097	-.0100	.0003	.035	.030	.005
54-1	.0031	.0021	.0010	-.0136	-.0016	-.0120	.050	.043	.007
54-2	.0023	.0060	-.0037	-.0041	-.0003	-.0038	.055	.056	-.001
54-3	.0092	.0070	.0022	.0144	.0047	.0097	.057	.055	.002
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 3 (continued)

(1)	(2) DM	(3) $\widehat{DM}$	(4) DMR	(5) Dy	(6) $\widehat{Dy}$	(7) DyR	(8) U	(9) $\hat{U}$	(10) UR
1955-1	.0113	.0096	.0017	.0237	.0143	.0094	.045	.044	.001
55-2	.0060	.0075	-.0015	.0150	.0122	.0028	.042	.043	-.001
55-3	.0045	.0054	-.0009	.0145	.0095	.0050	.039	.040	-.001
55-4	.0015	.0047	-.0032	.0101	.0053	.0048	.040	.039	.001
1956-1	.0037	.0032	.0005	-.0044	.0030	-.0074	.038	.041	-.003
56-2	.0022	.0056	-.0034	.0051	-.0013	.0064	.040	.039	.001
56-3	.0007	.0033	-.0026	.0006	.0009	-.0003	.039	.043	-.004
56-4	.0044	.0031	.0013	.0116	.0046	.0070	.039	.040	-.001
57-1	.0022	.0046	-.0024	.0069	.0083	-.0014	.037	.041	-.004
57-2	.0000	.0031	-.0031	.0007	.0040	-.0033	.039	.038	.001
57-3	.0007	.0011	-.0004	.0069	.0066	.0003	.040	.042	-.002
57-4	-.0059	.0029	-.0088	-.0132	.0030	-.0162	.047	.044	.003
58-1	-.0015	-.0015	.0000	-.0197	-.0015	-.0182	.061	.052	.009
58-2	.0117	.0034	.0083	.0072	.0124	-.0052	.071	.063	.008
58-3	.0101	.0125	-.0024	.0240	.0172	.0068	.070	.068	.002
58-4	.0122	.0107	.0015	.0255	.0201	.0054	.062	.062	.000
59-1	.0134	.0113	.0021	.0122	.0275	-.0153	.056	.053	.003
59-2	.0084	.0104	-.0020	.0217	.0145	.0072	.049	.049	.000
59-3	.0049	.0078	-.0029	-.0107	.0126	-.0233	.051	.046	.005
59-4	-.0062	.0067	-.0129	.0105	.0002	.0103	.054	.052	.002
1960-1	-.0042	.0017	-.0059	.0198	.0008	.0190	.049	.057	-.008
60-2	-.0014	.0042	-.0056	-.0024	.0062	-.0086	.050	.052	-.002
60-3	.0077	.0032	.0044	-.0043	.0028	-.0071	.053	.052	.001
60-4	.0021	.0073	-.0052	-.0052	.0047	-.0099	.061	.058	.003
61-1	.0041	.0042	-.0001	.0064	.0097	-.0033	.066	.062	.004
61-2	.0083	.0063	.0020	.0167	.0211	-.0044	.068	.064	.004
61-3	.0061	.0094	-.0033	.0129	.0222	-.0093	.066	.062	.004
61-4	.0095	.0079	.0016	.0237	.0199	.0038	.060	.058	.002
62-1	.0061	.0112	-.0051	.0143	.0213	-.0070	.054	.055	-.001
62-2	.0040	.0077	-.0037	.0129	.0086	.0043	.053	.050	.003
62-3	-.0020	.0060	-.0080	.0075	.0072	.0003	.054	.055	-.001
62-4	.0060	.0041	.0019	.0019	.0080	-.0061	.053	.053	.000
63-1	.0093	.0085	.0008	.0095	.0083	.0012	.056	.054	.002
63-2	.0098	.0091	.0007	.0125	.0126	-.0001	.055	.055	.000
63-3	.0097	.0096	.0001	.0182	.0154	.0028	.053	.053	.000
63-4	.0103	.0096	.0007	.0096	.0188	-.0092	.054	.049	.005
64-1	.0057	.0088	-.0031	.0166	.0121	.0045	.053	.052	.001
64-2	.0095	.0080	.0015	.0126	.0140	-.0014	.050	.050	.000
64-3	.0162	.0102	.0060	.0097	.0145	-.0048	.048	.047	.001
64-4	.0123	.0129	-.0006	.0038	.0101	-.0063	.048	.046	.002
1965-1	.0067	.0098	-.0031	.0214	.0065	.0149	.047	.047	.000
65-2	.0079	.0081	-.0002	.0147	.0146	.0001	.044	.046	-.002
65-3	.0114	.0090	.0024	.0172	.0112	.0060	.042	.042	.000
65-4	.0166	.0103	.0063	.0209	.0122	.0087	.039	.041	-.002
66-1	.0157	.0135	.0022	.0183	.0133	.0050	.037	.038	-.001
66-2	.0121	.0120	.0001	.0069	.0088	-.0019	.036	.036	.000
66-3	-.0017	.0098	-.0115	.0093	.0011	.0082	.036	.037	-.001
66-4	.0011	.0033	-.0022	.0075	.0009	.0066	.035	.037	-.002
67-1	.0102	.0064	.0038	.0016	.0029	-.0013	.036	.038	-.002
67-2	.0146	.0105	.0041	.0069	-.0002	.0071	.036	.038	-.002
67-3	.0220	.0118	.0102	.0122	.0074	.0048	.036	.037	-.001
67-4	.0146	.0154	-.0008	.0078	.0146	-.0068	.037	.036	.001
68-1	.0128	.0100	.0028	.0096	.0104	-.0008	.035	.035	.000
68-2	.0189	.0111	.0078	.0173	.0188	-.0015	.034	.033	.001
68-3	.0206	.0150	.0056	.0117	.0162	-.0045	.033	.032	.001
68-4	.0197	.0153	.0044	.0027	.0060	-.0033	.033	.033	.000
69-1	.0133	.0133	.0030	.0094	.0084	.0010	.033	.033	.000
69-2	.0107	.0143	-.0036	.0045	.0065	-.0020	.034	.033	.001
69-3	.0058	.0099	-.0041	.0035	.0006	.0029	.035	.036	-.001
69-4	.0058	.0087	[illegible]	-.0035	.0005	-.0060	.035	.037	[illegible]

(1)	(2) DM	(3) $\widehat{DM}$	(4) DMR	(5) Dy	(6) $\widehat{Dy}$	(7) DyR	(8) U	(9) $\widehat{U}$	(10) UR
1970-1	.0091	.0089	.0002	-.0036	-.0047	.0011	.039	.039	.000
70-2	.0128	.0096	.0032	.0005	-.0053	.0058	.046	.048	-.002
70-3	.0126	.0117	.0009	.0073	.0010	.0063	.050	.054	-.004
70-4	.0133	.0120	.0013	-.0098	.0052	-.0150	.056	.054	.002
71-1	.0168	.0117	.0051	.0221	.0070	.0150	.063	.058	.005
71-2	.0249	.0147	.0102	.0073	.0206	-.0133	.056	.061	-.005
71-3	.0165	.0206	-.0041	.0070	.0090	-.0020	.058	.053	.005
71-4	.0065	.0134	-.0069	.0085	.0023	.0062	.053	.058	-.005
72-1	.0178	.0109	.0069	.0183	.0100	.0083	.061	.052	.009
72-2	.0200	.0161	.0039	.0189	.0118	.0071	.054	.064	.010
72-3	.0208	.0190	.0018	.0128	.0036	.0092	.054	.052	.002
72-4	.0220	.0175	.0045	.0203	.0084	.0119	.048	.055	-.007
73-1	.0184	.0192	-.0008	.0227	.0091	.0136	.053	.047	.006
73-2	.0158	.0137	.0021	.0011	.0051	-.0040	.047	.055	-.008
73-3	.0137	.0166	-.0029	.0042	-.0002	.0044	.047	.047	.000
73-4	.0127	.0132	-.0005	.0051	-.0047	.0098	.043	.050	-.007
74-1	.0148	.0138	.0010	-.0100	-.0029	-.0071	.054	.047	.007
74-2	.0138	.0127	.0011	-.0046	-.0029	-.0017	.056	.061	-.005
74-3	.0104	.0156	-.0052	-.0062	-.0029	-.0033	.054	.060	-.006
74-4	.0100	.0124	-.0024	-.0142	.0002	-.0144	.060	.056	.004
1975-1	.0014	.0112	-.0098	-.0252	-.0019	-.0234	.080	.067	.013
75-2	.0182	.0077	.0105	.0156	.0040	.0116	.085	.085	.000
75-3	.0176	.0207	-.0031	.0270	.0208	.0062	.084	.086	-.002
75-4	.0058	.0179	-.0121	.0074	.0095	-.0021	.083	.081	.002
76-1	.0071	.0101	-.0030	.0211	.0089	.0122	.074	.083	-.009
76-2	.0204	.0129	.0075	.0123	.0225	-.0102	.073	.068	.005
76-3	.0108	.0167	-.0058	.0096	.0063	.0033	.077	.074	.003
76-4	.0162	.0127	.0035	.0029	.0095	-.0066	.077	.076	.001
77-1	.0178	.0173	.0005	.0182	.0157	.0025	.074	.075	-.001
77-2	.0194	.0169	.0025	.0149	.0153	-.0004	.067	.069	-.002
77-3	.0199	.0170	.0029	.0125	.0178	-.0053	.065	.062	.003
77-4	.0178	.0184	-.0006	.0095	.0154	-.0059	.060	.061	-.001
78-1	.0124	.0165	-.0041	-.0010	.0055	-.0065	.061	.060	.001

Notes to Table 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 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, col. 8.

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

Footnotes

[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 3.

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

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

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

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 (1977).

[4]The estimated equation over 1946 to 1977 is

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

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

[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

$$\mathrm{DlogP}_t = \underset{(.0031)}{-.0082} + \mathrm{DlogM}_t - \underset{(.20)}{.81}\mathrm{DDMR}_t - \underset{(.28)}{1.30}\mathrm{DDMR}_{t-1} - \underset{(.32)}{1.43}\mathrm{DDMR}_{t-2} - \underset{(.29)}{1.06}\mathrm{DDMR}_{t-3}$$

$$- \underset{(.25)}{.57}\mathrm{DDMR}_{t-4} - \underset{(.16)}{.21}\mathrm{DDMR}_{t-5} + \underset{(.21)}{.38}\mathrm{D}(G/y)_t + \underset{(0.8)}{2.5}\mathrm{DR}_t,$$

$$\hat{\sigma} = .0143, \quad DW = 2.1.$$

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

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

[7]See Leiderman (1978) for a discussion of this matter.

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

[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.

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

[12]With $FEDV_{t-1}$ substituted for $FEDV_t$, the $\hat{\sigma}$ value for the DM equation rises from .00490 to .00496. The estimated coefficient of $FEDV_{t-1}$ is .0089, s.e. = .0031, as compared to .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 non-stationary region. In particular, the value of -2·log(likelihood 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. However, a difficulty with this test 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 equation (table 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·log(likelihood ratio) corresponding to $\rho_1 + \rho_2 = 1$ is 23.0 in this case. Finally, for the price level equation (table 2, col. 5), the upper limit of the 95% confidence

interval for $\widehat{(\rho_1 + \rho_2)}$ is .97 and the value of -2·log(likelihood ratio) corresponding to $\rho_1 + \rho_2 = 1$ is 10.8.

[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, ...

[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.