A Review of the Performance of a Reduced-Form Macroeconomic Model

Authors	John A. Tatom
Working Paper Number	1984-015A
Creation Date	January 1984
Citable Link	https://doi.org/10.20955/wp.1984.015
Suggested Citation	Tatom, J.A., 1984; A Review of the Performance of a Reduced-Form Macroeconomic Model, Federal Reserve Bank of St. Louis Working Paper 1984-015. URL https://doi.org/10.20955/wp.1984.015

A REVIEW OF THE PERFORMANCE OF A REDUCED-FORM MACROECONOMIC MODEL

John A. Tatom
Federal Reserve Bank of St. Louis

84-015

ID 8153R
JAT:lmw
Disk 77R
Draft 4
1/25/84

A REVIEW OF THE PERFORMANCE OF A REDUCED-FORM MACROECONOMIC MODEL

John A. Tatom

During the past few years, there has been increasing criticism of the forecast performance of the small reduced-form model of the economy. During the same period, several unusual economic developments led to the formulation of new hypotheses and questions concerning the reliability of old ones. Among these developments are the increased volatility of observed money growth and suggestions of increased monetary uncertainty, the establishment of record high interest and exchange rates and suggestions of similar real interest rate behavior, unprecedented (for the post-war period) unemployment rates, and finally, financial innovations that have raised concern about the reliability of monetary aggregate measures.

This paper reviews the simulation performance of a simple reduced-form model of the U.S. economy since 1978. The purpose is to not only assess the magnitude of errors and evidence of systematic bias in that period, but also to assess the extent to which the unusual economic developments of the past several years have been responsible for such errors. In this regard, it is important also to determine whether any "new" influences revealed by the experience of the past five years are truly new; that is, could their influence have been anticipated based on the prior historical record?

THE INFLATION RATE EQUATION

To examine recent errors in the price equation, it is initially run over the period I/1955 to IV/1978. The equation is:

$$(1)\quad \dot{P}_t = \underset{(22.18)}{0.998} \sum_{j=0}^{20} w_{t-j} \dot{M}_{t-j} + \underset{(0.98)}{0.015} \dot{p}^e_{t-1} + \underset{(2.68)}{0.044} \dot{p}^e_{t-2}$$

$$- \underset{(-0.99)}{0.016} \dot{p}^e_{t-3} + \underset{(2.12)}{0.031} \dot{p}^e_{t-4} - \underset{(-3.27)}{1.92} D1 + \underset{(1.85)}{1.33} D2$$

$\bar{R}^2 = 0.71$ S.E. = 1.17 D.W. = 2.00 $\rho = 0.20$

An out-of-sample simulation of the equation was run to assess the magnitude of errors since 1978. These results are reported in table 1. The starred entries are more than twice the in-sample standard error. Overall, the errors do not appear to be problematical. The residuals over the last six quarters have been relatively large, however, especially in 1983.

When the equation above is reestimated to II/1983, few differences result. The estimate is:

$$(2)\quad \dot{P}_t = \underset{(22.93)}{0.963} \sum_{j=0}^{20} w_{t-j} \dot{M}_{t-j} + \underset{(0.64)}{0.008} \dot{p}^e_{t-1} + \underset{(3.77)}{0.051} \dot{p}^e_{t-2}$$

$$- \underset{(-0.51)}{0.007} \dot{p}^e_{t-3} + \underset{(2.38)}{0.030} \dot{p}^e_{t-4} - \underset{(-2.27)}{1.47} D1 + \underset{(1.62)}{1.06} D2$$

$\bar{R}^2 = 0.68$ S.E. = 1.27 D.W. = 2.03 $\rho = 0.25$

An F statistic for the additional 18 observations is $F_{18,\ 87} = 2.08$, which indicates a significant break, however. This break suggests that other important variables have been omitted, at least as one possibility.

The most noticeable changes in the economy since 1978 have been the sharp increase and historically high level of interest rates (r), the rise in volatility of money growth (σ) since 1980, the unusually high levels of unemployment (UN) since 1980, and the rapid appreciation of the dollar (E) judged relative to the in-sample experience (I/1955-IV/1978). There are theoretical reasons why one can expect that these influences affect prices but, except for lagged influences that act as exogenous initial conditions, it is difficult to rationalize their inclusion in an equation that is purportedly a reduced form. Nonetheless, the statistical analysis of these factors was conducted in the hope that it might reveal the source of recent errors.

Tests were conducted to examine whether current and lagged values of $\Delta\sigma$, ΔUN, UN, dln r and dln E were significant in the I/1955-IV/1978 period. The variable σ is the 12-quarter standard deviation of money (M1) growth; according to the monetary uncertainty hypothesis, aggregate demand is a function of σ so that GNP growth, price increases, and real growth should be a function of changes in σ, temporarily, i.e., once-and-for-all changes. UN is the demographically adjusted excess unemployment rate, $U-U_F$. The interest rate examined is the Aaa bond yield, and the trade weighted value of the dollar is used for E. Up to seven lags of each variable were included and, with the exception of interest rates, none were significant, either contemporaneously or lagged, according to sequential and joint F-tests. The interest rate results are described later. For the most important variable, UN_t, the coefficient is -0.110 (t = -0.80).

When these tests are performed over the period ending in II/1983, the results are different only for the unemployment rate, and differ slightly for interest rates. For unemployment, the resulting estimate is:

$$(3) \quad \dot{P}_t = \underset{(19.74)}{1.046} \sum_{j=0}^{20} w_{t-j} \dot{M}_{t-j} + \underset{(0.46)}{0.006} \dot{p}^e_{t-1} + \underset{(3.73)}{0.050} \dot{p}^e_{t-2}$$

$$- \underset{(-0.38)}{0.005} \dot{p}^e_{t-3} + \underset{(2.72)}{0.034} \dot{p}^e_{t-4} - \underset{(-2.83)}{1.760} D1 + \underset{(1.54)}{0.95} D2 - \underset{(-2.28)}{0.279} UN_t$$

$\bar{R}^2 = 0.71$ S.E. = 1.25 D.W. = 2.02 $\rho = 0.20$

The level of UN_t is now significantly negative.

When this equation is simulated for the in-sample period I/1979 to II/1983, the errors are those shown in Table 2. Note that none of them are as large as twice the standard error. The improvement over the errors in Table 1 are listed in the last column. The forecasts for 1979 are worsened slightly, but in 1982 and 1983 there are substantial improvements. For the current level of unemployment (9.3 percent in September), the inflation forecast is reduced by about 1.2 percentage points below what it would be on a high-employment basis.

These results are puzzling, to say the least, and may be spurious, since the coefficient on UN_t has risen in magnitude so substantially since 1978.

Interest Rates and Inflation

Current and lagged values of changes in interest rates were examined for both periods, I/1955 to IV/1978 and I/1955 to II/1983. Interest rate effects were tested using first differences and annualized logarithmic (percentage) changes.

The optimal lag is different for the two periods. For the pre-1979 period, the optimal lag length is two lagged values; and for the longer period, it is one lagged value. The contemporaneous change in interest rates did not have a t-statistic larger than one in any of the estimations, so it was dropped. The lag tests were conducted with and without the contemporaneous unemployment measure and for both measures of the change in interest rates. The best result (lowest standard error) for the two measures of interest rates in each comparison having the same specification is unambiguously the theoretically preferred Δr specification. Ignoring slack, for the moment the I/1955-IV/1978 equation estimate is:

$$(4)\quad \dot{P}_t = \underset{(24.28)}{0.947} \sum_{i=1}^{20} w_{t-j}\dot{M}_{t-j} - \underset{(-3.30)}{1.647}\,D1 + \underset{(1.90)}{1.164}\,D2 + \underset{(1.22)}{0.018}\,\dot{p}^e_{t-1} + \underset{(2.77)}{0.044}\,\dot{p}^e_{t-2}$$

$$- \underset{(-1.26)}{0.020}\,\dot{p}^e_{t-3} + \underset{(2.50)}{0.034}\,\dot{p}^e_{t-4} + \underset{(2.80)}{0.005}\,\Delta r_{t-1} + \underset{(2.24)}{0.004}\,\Delta r_{t-2}$$

$\bar{R}^2 = 0.79$ S.E. = 1.09 D.W. = 1.95 $\hat{\rho} = 0.07$

When this equation is estimated using $\Delta \ln r_{t-j}$, the coefficients for the first and second lags are 0.024 (2.47) and 0.018 (1.79), implying a sum elasticity of prices with respect to interest rates of 0.042; the standard error of this estimate is 1.11, however, inferior to the equation above. Finally, when the contemporaneous unemployment rate is added to the equation, it is insignificant. For example, when it is added to the equation above, its coefficient is -0.011 (t = -0.09). When it is added to the $\Delta \ln r_{t-j}$ specification, its coefficient is positive, 0.12 (t = 0.79).

The out-of-sample simulation results for the equation above are reported in Table 3. There are frequent significant errors in the table. The mean error and RMSE are somewhat worse than the Table 2 equation including the unemployment rate; however, the results are not strictly comparable because Table 2 is based on estimates that include the 1979-83 experience.

When the equation above is estimated over the I/1955-II/1983 period, the optimal lag results are altered. First, however, it should be noted that the equation is stable; the F-statistic for the additional 18 observations is $F_{18, 83} = 1.69$, which is below the critical F at a 95 percent confidence error. The best result, however, includes only one lag, Δr_{t-1}.

$$(5)\quad \dot{P}_t = \underset{(26.00)}{0.936} \sum_{i=0}^{20} w_{t-i} \dot{M}_{t-i} - \underset{(-2.91)}{1.647}\, D1 + \underset{(2.37)}{1.362}\, D2 + \underset{(0.62)}{0.007}\, \dot{p}^e_{t-1} + \underset{(4.24)}{0.053}\, \dot{p}^e_{t-2}$$

$$- \underset{(-1.93)}{0.025}\, \dot{p}^e_{t-3} + \underset{(3.38)}{0.040}\, \dot{p}^e_{t-4} + \underset{(4.77)}{0.004}\, \Delta r_{t-1}$$

$\bar{R}^2 = 0.75$ S.E. = 1.16 D.W. = 1.97 $\rho = 0.20$

For this longer period, the addition of the unemployment rate results in a coefficient on contemporaneous unemployment, -0.156, which is insignificant (t = -1.36). When $\Delta \ln r_{t-1}$ is used in equation (5), instead of Δr_{t-1}, its coefficient is 0.034 (t = 4.51), but the standard error of the equation is 1.17. When the unemployment rate is included with $\Delta \ln r_{t-1}$, its coefficient is -0.140 (t = -1.22). Thus, as in the earlier period, the unemployment rate is not statistically significant when interest rate effects are controlled for.

In the second and third columns of Table 3, in-sample simulations of equation (5) and equation (6), which include the insignificant unemployment rate variable, are reported.

$$(6)\quad \dot{P}_t = \underset{(19.31)}{0.985} \sum_{i=0}^{20} w_{t-j} \dot{M}_{t-j} - \underset{(-3.16)}{1.793}\, D1 + \underset{(2.26)}{1.289}\, D2 + \underset{(0.50)}{0.006}\, \dot{p}^e_{t-1} + \underset{(4.20)}{0.052}\, \dot{p}^e_{t-2}$$

$$- \underset{(-1.74)}{0.023}\, \dot{p}^e_{t-3} + \underset{(3.49)}{0.041}\, \dot{p}^e_{t-4} + \underset{(4.32)}{0.004}\, \Delta r_{t-1} - \underset{(-1.32)}{0.156}\, UN_t$$

$\bar{R}^2 = 0.76$ S.E. = 1.15 D.W. = 1.98 $\rho = 0.19$

In the last column of the table there is only one significant error, in II/1981. The summary statistics for both simulations (equations (5) and (6)) compare well with those in Table 2. Including the insignificant unemployment term appears to add little to the forecasting performance, however.

Innovations in Other Checkable Deposits and the Inflation Equation

The nationwide introduction of NOW accounts in 1981 and subsequent development of Super-NOWs has raised questions about the reliability of the M1 measure used above. To assess this concern, the price equation was estimated using a measure of adjusted M1, specifically M1 less other checkable deposits, M*. When this is done for the period I/1955 to II/1983, the result is:

$$(7)\quad \dot{P}_t = \underset{(22.24)}{1.112} \sum_{i=0}^{20} w_{t-i}\, \dot{M}^*_{t-i} - \underset{(-3.13)}{2.179}\, D1 + \underset{(1.67)}{1.173}\, D2 - \underset{(-0.00)}{0.000}\, \dot{p}^e_{t-1} + \underset{(3.65)}{0.049}\, \dot{p}^e_{t-2}$$

$$- \underset{(-0.47)}{0.006}\, \dot{p}^e_{t-3} + \underset{(1.27)}{0.017}\, \dot{p}^e_{t-4}$$

$\bar{R}^2 = 0.63$ S.E. = 1.29 D.W. = 2.09 $\rho = 0.31$

This equation is inferior to equation (2). Nonetheless, it may provide more accurate forecasts of recent inflation since adjusted money has grown so much less than M1, especially since 1980.

An in-sample simulation of equation (7) over the period I/1979 to II/1983 was conducted and the results are given in Table 4. For purposes of comparison, the same in-sample experiment was conducted using equation (2). The summary statistics indicate that, on average, adjusted M1 overpredicts inflation while M1 underpredicts it, but by a smaller amount. Adjusted M1 has a slightly smaller RMSE for the 18 quarters. Note, however, that the superior result is quite recent, only in the six quarters of 1982-83. In the prior three years, adjusted M1 underpredicted inflation by an average of 1.09 percentage points each quarter, more than twice the underprediction (0.42 percentage points) for M1.

Moreover, while M1 overpredicts inflation in each of the last six quarters of the experiment, adjusted M1 consistently underpredicts inflation for the whole 18-quarter period (only five of the residuals are negative and they are generally small, averaging only -0.70).

Thus, the more recent successful performance of the adjusted M1 series results from the systematic tendency to underpredict inflation in a period when inflation has been low relative to its in-sample history and relative to the forecasts using M1. Finally, it should be noted that the difference between the inflation simulated with each series will grow as the lagged effects of past differences in the growth of the two money measures feeds through and the future discrepancies come into the simulation. Thus, the growing tendency for adjusted M1 to underpredict inflation should continue to worsen.

A direct test of the financial innovations hypothesis can be conducted by adding the vector of variables (Δs_t, . . . Δs_{t-n}) to the price equation (2) using M1, where s_t is the ratio of other checkable deposits to M1. The expected sign on the coefficients of these terms is negative and should essentially sum to unity if other checkable deposits are not money, at least in the sense of influencing inflation.

Theoretically, one would expect the lag length on Δs to be the same as that for M1. Noticeable shifts to other checkable deposits only began about five years ago so that the appropriate lag is difficult to test. A lag search for Δs_{t-n} for n ranging up to 20 quarters was conducted, however, for the I/1955 to II/1983 estimate. Sequential F-tests indicate that no additional lags beyond four quarters are significant at a 95 percent confidence level. For this equation, the F-statistic for the addition of the five Δs variables is $F_{t, 95} = 2.94$, which is significantly above the critical value of 2.47 at a 95 percent significance level, but not the 3.52 critical value at a 1 percent level.

The equation estimate is:

$$(8)\quad \dot{P}_t = \underset{(21.67)}{0.997} \sum_{i=0}^{20} w_{t-i} \dot{M}_{t-i} - \underset{(-2.77)}{1.713}\, D1 + \underset{(1.47)}{0.927}\, D2$$

$$+ \underset{(1.20)}{0.015}\, \dot{p}^e_{t-1} + \underset{(3.15)}{0.043}\, \dot{p}^e_{t-2} - \underset{(-0.67)}{0.009}\, \dot{p}^e_{t-3} + \underset{(3.12)}{0.041}\, \dot{p}^e_{t-4}$$

$$+ \underset{(0.84)}{0.046}\, \Delta s_t - \underset{(-2.40)}{0.134}\, \Delta s_{t-1} + \underset{(1.19)}{0.069}\, \Delta s_{t-2} + \underset{(0.70)}{0.040}\, \Delta s_{t-3}$$

$$- \underset{(-3.32)}{0.174}\, \Delta s_{t-4}$$

$\bar{R}^2 = 0.71$ S.E. = 1.21 D.W. = 2.03 $\rho = 0.23$

The sum of the Δs_{t-j} coefficients is -0.153 (t = 1.79). The principal significant Δs coefficients are indeed negative, but three of the five coefficients are not. Moreover, the sum effect is not significantly different from zero. Thus, the evidence does not support the hypothesis that M1 has been distorted by shifts to other checkable deposits.

The same experiment was conducted for money measured as M1 less other checkable deposits. There the additional variables capturing the shift to other checkable deposits is Δs^*_{t-j}, where s* is the share of other checkable deposits in the aggregate (M1 less other checkable deposits). If none of other checkable deposits are "money," then the addition of the vector of the shift variables, Δs^*_{t-j}, should add nothing to the equation. If other checkable deposits have equivalent effects on prices as the remainder of M1, the coefficients on the shift variables should be positive, have the same lag length as the monetary aggregate, and have a sum effect of about one.[1/]

Again, the optimal lag length was shorter than for "money;" it is five lags for Δs^*. The F-statistic for the addition of these six variables to equation (7) is $F_{6, 99}$ = 4.07, which is highly significant. The individual coefficients are:

$$(9)\quad \underset{(3.07)}{0.142}\ \Delta s^*_t - \underset{(-0.87)}{0.041}\ \Delta s^*_{t-1} + \underset{(2.70)}{0.136}\ \Delta s^*_{t-2} + \underset{(2.04)}{0.101}\ \Delta s^*_{t-3}$$

$$- \underset{(-1.47)}{0.072}\ \Delta s^*_{t-4} + \underset{(2.41)}{0.112}\ \Delta s^*_{t-5}$$

The sum of these coefficients is not near unity, however. Instead, it is 0.377 (t = 1.10). The hypothesis that the sum equals unity, however, cannot be rejected (t = -1.81). Unfortunately, the standard error of the sum coefficient is too large to delineate the alternatives well in this equation.

The GNP Equation

The same experiments as those above were performed for GNP. Such an examination is more critical since it is shown below that the 1979-83 GNP "forecasts" have been more substantially erroneous than those for prices. The GNP equation used here is that discussed in Tatom (1981). In the examination of the simulation experience of the past five years, however, a simpler version that is essentially an A-J equation is also examined.

The two equation estimates for the periods I/1955 to IV/1978 and III/1983 are given in Table 5. In the longer period, several changes can be noted. First, for either specification, the $\bar{R}^2$ declines, the autocorrelation coefficient and standard error rises, and the sum of the money growth coefficients declines, but not significantly so.

The difficulties with the GNP equation can be observed from the out-of-sample simulation of the equations estimated to IV/1978; these simulations are reported in Table 6. The simulated values "without shocks" are based on the GNP growth equation estimate that excludes strikes and energy price changes. Starred entries are errors that exceed twice the in-sample standard error of the respective equation. Ironically, these errors are more common with the more inclusive equation, largely because it fits better. For both simulations, the RMSE is at least 50 percent larger than the in-sample standard error. The mean error in both cases is fairly large, with GNP growth overpredicted in both cases by almost 2.8 percent. Note that the mean errors in Table 6 are over five times as large as that for prices in Table 1.

As with prices in Table 1, the lion's share of the problematical forecast error arises after 1980, especially in 1982-83. In 1982-83, the broader equation has a mean overprediction of GNP growth of 7.38 percent and an RMSE of 8.42 percent. Over the same six quarters, the average overprediction of inflation in Table 1 is 2.42 and the RMSE is 2.48. In both cases, the RMSE is significantly larger than twice the in-sample standard error, but in the case of prices this is only marginally the case.

Finally, note that the GNP overprediction during this period dominates, resulting in a relatively large overprediction of real GNP over the same six quarters. Table 7 repeats the error for GNP growth, inflation, and their difference, and real GNP growth ($\dot{x}$) errors from I/1979 to II/1983. The large one-sided errors (overpredictions) of GNP and real growth appear to begin in II/1981 and run at least through 1982. The overpredictions of inflation appear to start somewhat later, I/1982, and continue to the present (II/1983).

An Important Perspective on the Recent GNP Simulation Errors

The magnitude and one-sided nature of the prediction errors in 1982-83, shown in Table 6, may not represent a fundamental breakdown in the money-GNP link that is the basis of the Table 5 equations. Such error patterns are not new. The errors from the Andersen-Jordan equation have always been cyclical; when one considers the magnitude of the recent recession, the recent error pattern is not surprising.

To illustrate this point, the simple A-J equation reported in the first and third columns of Table 5 was estimated for the period I/1955 to III/1973 and then simulated to II/1983. The equation is essentially the same as in the first column of Table 5. In particular, the sum of the money coefficients is 1.073 (t = 5.96) and the sum of the expenditures coefficient is 0.0005 (t = 0.00). The adjusted R-squared is the same, 0.42, and the standard error is 3.157. As in Table 5, the third and fourth lagged values of money growth appear insignificant, t = 1.39 and -0.24, respectively. In the out-of-sample simulation, the mean error is -0.50 percent, and the RMSE is 4.727, about 50 percent larger than in the in-sample standard error.

For the period of the out-of-sample simulation ending in IV/1981 (that is, prior to the relatively large overpredictions of GNP growth), the mean error is 0.52 percent and the RMSE is 4.13, still somewhat above the in-sample standard error. For the last six quarters, the mean error is -6.16 percent and the RMSE is 7.166, more than twice the 1955-73 in-sample standard error. There is a cyclical pattern in the earlier errors, however. From I/1978 to II/1979, the equation underestimated GNP growth by an average 2.03 percent and the RMSE was 4.655 percent. Indeed, the equation generally underestimated GNP growth during the expansions from I/1975 to IV/1978 (in all but three of the 15 quarters) and in each quarter of the II/1980-I/1981 expansion. During the recessions, the equation systematically overestimated GNP growth—from IV/1973-I/1975 (mean error = -3.04 percent, RMSE = 3.824 percent), and from I/1980-III/1980 (mean error = 2.17

percent). The cyclical behavior of the errors is also evidence in the in-sample errors, but these are not reported since evidence of cyclical velocity is given below.

Recent Economic Developments and GNP Growth Errors

Tests were conducted to examine whether current and lagged values of α, ΔUN, UN, Δln r, and Δln EX were significant in the I/1955-IV/1978 and I/1955-II/1983 periods for both GNP equations in Table 5. Both 4-6 month commercial paper rates and Aaa bond yields were used for interest rates. Only the addition of current and lagged ΔUN and five lags of the Aaa bond yield proved significant, jointly and separately and in both periods. A test of a permanent effect of unemployment on the growth rate of GNP rejected such an effect (i.e., the addition of UN_{t-2} was insignificant). The variable selection conclusions were identical for the longer period.

One of the more obvious (from table 5) problems, and one pointed out by Batten and Thornton (Review, April 1983), is that the lags on money and high-employment expenditure growth appear to be misspecified. In my velocity paper (Review, August/September 1983) the optimal money lag was five quarters (for expenditures, it was three quarters) but that is at odds with the results here. A test of the GNP equations in Table 5 for both periods using sequential F-tests for lags up to nine quarters that the optimum lag for both variables is two quarters. The tests reported above were repeated for these specifications. Again, current and lagged changes in excess unemployment were significant.

The basic equation estimates for both periods are given in Table 8. The sum of the money growth coefficients is 0.872 (SE = .104) and 0.751 (SE = .098), close, but not equal to unity. The sum of the expenditures coefficients is 0.071 (t = 1.37) and 0.123 (t = 2.24), respectively. The longer period results are at odds with conventional wisdom and warrant additional information.

When the cyclical variables (ΔUN_t, ΔUN_{t-1}) are added, energy price changes are not significant; adding the current and six lagged values of ($\dot{p}^e$) to the equations in Table 8 yields F-statistics of $F_{4, 81} = 2.21$ for the earlier period and $F_{4, 99} = 0.99$ for the longer period. The same result holds when the cyclical variables are introduced into the Table 5 equations that use longer lags on $\dot{M}$ and $\dot{E}$ ($F_{4, 81} = 1.75$ and $F_{4, 99} = 0.79$, respectively). Without the cyclical variables, the current and energy prices are significant. In the Table 8 equations without cyclical variables, the addition of the energy price changes yields $F_{4, 83} = 0.58$ and $F_{4, 101} = 2.97$, respectively, both are significant at a 95 percent level. For the Table 5 equations (standard lags on $\dot{M}$ and $\dot{E}$), the F statistics are $F_{4, 83} = 4.23$ and $F_{4, 101} = 2.56$, respectively; again both are significant, although some deterioration is indicated over the longer period.

In the equations in Table 8, it remains the case that there is some deterioration in the summary statistics when the post-1978 data is included. The $\bar{R}$-squared drops from 0.73 to 0.68 and the standard error of the equation rises from 2.257 to 2.561, a 13 percent increase. The summary statistics in Table 5 worsen considerably more, however. The $\bar{R}$-squared drops about 30 percent in both specifications in Table 5. More important, over the recent period, both GNP equations in Table 5 require autocorrelation corrections, while that in Table 8 does not.

Adding other variables to the GNP equations in Table 8, including interest rates, exchange rates, money growth variability and financial innovations, yields results that are little different than for the Table 5 GNP equations. In the period ending in IV/1978, none of the additional variables proved significant for up to seven lags. For the longer period, including 1979 through mid-1973, the lagged change in interest rates and the second lag on the exchange rate were significant. These results are detailed below along with the financial innovation results.

The magnitude of the errors in forecasts using the I/1955-IV/1978 equation for the subsequent 18-quarter period is indicated in Table 9. Errors that exceed twice the in-sample standard error occur in I/1981 when GNP growth was unusually strong, and in I/1982 and III/82-I/83 when it was unusually weak. In the last six quarters shown, GNP growth was weaker than predicted by an average 4.82 percent rate, as the RMSE for the whole period was quite large, 4.24 percent, almost twice as large as the in-sample standard error. The in-sample simulation of the I/1955-II/1983 estimate in Table 8 shows a mean error of -0.60 percent over the same period and RMSE of 3.38 percent, however. The mean error over the final six quarters is 3.30 percent.

The recent errors are significantly related to interest rate movements, as noted above. Table 10 presents GNP equations for both periods that add the lagged value of the change in the logarithm of the Aaa bond yield lagged one period. Longer lags and contemporaneous effects are not significant in either period. In the earlier period shown in Table 10, interest rates are not significant either. Thus, the appearance of the significant lag over the longer period is likely a spurious result.

The recent errors are also significantly related to exchange rate movements. Again, in the earlier period, exchange rate movements were insignificant; over the longer period, the exchange rate movement two quarters earlier is significant while contemporaneous and the first lag, as well as longer lag terms, are not. The coefficient on $\Delta \ln EX_{t-2}$ in the longer period is -0.070 (t = -2.77). A joint test of the addition of $\Delta \ln Ex_{t-2}$ and $\Delta \ln r_{t-1}$ reveals that only the lagged exchange rate is significant over the longer period, however, and neither is significant for the period ending in IV/1978; over the IV/1978 period, the coefficient on $\Delta \ln r_{t-1}$ is 0.021 (t = 1.06) and on $\Delta \ln EX_{t-2}$, it is -0.007 (t = -0.21). This equation was also estimated to III/1981. Neither variable is significant at conventional levels up until then. While both variables enter significantly and with the expected sign, when 1982 is included in the sample period, it appears that the result is spurious. Neither variable, alone or together, is significant prior to IV/1981.

Financial Innovations

Not surprisingly, movements in the share of other checkable deposits do not add significantly to the GNP equation up to the end of 1978. The lag search for the period ending in II/1983, also not surprisingly, indicated that movements in this share were significant. The optimum lag appears to be at t-6; it should be noted, however, that the sum effect is positive until t-6 and that sequential tests of additional lags beyond are not significant until t-6; that is, adding any additional lags up to five are insignificant. Moreover, this result appears to be sample specific since lag searches for earlier periods indicate only one lagged value is sometimes significant. Of course, to be consistent with the lag specification of money growth, only two lags would be included.

In my velocity paper for the San Francisco Fed Conference, I noted that the positive effect of shifts to other checkable deposits (OCD) arose from the unusual strength of GNP in I/1981, the quarter of the largest shift to OCD. When that unusual strength is controlled for, the results of the tests are altered somewhat as the sum effect appears more negative. Again, however, only the first lag appears significant in the sample period ending in II/1983 until the t-6 lag is added; that is, when the large swing in I/1981 is allowed to account for the II/1983 residual.

When the end of the sample period was varied from the end of 1980 to the present, the t-6 coefficient was not significant until the second quarter of 1982 and subsequently. Thus, this long a lag is not a robust result. For the period ending in the first quarter of 1982, four lags appear optimal, for the four periods ending I/1981 to IV/1981, one lag appears optimal and for periods ending prior to I/1981, no Δs terms are significant.

When the lag on Δs_t is set to be the same as on M (two quarters), the results are still mixed. For periods ending from I/1981 to IV/1981, the additional variables are significant as a group but seem positive and insignificant. For periods ending from I/1982 to II/1983, the additional three variables and their sums are insignificant but continue to sum positive. When the I/1981 GNP growth is dummied out, the in the standard Andersen-Jordan equation and this does not appear to be a recent development. Third, when cyclical movements are accounted for, lagged energy price effects tend to disappear; indeed, such effects are insignificant.

The resulting GNP equation, shown in Table 8, improves upon the variants of the Andersen-Jordan estimates substantially. Nonetheless, the summary statistics of the equation deteriorate somewhat in 1982-83 and the mean error is relatively large for such a period. The size of the errors from this equation in 1982-83 are sufficiently large that, combined with relatively large movements in other economic variables, the appearance of significant omitted variables arises. In particular, for GNP equation estimates after 1981, past movements in interest rates and exchange rates sometimes appear significant. Also, after 1981, financial innovations appear to affect the pattern of GNP growth but not in any stable fashion, and not in the manner expected by proponents of the financial innovations hypothesis. In particular, the sum effect of a shift to other checkable deposits should be negative if some part of OCD are not "money" to the extent of the remainder of M. In no test is this sum different from zero. The optimal lag on shifts to other checkable deposits is also unstable, indicating that, depending on the period chosen, the regression tries to fit the large shift to OCD in I/1981 to subsequent residuals that occur in the absence of this factor.

Perhaps, most important, the results through 1981, when such shifts were largest and should have had their largest impact, do not provide even casual evidence supportive of the financial innovations argument.

Many issues have been raised in this review. For the near term, an assessment of interest rate movements and slack will likely remain important for short-term inflation forecasting, despite the lack of significance of the latter before 1981. Inclusion of cyclical influences on spending appears to be critical for short-term spending and real output forecasts. Other unusual developments of the past four years do not appear to bear any systematic influences to spending. Even with cyclical adjustments, the recent GNP (and implicity real GNP) forecasting experience appears fairly poor.

Many analysts will no doubt disagree with conclusions reached here. Certainly more work on unusual factors, especially joint hypotheses tests, or work on lags could offer some important refinements to these conclusions or perhaps reverse some of them. At least, this paper provides a basis for discussions of the recent forecasting performance of small models, the relative magnitudes, and sources of the errors.

FOOTNOTE

[1] The sum effect should be that for the monetary aggregate times $(1+s^*)^{-1}$, where s* is the mean value of s* in the sample period.

Table 1
Simulation Performance
I/1979-II/1983

	Actual $\dot{P}$	Simulated $\dot{P}$	Error
I/1979	8.20	6.38	1.82
II	8.11	6.73	1.38
III	8.00	7.81	0.19
IV	7.04	8.79	-1.76
I/1980	9.15	9.35	-0.20
II	10.38	8.50	1.88
III	8.48	9.71	-1.23
IV	10.71	8.60	2.10
I/1981	10.03	8.04	1.99
II	5.71	8.18	-2.46*
III	9.00	8.71	0.29
IV	8.60	6.88	1.72
I/1982	4.23	6.90	-2.67*
II	5.45	6.89	-1.44
III	3.63	5.86	-2.22
IV	3.77	6.00	-2.23
I/1983	5.35	8.25	-2.90*
II	3.22	6.29	-3.07*
Mean	7.17	7.66	-0.49
			RMSE = 1.94

Table 2
Residuals From Inflation Simulation
Including Unemployment Effect

	Residual	Improvement*
I/1979	1.83	-0.01
II	1.47	-0.09
III	0.54	-0.35
IV	-1.66	0.10
I/1980	-0.55	-0.35
II	1.18	0.70
III	-1.41	-0.18
IV	1.94	0.16
I/1981	1.92	0.07
II	-1.95	0.51
III	0.48	-0.19
IV	1.50	0.22
I/1982	-2.30	0.37
II	-0.60	0.84
III	-1.33	0.89
IV	-0.45	1.78
I/1983	-1.17	1.73
II	-1.77	1.30
Mean	-0.13	
RMSE	1.45	

*Equals residual in the first column minus the residual in Table 1.

Table 4
Inflation Simulation Errors With and Without
Adjusting the Money Stock for Other Checkable Deposits

	M1	Adjusted M1
I/1979	1.75	2.16
II	1.46	1.93
III	0.51	1.16
IV	-1.76	-1.01
Annual Average	0.49	1.06
I/1980	-0.59	0.10
II	0.94	1.69
III	-1.41	-0.64
IV	2.08	2.54
Annual Average	0.26	0.92
I/1981	2.08	2.66*
II	-1.86	-1.01
III	0.46	1.33
IV	1.35	2.14
Annual Average	0.51	1.28
I/1982	-2.41	-0.80
II	-1.06	0.97
III	-2.00	-0.03
IV	-1.32	1.52
Annual Average	-1.70	0.42
I/1983	-1.95	1.67
II	-2.51	1.47
Average	-2.23	1.57
Mean Error	-0.34	0.99
RMSE	1.65	1.56

Table 5
Alternative Estimates of GNP Growth

Variable	I/1955 - IV/1978		I/1955 - II/1983	
Constant	2.515 (2.89)	2.570 (3.37)	2.921 (3.02)	2.909 (2.91)
$\dot{M}_t$	0.361 (2.85)	0.337 (2.95)	0.263 (2.32)	0.284 (2.63)
$\dot{M}_{t-1}$	0.444 (6.05)	0.451 (6.86)	0.384 (5.66)	0.384 (5.57)
$\dot{M}_{t-2}$	0.317 (2.87)	0.342 (3.47)	0.307 (3.15)	0.292 (3.15)
$\dot{M}_{t-3}$	0.091 (1.22)	0.098 (1.47)	0.088 (1.19)	0.080 (1.07)
$\dot{M}_{t-4}$	-0.080(-0.64)	-0.104(-0.92)	-0.107(-0.98)	-0.096(-0.90)
$\Sigma\dot{M}$	1.134 (6.75)	1.123 (7.64)	0.935 (5.47)	0.943 (5.30)
$\dot{E}_t$	0.061 (1.50)	0.083 (2.24)	0.060 (1.50)	0.062 (1.62)
$\dot{E}_{t-1}$	0.059 (1.87)	0.044 (1.56)	0.051 (1.51)	0.037 (1.09)
$\dot{E}_{t-2}$	0.013 (0.37)	-0.020(-0.65)	0.007 (0.19)	-0.010(-0.28)
$\dot{E}_{t-3}$	-0.047(-1.78)	-0.054(-2.21)	-0.039(-1.38)	-0.037(-1.25)
$\dot{E}_{t-4}$	-0.072(-2.02)	-0.039(-1.19)	-0.053(-1.43)	-0.031(-0.84)
$\Sigma\dot{E}$	0.014 (0.17)	0.013 (0.18)	0.026 (0.30)	0.021 (0.23)
ΔS_t		-0.487(-3.79)		-0.539(-4.06)
$\dot{P}^e_t$		-0.039(-1.28)		-0.036(-1.29)
$\dot{P}^e_{t-1}$		0.013 (0.60)		0.019 (0.94)
$\dot{P}^e_{t-2}$		-0.002(-0.12)		0.002 (0.10)
$\dot{P}^e_{t-3}$		-0.037(-2.15)		-0.036(-2.07)
$\dot{P}^e_{t-4}$		-0.047(-2.32)		-0.042(-2.13)
$\dot{P}^e_{t-5}$		0.016 (0.41)		0.034 (1.01)
$\dot{P}^e_{t-6}$		0.097 (2.85)		0.060 (1.88)
D3			-3.634(-1.33)	-3.357(-1.45)
$\bar{R}^2$	0.41	0.55	0.29	0.38
S.E.	3.38	2.95	3.69	3.36
D.W.	2.02	1.97	1.98	2.01
p	--	--	0.08	0.22
			$F_{17,89}=2.20$	$F_{17,84}=2.75$

Table 6
Out-of-Sample Simulation Errors for GNP Equations

	Actual	Simulated	Error	Simulated Without Shocks	Error
I/1979	9.34	10.60	-1.26	10.80	-1.46
II	7.20	8.02	-0.82	10.22	-3.02
III	12.73	11.30	1.43	12.03	0.70
IV	7.76	11.16	-3.39	12.20	-4.44
I/1980	11.03	8.81	2.22	11.88	-0.84
II	0.91	2.85	-1.93	6.22	-5.30
III	9.25	4.99	4.26	8.06	1.18
IV	14.42	13.36	1.06	12.09	2.33
I/1981	18.65	14.31	4.34	12.40	6.25
II	6.35	12.82	-6.47*	11.87	-5.51
III	12.49	13.73	-1.24	8.32	4.17
IV	3.62	9.51	-5.89	7.89	-4.27
I/1982	-1.43	6.77	-8.19*	9.04	-10.47*
II	6.44	7.97	-1.54	7.92	-1.48
III	2.64	12.67	-10.04*	8.67	-6.03
IV	2.44	16.33	-13.89*	13.11	-10.67*
I/1983	7.88	14.93	-7.05*	15.75	-7.87*
II	12.23	15.77	-3.54	16.62	-4.39
Mean	8.00	10.89	-2.89	10.84	-2.84
			RMSE = 4.81		RMSE = 5.35

Table 7
Reduced-Form Model Out-of-Sample Errors

	$\dot{GNP}$ Error (Table 6)	$\dot{P}$ Error (Table 1)	$\dot{X}$ Error (Difference)
I/1979	-1.26	1.82	-3.08
II	-0.82	1.38	-2.20
III	1.43	0.19	1.24
IV	-3.39	-1.76	-1.63
I/1980	2.22	-0.20	2.42
II	-1.93	1.88	-3.81
III	4.26	-1.23	5.49
IV	1.06	2.10	-1.04
I/1981	4.34	1.99	2.35
II	-6.47	-2.46	-4.01
III	-1.24	0.29	-1.53
IV	-5.89	1.72	-7.61
I/1982	-8.19	-2.67	-5.52
II	-1.54	-1.44	-0.10
III	-10.04	-2.22	-7.82
IV	-13.89	-2.23	-11.66
I/1983	-7.05	-2.90	-4.15
II	-3.54	-3.07	-0.47

Table 8
Alternative Estimates of GNP Growth

Variable	I/1955 - IV/1978		I/1955 - II/1983	
Constant	3.264	(5.73)	3.245	(5.41)
$\dot{M}_t$	0.301	(2.50)	0.047	(0.45)
$\dot{M}_{t-1}$	0.333	(2.28)	0.389	(3.69)
$\dot{M}_{t-2}$	0.242	(2.04)	0.303	(3.40)
$\dot{E}_t$	0.085	(2.66)	0.125	(3.88)
$\dot{E}_{t-1}$	0.053	(1.70)	0.054	(1.70)
$\dot{E}_{t-2}$	-0.074	(-2.43)	-0.055	(-1.72)
S_t	-0.438	(-4.51)	-0.482	(-4.53)
ΔUN_t	-7.233	(-9.35)	-7.017	(-8.84)
ΔUN_{t-1}	3.250	(4.12)	2.089	(2.55)
D3	----		-2.705	(-1.17)
$\bar{R}^2$	0.74		0.68	
S.E.	2.257		2.561	
D.W.	2.03		2.00	
ρ	----		----	

Table 9
GNP Residuals for 1979-83
Using Shorter Lags and for Money and Expenditures
and Cyclical Adjustments for Spending

	GNP Errors (actual-predicted)
I/1979	0.43
II	-2.50
III	1.56
IV	-3.81
I/1980	3.44
II	0.68
III	-0.14
IV	-0.73
I/1981	7.14
II	-2.16
III	2.79
IV	0.14
I/1982	-7.67
II	1.65
III	-5.52
IV	-6.74
I/1983	-9.18
II	-1.47
Mean Error	-1.227
RMSE	4.238

Table 10
GNP Equations Containing Lagged Interest Rate Change

Variable	I/1955 - IV/1978		I/1955 - II/1983	
Constant	3.203	(5.57)	3.159	(5.46)
$\dot{M}_t$	0.350	(2.72)	0.172	(1.56)
$\dot{M}_{t-1}$	0.334	(2.28)	0.387	(3.81)
$\dot{M}_{t-2}$	0.208	(1.69)	0.231	(2.59)
$\dot{E}_t$	0.081	(2.53)	0.108	(3.41)
$\dot{E}_{t-1}$	0.047	(1.49)	0.040	(1.28)
$\dot{E}_{t-2}$	-0.079	(-2.55)	-0.076	(-2.40)
S_t	-0.441	(-4.51)	-0.479	(-4.67)
ΔUN_t	-7.270	(-9.34)	-7.308	(-9.48)
ΔUN_{t-1}	3.455	(4.24)	2.824	(3.41)
$\Delta \ln r_{t-1}$	0.023	(1.10)	0.056	(2.97)
D3	---		-3.729	(-1.65)
$\bar{R}^2$	0.73		0.70	
S.E.	2.267		2.468	
D.W.	2.04		2.02	

APPENDIX
The Recent Performance of the St. Louis Model

As a standard of comparison for the simulations of the reduced-form model, the St. Louis model was estimated from I/1955 to IV/1978 and then simulated to II/1983. The errors in the forecasts of the GNP equation have been discussed in the text for a $\Delta \ln$ specification. The results for GNP, prices and real GNP are given in table 1.

The GNP results are about the same as in table 6, so they are not discussed here. The price results are quite striking. The price forecasts initially underestimate inflation quite substantially, then overestimate inflation. The mean error for the period is 1.84 indicating that for the period as a whole, inflation outstripped the forecasts. In the first 12 quarters, inflation is underestimated by an average of 3.41 percentage points (RMSE = 3.80%).

For the full sample period, the model price equation performs worse than the reduced form model as judged by the mean error or RMSE. It has, however, outperformed the reduced-form equation in the six quarters I/1982-II/1983. Comparable error statistics from table 1 in the text are a mean error for the last six quarters of 2.42 percent (RMSE = 2.48), about 1.1 percent higher than the model forecast. (The comparison for 1979-81 favors the reduced form price equation by a wider margin: the mean error in table 1 for this period is 0.47 percent (RMSE = 1.60).

These results are somewhat surprising. While the overall performance of the St. Louis model has been worse, it has had superior price performance over the most recent six quarters. (Note the mean nominal GNP errors and real GNP errors for the six latest quarters are little different from those shown for the reduced form model in table 7: -7.19 percent for the St. Louis model compared with -7.38 percent in the reduced form model for GNP and -5.57 percent for the St. Louis model compared with -4.97 percent for real GNP in the reduced form model.) Moreover, the St. Louis results show an overprediction of recent inflation which is contrary to some prior expectations. The reason for this difference is that recent St. Louis model estimates include exports on the right-hand-side. This improves the GNP forecasts and worsens the inflation forecasts. We turn next to the performance of this model.

The St. Louis Model with Exports in the GNP Equation

In order to capture some of the recent decline in the growth rate of spending, the growth of nominal exports is sometimes added to the spending equation. For this appendix, the current and two lagged values of the annualized percentage change in the log of exports were added to the GNP equation above. The coefficients are 0.017 ($t = 1.61$), 0.003 (0.11), and -0.024 (-1.09), for the current, first and second lagged values, suggesting that these variables are insignificant. The simulation of this model to II/1983 for GNP, price and real GNP is reported in table 2.

The GNP errors improve only slightly due to the inclusion of exports. For example, over the last six quarters, the mean error declines from -7.2 percent to 6.8 percent. The price forecasts change substantially, however, and are more similar to those of the reduced form equation in table 2 in the text. For example, the mean error over the 1979-81 period is only 0.42 percent (RMSE = 1.60), about the same as for the reduced form model, but over the latest six quarters the mean error is -2.88 percent (RMSE = 2.90), somewhat worse than for the reduced form. Overall, the assessment of the addition of exports to the model is that GNP forecasts are improved slightly and price forecasts are improved substantially. Over the latest six quarters, however, the price forecasts are inferior to those of the reduced-form model. One might infer that the A-J equation with exports and the reduced form price equation provide the best simulation results, but that conjecture is not examined here.

Appendix Table 1
Out-of-Sample Simulation Errors for the St. Louis Model

	$\dot{GNP}$	$\dot{P}$	$\dot{X}$
I/1979	-1.44	5.22	-6.50
II	-2.87	4.93	-7.50
III	1.08	3.93	-2.94
IV	-5.30	1.60	-6.54
I/1980	-0.85	3.30	-3.94
II	-5.72	4.77	-9.48
III	2.16	1.88	0.24
IV	2.80	5.33	-2.58
I/1981	6.35	4.77	1.08
II	-7.10	-0.23	-6.49
III	5.12	2.19	2.66
IV	-4.66	3.26	-7.35
I/1982	-10.41	-1.25	-8.73
II	-1.65	-0.55	-1.04
III	-7.38	-1.67	-5.44
IV	-10.99	-1.17	-9.38
I/1983	-7.45	-1.50	-5.52
II	-5.24	-1.57	-3.32
Mean	-2.97 (RMSE=5.74)	1.84 (RMSE=3.20)	

Appendix Table 2
Out-of-Sample Simulation Errors of the
St. Louis Model with Exports

	$\dot{GNP}$	$\dot{P}$	$\dot{X}$
I/1979	-1.54	1.13	-2.49
II	-2.59	1.24	-3.57
III	0.98	0.47	0.42
IV	-5.37	-1.62	-3.43
I/1980	-0.93	0.27	-1.08
II	-5.09	1.93	-6.28
III	3.12	-0.80	3.58
IV	2.65	2.66	-0.10
I/1981	5.53	2.13	2.96
II	-6.97	-2.86	-3.76
III	6.42	-0.33	6.17
IV	-4.34	0.90	-4.81
I/1982	-9.87	-3.36	-6.20
II	-1.74	-2.48	0.68
III	-6.52	-3.44	-2.90
IV	-8.96	-2.65	-5.98
I/1983	-7.88	-2.69	-4.73
II	-5.86	-2.63	-2.78
Mean	-2.72 (RMSE = 5.48)	-0.67 (RMSE = 2.12)	-1.91 (RMSE = 3.96)