THE FORECAST PERFORMANCE OF ALTERNATIVE MODELS OF INFLATION

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I
INTRODUCTION

What determines inflation? Several theoretical models of the inflation process have been advanced in the literature, and these models typically yield different predictions about the role of certain variables in determining prices. To illustrate, consider, for example, the expectations-augmented Phillips curve model. This model generally assumes prices are set as a markup over labor costs, the latter being determined by expected inflation and the degree of demand pressure. It is assumed further that expected inflation is a function of past price history, and demand pressure can be measured by the excess of real growth over potential (termed the output gap). Thus, in the reduced-form price equation associated with the Phillips curve model, past prices and the output gap (or another demand pressure variable) play a key role in determining the price level. This model thus implies that by monitoring the behavior of these two variables one could assess the outlook for inflation. Another example is provided by the price equation associated with the traditional monetarist model. In this equation, lagged money growth is the predominant force in price determination. Thus, depending upon the nature of the price structure chosen different determinants of inflation have been suggested in the literature.

The most controversial question raised by these competing inflation models is, however, the following: which one of the theoretical models (equivalently, the key variables implied by the associated reduced form price equations) can most accurately describe the actual behavior of prices in recent years? Interest in this question has revived as a result of some recent evidence that the relationship that had existed in the past between money and prices has been severed in recent years. For example, in an important contribution, Stockton and Glassman (1987) select four inflation models (three structural and one nonstructural), estimate the associated reduced form price equations, and evaluate their comparative forecast performance over a common period 1977-84. In two of the structural models (termed by them as the traditional monetarist model and the rational expectations model with instantaneous market clearing), actual or expected money (M1) plays a key role in determining the price level. The third structural model examined is the expectations-augmented Phillips curve, in which past prices and the output gap are the prominent variables. They report that over the period 1977-84 the Phillips curve model rarely performs worse and in the period 1981-84 performs substantially better than the other two structural models. They also show that in many cases a simple nonstructural time series model of inflation provides quite respectable forecasts relative to the theoretically based price equations. They conclude that, at least in the 1980s, there is no support for the monetarist view of the inflation process.

The main objective of this article is to present additional evidence on the forecast performance of alternative inflation models. It is now widely known that the recent financial deregulation and disinflation have altered the character of M1 demand. However, such developments have not affected as much the character of M2 demand.[1] Hence, the relative poor forecast performance of the inflation models in which money growth as gauged by the behavior of M1 plays a key role might be due to shifts in M1 demand. This paper, therefore, reexamines the evidence using the broader monetary aggregate M2. This article also considers Fama's (1982, 1983) alternative structural model of the inflation process, in which inflation is explained by money growth in excess of growth in real money demand. The Fama model implies that in assessing implications of higher money growth for future inflation it is necessary to control for changes in the demand for money.[2]

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[1] Simpson and Porter (1984), Mehra (1986), Judd and Trehan (1987), Rasche (1987), Hetzel and Mehra (1988), and Moore, Porter and Small (1988).

[2] Hetzel (1984) implements this approach in the context of the M1 demand function. Fama's model is monetarist in the sense that excessive monetary growth leads to higher prices in the long run.

This article compares over the period 1977 to 1987 the relative forecast performance of the four inflation models including the one due to Fama. The evidence reported here is very favorable to Fama's model. Consistent with Stockton and Glassman's results, the Phillips curve model outperforms the monetary models in predicting the rate of inflation when money is defined as M1, but that is not always the case when money is defined as M2. The evidence shows that over the period 1977 to 1987 the Fama model based on M2 demand outperforms the Phillips curve model in predicting the rate of inflation. In the subperiod 1981 to 1987, however, its performance is second to that of the Phillips curve model. Both the Fama money demand and the Phillips curve models outperform the simple time series model. This evidence thus implies that it is inappropriate to ignore the role of money in explaining the generation and perpetuation of inflation.[3] In particular, the results imply that a sustained increase in M2 growth in excess of growth in real money demand will be associated with a higher inflation rate.

Section II describes briefly the specification and estimation of the inflation models used. Section III reports the empirical results. Concluding remarks are in the final section.

II
SPECIFICATION AND ESTIMATION ISSUES

2.1 Specification of Inflation Models

This section describes briefly the price equations that underlie this study. I have chosen three structural models of the inflation process: the traditional monetarist model, the expectations-augmented Phillips curve, and the Fama money demand model.[4] The specification of price equations used for the first two inflation models is similar to those described in Glassman and Stockton (1983) and Stockton and Glassman (1987). The price equation that underlies the money demand model is similar to those given in Fama (1982) and Hetzel and Mehra (1988).

The Traditional Monetarist Model The traditional monetarist price equation considered here expresses inflation as a function of current and past values of the monetary variable (measured commonly by M1) and the fiscal policy variable (measured commonly by high employment government expenditures). As pointed out in Glassman and Stockton (1983), this equation can be shown to be the reduced form equation associated with a structural model that is similar in spirit to the St. Louis structural model discussed in Andersen and Carlson (1970).

To illustrate this, consider the following aggregate supply, aggregate demand, and expected inflation equations.

$$\dot{P}_t = \dot{P}^e_t + d_1 (\dot{y}_t - \dot{y}_{pt}) + d_2 SH_t \tag{1.1}$$

$$\dot{P}_t + \dot{y}_t = f_0 + \sum_{s=0}^{n1} f_{1s} \dot{M}_{t-s} + \sum_{s=0}^{n2} f_{2s} \dot{G}_{t-s} \tag{1.2}$$

$$\dot{P}^e_t = g_0 + \sum_{s=0}^{n1} g_{1s} \dot{M}_{t-s} \tag{1.3}$$

Equation (1.1) shows the aggregate supply curve which includes expected inflation ($\dot{P}^e$), excess demand as measured by the rate of change of real output ($\dot{y}$) over potential output ($\dot{y}_p$), and the supply shocks (SH). Equation (1.2) shows the aggregate demand curve which includes current and past values of money growth ($\dot{M}$) and government expenditures ($\dot{G}$). Equation (1.3) describes the formation of ex pected inflation, which is modeled as a function of current and past values of money growth. Solving equation (1.2) for the growth of real output and then substituting it and equation (1.3) into equation (1.1) enables one to express inflation in general form as

$$\dot{P}_t = a + \sum_{s=0}^{n1} b_s \dot{M}_{t-s} + \sum_{s=0}^{n2} c_s \dot{G}_{t-s} + d\, SH_t. \tag{1.4}$$

Thus, in equation (1.4) inflation is determined by current and past values of the growth rates in money and government expenditure variables. In the empirical work reported below, supply shocks (SH_t) are captured by relative food and energy prices, and the government expenditure variable by high employ-

[3] In Stockton and Glassman (1987) the forecast performance of alternative models is evaluated conditional on actual as well as projected values of the right-hand side exogenous variables in the price equations. In this paper the forecast performance is conditional only on actual values of the right-hand side exogenous variables. This means that the evidence reported in this paper does not necessarily imply that the inflation model based on M2 demand can be used as a forecasting tool.

[4] I have not considered the rational expectations model in this paper. It is quite difficult in practice to measure rational expectations accurately and thus test this model. See Stockton and Glassman (1987) and Stockton and Struckmeyer (1988) for an attempt in this direction.

ment government expenditures.[5] Hence, the inflation equation (hereafter called Monetarist) estimated here is of the following form

$$\dot{P}_t = a + \sum_{s=0}^{n1} b_s \dot{M}_{t-s} + \sum_{s=0}^{n2} c_s \dot{E}_{t-s} + \sum_{s=0}^{n3} d_s \dot{REP}_{t-s} + \sum_{s=0}^{n4} e_s \dot{RFP}_{t-s} \quad (1.5)$$

where $\dot{E}$ is the growth rate of high employment government expenditures; $\dot{REP}$, change in the relative price of energy; $\dot{RFP}$, change in the relative price of food; and other variables are defined as before. Each n_i is the number of lagged values of the relevant variable included in the equation.

The Phillips Curve Model The expectations-augmented Phillips curve model expresses inflation as a function of its own lagged values (capturing expectations), the output gap (a demand pressure variable), and changes in the relative prices of food and energy. As shown in Glassman and Stockton (1983), this inflation equation can be derived from separate wage and price equations. To see this, consider the following price and wage equations

$$\dot{P}_t = h_1 \, GAP_t + h_2 (\dot{W}_t - \dot{q}_n) + h_3 \, SH_{pt} \quad (2.1)$$

$$\dot{W}_t = k_0 + k_1 \, GAP_t + k_2 \dot{P}^e_t + k_3 \, SH_{wt} \quad (2.2)$$

$$\dot{P}^e_t = \sum_{j=1}^{n} \lambda_j \dot{P}_{t-j} \quad (2.3)$$

where $\dot{W}$ is wage growth; $\dot{q}_n$, trend growth rate of labor productivity; SH_{pt}, supply shocks affecting the price equation; SH_{wt}, supply shocks affecting the wage equation; GAP, the GNP gap variable defined as the difference between actual real output and potential real output; and $\dot{P}^e_t$, the expected rate of inflation. Equation (2.1) describes price markup behavior. Prices are marked up over productivity-adjusted labor costs $(\dot{W} - \dot{q}_n)$ and are influenced by cyclical demand (measured by the GAP variable) and the exogenous relative price shocks (SH_p). Wage inflation (2.2) is assumed to be a function of cyclical demand and expected price inflation $(\dot{P}^e)$, the latter modeled as a lag on past inflation as in equation (2.3).

Combining (2.1), (2.2), and (2.3) yields the Phillips curve equation (2.4) below

$$\dot{P}_t = f_0 + \sum_{s=0}^{n} f_{1s} \dot{P}_{t-s} + f_2 \, GAP_t + f_3 \, SH_{pt} + f_4 \, SH_{wt} \quad (2.4)$$

where f_i's are the parameters and where other variables are as defined before.

The empirical work below estimates an alternative version of equation (2.4). Noting that the GAP variable can be expressed as

$$GAP_t = y_t - y_{pt} = Y_t - P_t - y_{pt} \quad (2.5)$$

where Y_t is the log of nominal GNP; y_t, the log of real GNP; and y_p, the log of potential GNP. Taking first difference of (2.5) results in expressing GAP as

$$GAP_t = y_t - y_{pt} = (y_{t-1} - y_{pt-1}) + (\dot{Y}_t - \dot{y}_{pt}) - \dot{P}_t. \quad (2.6)$$

If we substitute (2.6) into (2.4), the Phillips curve inflation equation can be expressed as

$$\dot{P}_t = f_0 + \sum_{s=0}^{n} f_{1s} \dot{P}_{t-s} + f_2 (y_{t-1} - y_{pt-1}) + f_2 (\dot{Y}_t - \dot{y}_{pt}) + f_3 \, SH_{pt} + f_4 \, SH_{wt}. \quad (2.7)$$

This specification of the Phillips curve equation allows explicitly the influence of nominal aggregate demand (via the term $\dot{Y}_t - \dot{y}_{pt}$) on inflation. SH_p and SH_w terms in (2.7) are captured in the empirical work by changes in relative food and energy prices. Hence, the Phillips curve equation estimated is of the form (2.8).

$$\dot{P}_t = g_0 + g_1 (y_{t-1} - y_{pt-1}) + g_2 (\dot{Y}_t - \dot{y}_{pt}) + \sum_{s=0}^{n1} g_{3s} \dot{P}_{t-s} + \sum_{s=0}^{n2} g_{4s} \dot{REP}_{t-s} + \sum_{s=0}^{n3} g_{5s} \dot{RFP}_{t-s} \quad (2.8)$$

[5] An alternative specification used in Stockton and Glassman (1987) has inflation determined primarily by current and past values of money growth. This specification reflects the empirical assumption, consistent with the monetarist view, that fiscal policy actions have no long-run effect on nominal aggregate demand. However, I have kept the specification used here somewhat more general by letting government expenditures stay in the inflation equation. The main conclusions of this paper are unaffected if one excludes government expenditures when estimating the inflation equation.

Money Demand Model The price equation based on money demand views inflation as being caused by money growth in excess of growth in real money demand. In order to derive the inflation equation used here, consider the following relationship

$$\ln P_t = \ln M_t^s - \ln md_t \qquad (3.1)$$

where md_t is the public's demand for real money; M_t, actual level of money balances; P_t, the price level; and ln is the natural logarithm. Equation (3.1) says that the price level is determined by the actual level of money balances in excess of real money demand. It is assumed that actual level of money balances are exogenously given by the monetary authority. The price level then adjusts so as to equate the public's demand for real money balances to the nominal money balances. Thus in (3.1) an increase in nominal money stock given real money demand causes the price level to rise, and a rise in the public's real money demand given the fixed money stock causes the price level to fall.

The empirical work reported below assumes that the public's demand for real money balances depends positively on real income y (which measures the real value of transactions financed by money) and inversely on the opportunity cost variable defined as the difference between the market rate of interest (R) and the own rate on money (RM).[6] This is expressed as

$$\ln md_t = a + b \ln y_t - c\,(R-RM)_t. \qquad (3.2)$$

Substituting (3.2) into (3.1) yields (3.3)

$$\ln P_t = -a + \ln M_t - b \ln y_t + c\,(R-RM)_t. \qquad (3.3)$$

In equation (3.3) the price level depends upon levels of the actual money stock (M), real income (y), and the nominal interest rate (R – RM). An increase in real income raises the public's demand for real money balances. Given the exogenous money stock, the price level would have to fall to equate the rise in real money demand to the real money supply. Thus, an increase in real income depresses the price level. Similarly, a rise in the opportunity cost of holding money would reduce the public's demand for real money balances, and the price level would have to rise to equate the reduced demand for real money balances to the predetermined stock of money. Thus, a rise in the opportunity cost of holding money raises the price level.

Since, in the short run, there are lags in the adjustment of the price level to changes in its determinants identified in (3.3), the inflation equation consistent with this approach could be expressed as

$$\dot{P}_t = k_0 + \sum_{s=0}^{n1} k_{1s}\,\dot{M}_{t-s} - \sum_{s=0}^{n2} k_{2s}\,\dot{y}_{t-s} + \sum_{s=0}^{n3} k_{3s}\,(R-\dot{R}M)_{t-s} \qquad (3.4)$$

where k_i's are the parameters and where other variables are as defined before.

It should, however, be pointed out that the aggregate labeled M in the price equation (3.1) is presumed to possess some well-defined properties. In particular, it should fulfill two conditions as discussed in Patinkin (1961) and Fama (1983). The first is that the aggregate has a well-defined real demand. The second is that the interest rate on this aggregate is fixed at below its free-market value. If these two conditions are fulfilled, then one could view the price level as being causally determined by the supply of this monetary asset in excess of its real demand.

Fama (1982) has argued that the relevant aggregate in the U.S. inflation process is the monetary base. Before 1981 the monetary base and perhaps M1 fulfilled the above noted two conditions. That has not been the case during the period since then. As noted before, there is considerable evidence consistent with the view that the character of M1 and base demands has changed during the 1980s, and M1 since 1981 includes assets that pay explicit market interest rates. In case of M2,only one of the above conditions appears to hold. M2 demand has been relatively stable during the 1980s. But some components of M2 do pay market-determined interest rates.

Time Series Model As an alternative to the theoretically based models of the inflation process, the study included a simple autoregressive model of inflation

$$\dot{P}_t = a + \sum_{s=1}^{n} a_{1s}\,\dot{P}_{t-s}. \qquad (4)$$

If the theories are of any value they should at least outperform this simple time series model.

[6] Hetzel and Mehra (1987) and Moore, Porter and Small (1988). See Reichenstein and Elliott (1987) for a different specification of the money demand function.

2.2 Estimation, Data, and Forecast Evaluation Strategy

The inflation equations (1.5), (2.8), (3.4), and (4) were estimated using quarterly data that span the period 1959-87. The price index used as the dependent variable in these equations is the fixed-weight GNP deflator. In equation (1) the monetary variable used is either M1 or M2 and the fiscal policy variable used is high employment government expenditures. Relative food and energy prices were calculated as the prices of food and energy in the fixed-weight personal consumption expenditure deflator relative to the fixed weight consumption expenditure deflator excluding food and energy. In the Phillips curve equation (2.8) potential output was an extended Council of Economic Advisers series. Since 1984 potential output is assumed to grow at a 2.5 percent annual rate.[7] In the money demand equation (3.4) the scale variable used is real GNP and the opportunity cost variable is the 4-6 month commercial paper rate minus the own rate of return on the monetary aggregate used. Thus, in case of M2 the own rate is the weighted average of the explicit deposit rates paid on the various components of M2, with weights given by relative component shares. In case of M1, the own rate is the weighted average of the rates paid on NOW and Super NOW accounts.

The price equations associated with inflation models were estimated either by ordinary least squares (equations (2.8) and (4)) or by generalized least squares to correct for the presence of first order serial correlation (equations (1.5) and (3.4)).[8] Another issue in the estimation of these equations was the choice of lag lengths on various monetary and fiscal policy variables. Since economic theory provides no guidance on this issue, one approach commonly used has been to select either 8- or 16-quarter lags on the key variables and estimate lag shapes using polynomial lag structures. This study follows a similar procedure with two differences. The first is that the lag shape is not restricted a priori. All lags are estimated freely. The second is that F-tests were performed to choose between 8- and 16-quarter lags. This procedure indicated 8-quarter lags for most of the key variables used, except those on M2 in Fama's model and past prices in the Phillips curve model. On these two variables 16-quarter lags were used.[9]

The focus of this study is on the relative forecast performance of the above four inflation models over a relatively longer-term forecast horizon. With this goal in mind, the 8-quarter ahead inflation forecasts from these models were generated and evaluated over a ten-year period in the following manner. Each model's coefficients were estimated using quarterly data from 1963Q2 to 1976Q4. Out-of-sample dynamic forecasts conditional on actual values of the exogenous variables were constructed for the 8-quarter period from 1977Q1 to 1978Q4. These quarterly forecasts were then assembled to calculate the expected 8-quarter inflation rate

$$\hat{\Pi}_t = \prod_{s=1}^{8} (1 + \hat{P}_{t+s}) - 1$$

where $\hat{\Pi}_t$ is the 8-quarter inflation rate expected at time t and where $\hat{P}_{t+s}$'s are the model's quarterly forecasts for eight quarters. The error was calculated as the subsequent actual 8-quarter inflation rate minus the rate predicted. In order to generate another observation on the prediction error, each model's coefficients were reestimated using data from 1963Q2 to 1977Q1, and out-of-sample forecast constructed from 1977Q2 to 1979Q1. That procedure was repeated until the model was reestimated and forecasts prepared based on data ending in each quarter through 1985Q4. Thus, the last estimation period was 1963Q2 to 1985Q4, and the last out-of-sample forecast interval, 1986Q1 to 1987Q4. This procedure generated for each model 37 observations on the error in predicting the subsequent 8-quarter inflation rate spanning the period 1977-87. These forecast errors were then compared across models for their relative performance.[10]

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[7] Estimates of growth in potential output range from 2 to 3 percent. I have used the midpoint of this suggested range in this paper.

[8] It should, however, be pointed out that some of the right-hand side explanatory variables included in these price equations could be correlated with the error term and hence not strictly exogenous in a statistical sense. Therefore, estimation by ordinary (or generalized) least squares could have produced biased coefficient estimates. In order to examine the effect of this potential bias, the price equations were reestimated using only lagged values of the key right-hand side explanatory variables and the forecasting exercise was repeated. This had no effect on major conclusions of the paper (see footnote 10 for the resulting ranking of inflation models).

[9] The sample period over which the lag lengths were searched is 1963Q2-1987Q4. This amounts to assuming that lag lengths had been invariant over the period. Alternatively, the choice between 8- and 16-quarter lags within each model group could be made on the basis of the out-of-sample forecast performance. This procedure was also employed and yielded lag lengths similar to those based on F-tests.

[10] Reichenstein and Elliott (1987) adopt a similar approach.

III
EMPIRICAL RESULTS

Table I reports the estimated coefficients in the four inflation models for the whole sample period, 1963Q2 to 1987Q4. As can be seen, these estimated coefficients have the theoretically predicted signs and in most cases are significant at the conventional 5 percent level. The parameter estimates for the Phillips curve and M2 demand equations are statistically significant and pass the Chow test of structural stability over the sample period (see Fs in the last column of Table I). However, the parameters that appear on the monetary aggregate used in the Monetarist and M1 demand equations are generally not significant. Furthermore, the parameter estimates of the Monetarist equations are not stable over time (see Fs in the last column of Table I).

Table II reports the results of the forecast experiment described in the previous section. Column 1 ranks the inflation equations (which are summarized in Table I) by the root mean squared error (RMSE) calculated using errors over 37 overlapping forecast intervals spanning 1977Q1 to 1987Q4. The mean error (ME) and the mean absolute error (MAE) are also presented. Charts 1 through 3 display for some models period-by-period expected and subsequent actual 8-quarter inflation rates.

If one ranks inflation models by the RMSE criterion, then the M2 demand model outperforms the Phillips curve in predicting inflation over the 1977 to 1987 period. The Phillips curve model, in turn, performs much better than M1 demand, the time series, and Monetarist models by a substantial margin (see Table I).[11]

[11] As explained in footnote 7, the forecasting exercise was repeated using price equations that were estimated omitting contemporaneous values of the right-hand side key explanatory variables. Thus, in the reestimated Monetarist and money demand equations, only past values of money, government expenditures, real income, and opportunity cost appear. In the Phillips curve equation, the past value of output gap appears. Other remaining variables appear in the form shown in equations reported in Table I. For the estimating periods ending in 1976Q4 to 1985Q4, the six inflation models ranked by the RMSE criterion are: Money Demand (M2), 1.94; Phillips Curve, 2.86; Monetarist (M2) 3.69; Monetarist (M1), 3.89; Time Series, 3.93; and Money Demand (M1), 3.99. Money demand (M2) and Phillips curve models continue to be the best two performing models, doing much better than the time series model. The worst performing model is the M1 demand model.

Table I

Estimates of Inflation Equations, 1963Q2-1987Q4

Monetarist

Monetary Aggregate	Constant	ΔM	ΔE	ΔREP	ΔRFP	SER	DW	F
M2	.0008 (.2)	.07 (.35;8)	.20 (1.7;8)	.04 (2.8;0)	.11 (2.9;0)	.00289	2.40	1.66**
M1	−.008 (.2)	.26 (1.4;8)	.28 (2.6;8)	.04 (2.9;0)	.10 (3.0;0)	.00276	2.42	2.6 *

Phillips Curve

Constant	Δp	$(y_{t-1}-y_{pt-1})$	$(\Delta Y_t-\Delta y_{pt})$	ΔREP	ΔRFP	SER	DW	
.0002 (.3)	.97 (14.7;16)	.0005 (3.9;0)	.082 (3.1;0)	.03 (2.9;0)	.09 (3.3;0)	.00229	1.92	1.11

Money Demand

Monetary Aggregate	Constant	ΔM	Δy	$\Delta(R-RM)$	SER	DW	
M2	-.001 (2.1)	1.2 (6.27;16)	-.70 (4.8;8)	.02 (5.2;8)	.00329	2.06	.91
M1	.011 (2.4)	.17 (2.72;8)	-.33 (1.2;8)	.01 (2.7;8)	.00338	2.54	1.11

Time Series

Constant	Δp	SER	DW	
.0016 (2.2)	.87 (15.0;8)	.00319	1.99	.63

Notes: All variables are in first differences of logs except the interest rate variables which are in first differences of the levels. M is M1 or M2; E, high employment government expenditures; REP, the relative price of energy; RFP, the relative price of food; y, the log of real GNP; Y_p, the log of the potential GNP; Y, the log of nominal GNP; R, 4-6 *month commercial paper rate*; RM, the own rate on money, and p, the log of the price level. Coefficients reported are sums of lagged coefficients, with t values and lag lengths reported in parentheses. A zero lag length implies that only the contemporaneous value is included. SER is the standard error of the regression, and DW is the Durbin-Watson statistic. F tests the hypothesis that the estimated coefficients are constant over time.

* Significant at .05 level

** Significant at .10 level

Table II

Summary Statistics for Errors in Predicting the Eight-Quarter Inflation Rate from Alternative Inflation Models

Estimation Periods End 1976Q4 to 1985Q4[a]

Rank	Model	RMSE	ME	MAE
1	Money Demand (M2)	1.62	.0003	1.3
2	Phillips Curve	2.65	1.54	2.1
3	Monetarist (M2)	3.66	.013	2.9
4	Money Demand (M1)	3.79	−.020	2.8
5	Time Series	3.93	−.002	3.2
6	Monetarist (M1)	3.97	−.008	2.9

Subperiod Results

Estimation Periods End[b] 1974Q4 to 1980Q3

Rank	Model	RMSE	ME	MAE
1	Money Demand (M2)	1.35	1.0	1.11
2	Money Demand (M1)	1.36	.78	1.02
3	Monetarist (M1)	3.56	3.33	3.33
4	Phillips Curve	3.75	3.53	3.53
5	Time Series	4.10	3.25	3.57
6	Monetarist (M2)	5.1	4.87	4.87

Estimation Periods End[c] 1980Q4 to 1985Q4

Rank	Model	RMSE	ME	MAE
1	Phillips Curve	1.28	.03	1.10
2	Money Demand (M2)	1.79	−.71	1.45
3	Monetarist (M2)	2.05	−1.41	1.50
4	Time Series	3.8	−2.76	2.89
5	Monetarist (M1)	4.3	−3.91	3.91
6	Money Demand (M1)	4.9	−4.17	4.29

Notes: The inflation equations that underlie these models are reported in Table I. See the text for the procedure used to generate forecast errors. RMSE is the root mean squared error; ME, the mean error; and MAE, the mean absolute error.

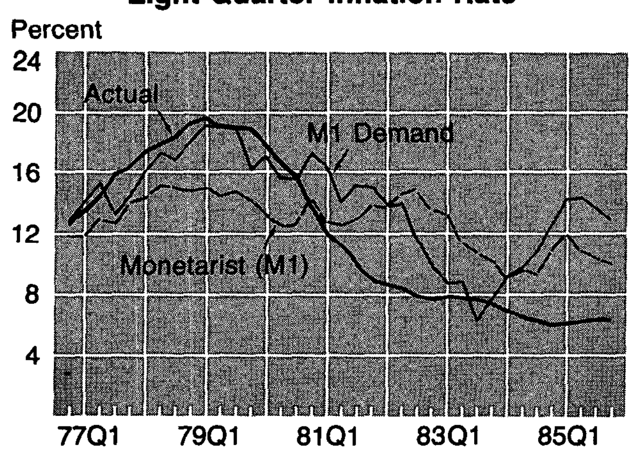
a. The forecast period is 1977Q1 to 1987Q4
b. The forecast period is 1977Q1 to 1982Q3
c. The forecast period is 1981Q1 to 1987Q4

The inflation model that performs poorly, in some cases even worse than the time series model, is the Monetarist model in which money growth is measured by M1. This can be seen in Chart 1 which graphs predictions from the Monetarist model; the inflation rate is consistently overpredicted during the 1980s. With the acceleration of M1 growth first in 1982-83 and then in 1985-86, this inflation model predicts an acceleration of inflation that did not occur. This breakdown reflects the random shifts that have occurred in M1 demand during this period due to factors such as financial deregulation and disinflation. This point is further illustrated by predictions of the M1 demand model, also graphed in Chart 1, which does control for the systematic shifts in money demand due to changes in real income and the nominal interest rate. Early in the period it performs better than the Monetarist model; its performance, however, also deteriorates over time as M1 demand has changed during the 1980s.

Another point suggested by the results in Table I is that the M2 demand model performs much

Chart 1

Expected and the Subsequent Actual Eight-Quarter Inflation Rate



Note: X axis measures the end of the sample period over which the model is estimated. Y axis measures the inflation rate over the out-of-sample eight-quarter prediction interval.

better than the Monetarist model based on M2 measure of money. This result suggests that it is not M2 growth per se but M2 growth in excess of growth in real M2 demand that determines inflation. This point is illustrated further in Chart 2 which graphs predictions from these two inflation models.

The Phillips curve model is the second best performing model. The predictions from this model are displayed in Chart 3. In contrast with the Monetarist equations, the Phillips curve model predicts reasonably well the sharp deceleration in the rate of inflation which occurred in the early 1980s. The recession in 1982 generated a great deal of slack in labor and product markets and widened the gap between actual and potential GNP. The Phillips curve model views the widening gap as a source of decelerating prices. But, as can be seen, it does not predict the sharp acceleration in inflation that occurred in the 1977-79 period.

The predictions from the time series model are also graphed in Chart 3. As is clear, this model lags in predicting turning points in the rate of inflation.

Turning to the subperiods, no clearcut ranking of models emerges (see Table II). During the estimating periods ending in 1976Q4 to 1980Q3, a period of rapidly accelerating prices, money demand models based on M1 or M2 substantially outperform the Phillips curve model. The root mean squared error value from the M2 demand model is 1.35,[12] which is substantially lower than the value 3.77 from the Phillips curve model. However, during the estimating periods ending in 1980Q4 to 1985Q4, a period of decelerating prices, the Phillips curve model turns in a somewhat better performance than the M2 demand model, as measured by their relative root mean squared error values (1.28 vs 1.79). This point is also clear if we compare Charts 2 and 3 over these two subperiods.

As noted before, Fama (1982) has argued that the relevant monetary variable in the U.S. inflation process is the monetary base (MB). In order to evaluate the role of the monetary base, the forecast performance of the inflation equation (3.4) using MB was also evaluated.[13] For the estimation periods ending in 1976Q4 to 1985Q4 the root mean squared error

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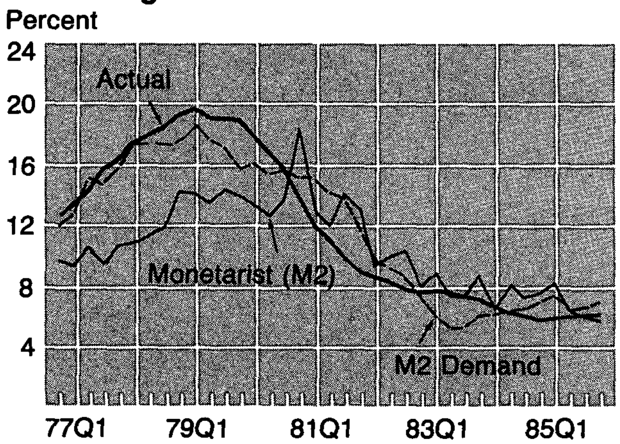
[12] It should be noted that over the early subperiod there is no difference in the RMSE values of the M1 and M2 demand models, suggesting that the non-M1 components of M2 did not matter. However, that is not the case for the latter subperiod.

[13] Fama's MB demand model was estimated using the measure of base collected by the Federal Reserve Bank of St. Louis. Four lagged values of the monetary base, real income, and the nominal interest rate were used in the inflation equation. The monetary base equation did not pass the Chow test for structural stability. Estimation was by generalized least squares to correct for the presence of first order serial correlation. The base equation was also estimated using only past values of the right-hand side explanatory variables. It did not have any major effect on the relative rankings of the inflation models.

Chart 2

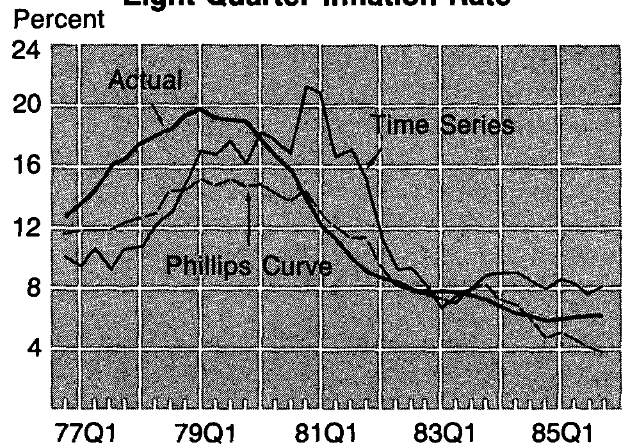
Expected and the Subsequent Actual Eight-Quarter Inflation Rate



Note: X axis measures the end of the sample period over which the model is estimated. Y axis measures the inflation rate over the out-of-sample eight-quarter prediction interval.

Chart 3

Expected and the Subsequent Actual Eight-Quarter Inflation Rate



Note: X axis measures the end of the sample period over which the model is estimated. Y axis measures the inflation rate over the out-of-sample eight-quarter prediction interval.

in predicting the 8-quarter inflation rate is 3.07, which makes it the third best performing model after M2 demand and the Phillips curve models (compare with the RMSE values reported in Table II). For the estimating subperiods ending in 1976Q4 to 1980Q3 and 1980Q4 to 1985Q4, the RMSE values for the MB demand model are 2.59 and 3.39, respectively. Thus, even over the subperiods the inflation model based on M2 demand outperforms its counterpart using MB.

IV
CONCLUDING OBSERVATIONS

The empirical results presented here lead to two observations. First, the relatively poor forecast performance of inflation models in which M1 growth appears suggests that the character of M1 demand has changed. In contrast, the M2 demand model, in which inflation is related to M2 growth in excess of growth in real money demand, performs reasonably well, suggesting that M2 demand has been relatively stable over time. This result implies that a sustained increase in M2 growth in excess of growth in its real demand has been associated with higher inflation. Second, two structural models of the inflation process, the Phillips curve and the M2 demand model, outperform a simple time series model by a substantial margin.

A 1987 study by Reichenstein and Elliott reaches a similar conclusion about M2. These authors compare forecasts of the long-term inflation rate from several nonstructural inflation models (drawn from time series and interest rate relationships) to forecasts generated by Fama's M2 demand model. They find that over the period 1975 to 1982 Fama's structural model is best in predicting the long-term inflation rate.[14]

The relative superior forecast performance of M2 in Fama-type inflation equations raises an interesting question about the nature of the monetary aggregate that is causal in determining the price level. Fama (1982, 1983) has suggested that in theory the price level can be determined by the supply of a nominal asset that has a well-defined real demand and pays a fixed below-market rate of interest. He has argued that the relevant monetary asset is the monetary base. The empirical evidence reported in this paper, however, favors M2 as the relevant aggregate, even though it violates one of the conditions laid down by Fama. While this might suggest some caution, the results overall do imply that it might be inappropriate to ignore the role of money in explaining the generation and evolution of inflation over time.

[14] The results presented in Stockton and Struckmeyer (1988) also suggest that the monetarist models contain information about aggregate inflation that is not incorporated in an expectations-augmented version of the Phillips curve.

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