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The Formation of Inflation Expectations

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THE psychology of inflation is often cited as a major barrier in the war against inflation. One currently popular view contends that anti-inflation policies must not only attack the causes of inflation but also lower inflation expectations. In 1971, the Nixon Administration used this argument to justify the imposition of wage and price controls. More recently, President Carter's March 14 economic policy initiative was intended, in part, to calm financial markets by signaling that inflation expectations should be lowered. Similarly, the objective of lowering inflation expectations has also been used to justify proposed inflation remedies such as the tax-based incomes policy (TIP).[1]

Concern over inflation expectations has been motivated primarily by recent developments in macroeconomic theory that place the expectations of important economic variables at the forefront of analysis. For instance, many economists attribute the existence of the so-called Phillips curve trade-off between inflation and unemployment to unrealized inflation expectations rather than to inflation *per se*.[2]

Although inflation expectations have become crucial to both theoretical and policy analysis, they remain extraordinarily difficult to measure. Generally, economists have relied on various distributed lag models of past inflation rates to estimate inflation expectations. To a lesser extent, they have employed data gathered from surveys of economists, such as those conducted semiannually by Joseph Livingston of the Philadelphia *Inquirer*, or from surveys of households, such as those conducted by the Institute for Social Research of the University of Michigan.[3] Although most studies using these data do so to test alternative hypotheses about economic activity, other scholars have been concerned with the actual process by which price expectations are generated.[4]

Forecasts of inflation can be modeled in various ways. One simple approach formulates the inflation forecast based solely on the history of inflation. As noted above, variations of such autoregressive schemes have dominated studies that include measures of inflation expectations. If independently determined forecasts of inflation are available, then one could test whether *only* the history of infla-

[1]For a discussion and analysis of the TIP program see Nancy Ammon Jianakoplos, "A Tax-Based Incomes Policy (TIP): What's It All About?" this *Review* (February 1978), pp. 8-12.

[2]Milton Friedman, in his 1977 Nobel Laureate address, details the intellectual evolution of various theories of the inflation-unemployment trade-off. See Friedman, "Nobel Lecture: Inflation and Unemployment," *Journal of Political Economy* (June 1977), pp. 451-72.

[3]See Joseph Livingston, (biannual surveys), *Philadelphia Sunday Bulletin*, June and December, 1948-1971 and *Philadelphia Inquirer*, June and December, 1972 to the present; and Richard T. Curtin, ed., *Surveys of Consumers 1974-75, Contributions to Behavioral Economics* (Ann Arbor: Institute for Social Research, The University of Michigan, 1976).

[4]Some studies that have focused on this process include James Pesando, "A Note on the Rationality of the Livingston Price Expectations," *Journal of Political Economy* (August 1975), pp. 849-58; John A. Carlson, "A Study of Price Forecasts," *Annals of Economic and Social Measurement* (June 1977), pp. 27-56; Donald J. Mullineaux, "Inflation Expectations and Money Growth in the United States," *American Economic Review* (March 1980), pp. 149-161; and Edward J. Kane and Burton G. Malkiel, "Autoregressive and Nonautoregressive Elements in Cross-Section Forecasts of Inflation," *Econometrica* (January 1976), pp. 1-16.

tion is important in explaining those forecasts. Alternately, "rational expectations" hypotheses argue that *all* currently available information relevant to the actual inflation process is considered when forecasts are made. Although such information would not be confined solely to the history of inflation, the set of relevant information may be dominated by it. In this case, again, inflation expectations would be closely approximated by some autoregressive scheme.

Related to the process that generates inflation expectations is the mechanism by which revisions in expectations are determined as new information becomes available. Knowledge of whether such revisions are systematically related to recent forecasts is useful in assessing the impact that inflation expectations have on economic activity. The simplest hypothesis is that revisions in forecasts depend on past forecast errors.[5] This approach implicitly assumes that all information relevant to the forecast revision is contained in the most recent forecast error. As Mincer has noted, such error-learning models can be interpreted as a reduced form of an autoregressive forecasting model.[6] If the actual inflation forecasting process is not described solely by the history of inflation, however, then exclusive reliance on past forecast errors to describe expectations revisions would be inappropriate.

This article investigates the process by which inflation expectations are formed and the relevance of error-learning models for analyzing revisions in these expectations, using the Livingston survey data. The extent of error-learning in the revision of inflation expectations, as well as the process by which these expectations are formed, offers useful clues about the efficacy of inflation-reducing strategies.

INFLATION EXPECTATIONS AND FORECAST REVISIONS: THE LIVINGSTON DATA

Twice each year, Joseph Livingston, a financial reporter for the Philadelphia *Inquirer*, requests selected business, government, and academic economists to provide forecasts of various measures of economic activity, including levels of the Consumer Price Index (CPI). John Carlson used Livingston's data on these price level forecasts to generate a series on inflation expectations for the period from 1947 to 1975.[7] For this article, these data have been updated through 1978 using Carlson's methodology.

Although calculations of inflation expectations can be derived directly from price level forecasts, calculations of revisions in these expectations require information about inflation forecasts that were made over different time horizons. Since the price expectations reported by Livingston are for 6- and 12-month horizons, it is easy to calculate a rate of inflation expected over the 6-month period beginning six months hence.[8] Specifically, for the succeeding 6-month period, the inflation rate implied by the current 6- (π^*_6) and 12-month (π^*_{12}) inflation forecasts can be described as:

$$(1) \qquad f_{6,t} = \frac{(1 + \pi^*_{12,t})^2}{(1 + \pi^*_{6,t})} - 1.^9$$

The forecast revision, R_t, is then defined as:

$$(2) \qquad R_t = \pi^*_{6,t} - f_{6,t-1},$$

where the t subscripts identify the moment at which the expectations (or the implied forward inflation rate) are formed.

INFLATION EXPECTATIONS AND FORECAST REVISIONS: PREVIOUS STUDIES

Pesando and Mullineaux, among others, have used either the predictions published by Livingston or those revised by Carlson to estimate equations that

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[5]David Meiselman pioneered the use of the "error-learning" model in his study, *The Term Structure of Interest Rates* (Englewood Cliffs: Prentice-Hall, 1962).

[6]See Jacob Mincer, "Models of Adaptive Forecasting," in *Economic Forecasts and Expectations*, Jacob Mincer, ed. (New York: National Bureau of Economic Research, distributed by Columbia University Press, 1969).

[7]For details of how the expected rate of inflation is calculated from the Livingston price level forecasts, see Carlson, "A Study of Price Forecasts."

[8]Actually, Carlson calculated an implied inflation rate for an 8- and 14-month horizon. An example will clarify this point. The Livingston survey respondents are asked, prior to, say, the June survey, to forecast the level of the CPI for the coming December and the following June. Since this forecast is made a month or more prior to the survey's publication, Carlson assumed that most respondents would know only the level of the CPI data two months before (April or October) the survey's publication. Thus the economists were forecasting the CPI for 8 and 14 months ahead. In this article, these forecasts are described as 6- or 12-month forecasts but are, in fact, identical to those of Carlson. This means that the forecast inflation rates for 6- and 8-month and for 12- and 14-month horizons are assumed to be the same.

[9]In general, the implied j-month inflation rate for the interval from i to i + 1 is:

$$f_{j,i} = \frac{(1 + \pi^*_{j\cdot(i+1)})^{i+1}}{(1 + \pi^*_{j\cdot i})^i} - 1.$$

This expression is similar to that used in the term-structure of interest rate literature to describe the implied forward interest rate.

Table 1

Revisions in Inflation Expectations: The Carlson Model (ordinary least squares estimation)

$$R = b_0 + b_1 E + u$$

Period	Coefficients[a] b₀	b₁	$R^2/\bar{R}^2$	SEE	D.W.
1953-62	−.049 (−.318)	.045 (.484)	.013/−.042	.568	1.013
1963-71	−.264 (−2.458)	.085 (1.227)	.086/.029	.327	1.550[b]
1953-71	−.141 (−1.458)	.056 (.926)	.023/−.004	.466	1.072
1953-75	−.287 (−2.818)	.208 (4.075)	.274/.258	.539	1.513[c]
1953-78	−.305 (−3.319)	.212 (4.550)	.293/.279	.525	1.569[c]
1953-78 (omitting 1972-74)	−.250 (−2.630)	.118 (1.991)	.083/.062	.514	1.509

[a]t-statistics are in parentheses.

[b]Value of Durbin-Watson statistic permits rejection of positive serial correlation.

[c]Value of Durbin-Watson statistic is in the indeterminate range.

"explain" the forecasts in terms of observable economic variables, such as past actual rates of inflation, past rates of money growth, and so on. Most of these studies sought to investigate the rationality and efficiency of inflation forecasts. None have investigated explicitly the process by which forecasters revise their expectations.

Although Carlson did not explicitly examine the process by which inflation forecasts are formed, he did investigate the relevance of a simple error-learning model in explaining forecast revisions. He did not, however, derive his error-learning model from some underlying structural forecasting model. Consequently, his finding of only weak evidence that past forecast errors affected revisions in expectations warrants reexamination.

Carlson argued that forecast revisions depend on the most recent forecast error (E_t) in inflation expectations. This error is defined as:

$$(3) \qquad E_t = \pi_{6,t} - \pi^*_{6,t-1},$$

where $\pi_{6,t}$ is the most recent 6-month rate of inflation observed at time t. Carlson then investigated the error-learning hypothesis by estimating the equation:

$$(4) \qquad R_t = b_0 + b_1 E_t + u_t,$$

where u_t is a random error. This equation states that revisions of previous forecasts depend only on the most recent forecast error.

Carlson's estimations of equation 4 over three different sample periods (1953-62, 1963-71, and 1953-71) failed to uncover any consistent evidence in support of the error-learning hypothesis. Although he found some evidence of error-learning in inflation forecasts based on the Wholesale Price Index (WPI), he found no evidence that error-learning significantly affected revisions of 6-month inflation forecasts based on semiannual observations of the CPI.

To test whether this conclusion remains valid when more recent data are included, equation 4 was reestimated over selected time periods. The results, reported in table 1, do not support Carlson's conclusion when the sample period is extended to include the 1970s. For example, the estimated coefficient on past errors is positive and significant when the equation is estimated through 1975 or 1978.

Because the pervasive price controls in effect dur-

Table 2

Revisions in Inflation Expectations: The Carlson Model (Cochrane-Orcutt estimation)

$$R = b_0 + b_1 E + u$$

Period	Coefficients[a] b_0	b_1	$R^2/\bar{R}^2$	SEE	D.W.	Rho[b]
1953-62	–.149 (–.651)	.086 (1.172)	.259/.215	.493	1.967	.482 (2.396)
1953-71	–.218 (–1.642)	.077 (1.450)	.191/.168	.420	1.860	.432 (2.912)
1953-78	–.333 (–3.161)	.220 (4.684)	.340/.327	.508	2.024	.194 (1.413)
1953-78 (omitting 1972-74)	–.228 (–2.238)	.114 (2.263)	.142/.122	.440	1.759	.245 (1.674)

[a]t-statistics are in parentheses.

[b]The autocorrelation coefficient as estimated by the Cochrane-Orcutt technique; t-statistics are in parentheses.

ing the period 1972-74 may have distorted the effect of past errors, equation 4 was estimated through 1978 omitting 1972-74 data. Again, the hypothesis that error-learning has been an important factor in the formation of inflation expectations cannot be rejected.

The low Durbin-Watson (D.W.) statistics for several versions of equation 4 suggest the presence of serially correlated residuals (u_t). As a result, estimates of equation 4 may not be efficient. The Cochrane-Orcutt iterative technique was used to correct for the presence of autocorrelation for those sample periods in which the D.W. statistic indicated that the hypothesis of serially correlated residuals could not be conclusively rejected. Estimates of equation 4, using this method, are reported in table 2 and, like those discussed above, are less conclusive than Carlson's about the relevance of the error-learning hypothesis. For example, in the 1953-71 period, the t-statistic for the coefficient on the forecast error, though small, is significent at the 10 percent confidence level using a one-tailed test.[10] Nevertheless, over the two subsamples of the period, 1953-62 and 1963-71, the error-learning hypothesis still must be rejected. Coefficients for this parameter over all three periods, however, differ by less than .01, suggesting that estimates from the shorter sample periods may be inefficient but unbiased estimates of the true parameter.[11]

Since the error-learning model implies that all information relevant to forecast revisions is contained in the most recent error, the significant negative coefficient on the constant term requires further discussion. The significance of these coefficients, together with the low coefficient of determination (R^2), could be interpreted as evidence that important variables have been omitted from the specification. A careful examination of the expectations formation process underlying equation 4 provides additional support for this interpretation.

As noted above, the relevant error-learning model should be derived from and consistent with the underlying structural expectations formation model. Recalling the definitions for the revision and the forecast error, it is easy to see that the underlying fore-

[10]The one-tailed test is appropriate for testing the null hypothesis that $b_1 = 0$ against the alternative hypothesis that $b_1 > 0$.

[11]The estimated coefficients for the three pre-1972 sample periods do not differ significantly from each other, suggesting that they are all unbiased estimators of the true parameter. Because the variance of these estimated coefficients tends to decline with increases in the size of the sample, the estimates for the shorter periods cannot be considered efficient (i.e., they are not the minimum variance estimators). For a discussion of the efficiency of estimators, see Jan Kmenta, *Elements of Econometrics* (New York: MacMillan Publishing Company, 1971), pp. 157-69.

cast mechanism implied by equation 4 conforms to the following relationships:

(5a) $$\pi^*_{6,t} = a_0 + a_1 \pi_{6,t}, \text{ and}$$

(5b) $$f_{6,t} = \alpha_0 + \alpha_1 \pi^*_{6,t},$$

where $a_1 = \alpha_1$ and the t-subscripts identify the period in which the variable is observed.[12] (For example, $\pi_{6,t}$ is the most recently observed six-month inflation rate.)

Equations 5a and 5b imply a highly restrictive ("naive") version of the expectations process. These specifications imply that the forecasters' expectations of inflation for the next period depend only on the most recently observed rate of inflation. No other information is incorporated. Note also that both equations specify a constant. A nonzero constant in either equation implies that some premium (or discount) is added to the impact of the current 6-month inflation rate to obtain the relevant 6-month inflation forecasts.

AN ALTERNATIVE FORECAST MECHANISM

If the true underlying expectations formation mechanism is less restrictive or more complex than the one described by equations 5a and 5b, then the revision equation given in equation 4 is misspecified. Recent studies of inflation expectations offer some evidence for this interpretation.

Pesando, in his study of the Livingston data, hypothesized an autoregressive scheme for the price forecasts.[13] In another study of inflation forecasts based on different survey data, Kane and Malkiel emphasized the importance of including some return-to-normality variable.[14] The return-to-normality model implies that forecasters adjust their forecasts to some notion of the "normal" rate of inflation. Mullineaux also experimented with a variety of variables that could potentially influence inflation expectations and reported ". . . that inflation forecasts are systematically influenced by past inflation rates and past rates of money growth, but not by fiscal-policy-related variables. . . ."[15] Both the Kane-Malkiel and Mullineaux studies highlight the relevance of other information in addition to the past rate of inflation in the formation of inflation expectations. The remainder of this article explores an alternative inflation expectations formation mechanism that is hypothesized to depend on both the time series of past inflation rates and on elements that embody a return-to-normality notion.

A Return-to-Normality Model

The following mechanism is hypothesized for the expectations formation process:

(6a) $$\pi^*_{j,t} = a_0 + a_1 \pi^*_{j,t-1} + a_2 \pi_{j,t} + a_3 \pi^n_t, \text{ and,}$$

(6b) $$f_{j,t} = \alpha_0 + \alpha_1 \pi^*_t.$$

This process describes the current inflation forecast for the j-month horizon in terms of last period's forecast ($\pi^*_{j,t-1}$), the most recently observed j-month inflation rate ($\pi_{j,t}$), and the currently held expected normal rate of inflation (π^n_t). The implied forward rate of inflation, $f_{j,t}$ — the inflation rate expected to prevail for the j-month period beginning at the completion of the current j-month period — is hypothesized to equal the currently held forecast plus some premium (or discount), α_0.

This specification of inflation expectations embodies both autoregressive and return-to-normality elements.[16] The presence of a lagged dependent variable in equation 6a can also be interpreted as capturing the relevance of any inertia in the forecasts. The larger the coefficient, a_1, the more reluctant forecasters are to revise their expectations. The coefficient, a_2, which applies to the most recently observed inflation rate, measures the extent to which new information about inflation is deemed relevant for the current period's forecast. Finally, the coefficient, a_3, reflects the dependence of short-run inflation forecasts on the long-run normal rate of inflation.

Equation 6a can be rewritten in a form that captures the impact of past errors. Adding and sub-

[12]The revision equation (equation 4) is obtained by lagging each term in equation 5b and subtracting from 5a.

[13]Pesando, in "A Note on the Rationality," characterized the Livingston forecast by a highly restrictive autoregressive scheme.

[14]Kane and Malkiel, "Autoregressive and Nonautoregressive Elements."

[15]Mullineaux, "Inflation Expectations and Money Growth," p. 160.

[16]For example, by repeated substitution for the lagged dependent variable, equation 6a can be shown to be equivalent to

$$\pi^*_{j,t} = a_0 + a_2 \pi_{j,t} + a_3 \pi^n_t + \sum_{i=1}^{n} a_1 (a_0 + a_2 \pi_{j,t-1} + a_3 \pi^n_{t-1}),$$

where the last term embodies primarily autoregressive components as well as the history of the normal rate of inflation. Another point merits attention. Suppose forecasts are made for a minimum j-month horizon and for other horizons that are some multiple of that horizon (for example, a 6-month, a 12-month, and an 18-month horizon). If each of these forecasts are made every j-month, then all forecasts, regardless of the horizon, can be represented as a distributed lag on past j-month inflation rates.

tracting $a_2\pi^e_{6,t-1}$ from the right-hand side of 6a produces:

$$(7) \qquad \pi^e_{j,t} = a_0 + (a_1 + a_2)\,\pi^e_{j,t-1} + a_2E_{j,t} + a_3\pi^n_t.$$

Lagging all terms in equation 6b one period and subtracting from equation 7 produces a forecast revision equation that is consistent with this forecasting process:

$$(8)\ R_{j,t} = (a_0 - \alpha_0) + (a_1 + a_2 - \alpha_1)\,\pi^e_{j,t-1} + a_2E_{j,t} + a_3\pi^n_t.$$

Clearly, the simple revision equation estimated by equation 4 is not consistent with the forecast mechanism described here. The correct equation for estimating revisions in such inflation expectations is:

$$(9) \qquad R_{j,t} = \beta_0 + \beta_1\pi^e_{j,t-1} + \beta_2E_{j,t} + \beta_3\pi^n_t + u_t;$$

where $\beta_0 = a_0 - \alpha_0$, $\beta_1 = (a_1 + a_2 - \alpha_1)$, $\beta_2 = a_2$, $\beta_3 = a_3$, and u_t is a random error. Note that the logic of the model implies that a_0 and α_0 should be zero since all relevant information is presumed to be embodied in the variables $\pi^e_{j,t-1}$, $E_{j,t}$, and π^n_j. Consequently, estimated values of β_0 also should not differ significantly from zero.

The coefficient for the lagged dependent variable in equation 6a can be interpreted in terms of the speed with which forecasters adjust their expectations from one period to the next. Equation 6a describes the adjustment of inflation forecasts partly in terms of previously held forecasts. The size of the coefficient, a_1, on the lagged term measures the extent to which forecasters maintain previously held forecasts. The speed with which forecasts are adjusted over time, therefore, corresponds to $(1 - a_1)$. Larger values for a_1 imply that a stronger persistence effect is embedded in the forecast process or, alternatively, that forecasts are revised more slowly when new information becomes available.

Finally, the degree of persistence evident in the forecasts could vary with the forecast horizon. Because information about permanent structural changes in the economy evolves only slowly and is costly to distinguish from transitory phenomena, long-run inflation expectations could be expected to change less from one period to the next than short-run expectations. As a result, longer-range forecasts should show greater persistence than shorter-range forecasts.

The hypothesized forecasting process described by equations 6a and 6b contains a return-to-normality variable that reflects the view that forecasters incorporate information about the long-run expected inflation rate. This expected normal rate of inflation embodies relevant information from a wider variety of sources than simply the time series of past prices. For example, Kane and Malkiel found that ". . . return-to-normality elements dominate forecasts of future inflation and [show] . . . that developments outside the past history of prices importantly alter respondents' conceptions of what rate of inflation is 'normal.' "[17] In their investigations of the return-to-normality hypothesis, Kane and Malkiel surveyed large firms and major bond dealers to gather inflation forecasts over several horizons. They were thereby able to calculate a normal rate forecast as a weighted average of subperiod forecasts which extended as far as 10 years into the future. Unfortunately, the Livingston data do not permit the derivation of any comparable and meaningful normal rate. Because the longest horizon forecast is only 18 months, a test of the return-to-normality hypothesis comparable to the Kane-Malkiel study is not possible.[18] Consequently, tests of the return-to-normality hypothesis must rely on other measures of the normal rate of inflation.

One way to approximate the normal rate of inflation is to utilize some trend growth of the money stock. Such a proxy introduces a monetarist interpretation of inflation forecasts into the model — namely, that the trend growth of prices is determined by the trend growth of money.[19] In this study, a twenty-quarter moving average of past M1 growth is used as a proxy for the normal rate of inflation.

The use of a surrogate for the normal rate of inflation requires some modifications of the foregoing interpretation regarding equations 6a, 6b and 9. Suppose that equation 6a represents the true model that describes inflation expectations over some given short-run time horizon. If currently available information affects the *actual* rate of inflation only with some lag, then the forecast for the period beginning one period hence could differ from the forecast made for the period now beginning. To the extent that this currently available information is relevant to the long-run rate of inflation, it should be imbedded somehow in the normal rate of inflation. The proxy for the normal rate of inflation used here does not represent exactly the notion of the normal rate. For example, suppose the Federal Reserve announced that it intended to pursue a new money

[17]Kane and Malkiel, "Autoregressive and Nonautoregressive Elements," p. 3.

[18]These 18-month forecasts were collected only once each year and were discontinued after 1971.

[19]See Denis Karnosky, "The Link Between Money and Prices — 1971-76," this *Review* (June 1976), pp. 17-23 for a discussion of the link between the trend growth of money and inflation.

Table 3
Inflation Expectations: 6-Month Forecasts

$$\pi_t^e = a_0 + a_1\pi_{6,t-1}^e + a_2\pi_{6,t} + a_3\pi_t^n$$

Period	Coefficients[a] a_0	a_1	a_2	a_3	$R^2/\bar{R}^2$	SEE	Durbin-h	Rho[b]	F[c]
1953-78	−.413 (−1.996)	.654 (8.340)	.183 (3.832)	.186 (2.341)	.952/.949	.522	1.119		77.00
1963-78	−.197 (−.557)	.577 (6.139)	.262 (4.769)	.123 (1.064)	.947/.941	.488	.070		35.13
1953-71	−.191 (−.952)	.773 (7.445)	.039 (.660)	.156 (1.864)	.888/.878	.450	.594		52.82
1963-71	−.171 (−.593)	.552 (2.895)	.081 (1.101)	.260 (1.318)	.919/.900	.321	−.701	−.583 (−2.961)	17.27
1953-78 (omitting 1972-74)	−.330 (−1.462)	.715 (8.317)	.100 (1.659)	.190 (2.062)	.945/.941	.515	.493		73.69

[a]t-statistics are in parentheses.

[b]The autocorrelation coefficient is reported only for that equation which was estimated by the Cochrane-Orcutt technique because of evidence of serial correlation in the OLS estimates; t-statistic is in parentheses.

[c]F is the F-statistic for assessing the hypothesis that the estimates reported here do not differ from those obtained by estimating the more simple model described by equation 5a. The F-statistics permit rejection of this hypothesis at the .01 level for all time periods reported.

growth target over the coming six months. If this targeted growth rate differed from the previous trend growth of money, analysts might expect the trend in money growth to be changing during the current 6-month forecast horizon. Because the proxy for the normal rate used here is entirely "backward-looking," it omits such additional information. As a result, the implied forward rate equation could be expected to include additional terms. Since these terms are *currently* unmeasurable, however, they are assumed to be imbedded in the constant term; that is, the constant term in the implied forward inflation rate equation reflects the effect of currently available (but not measurable) information on the future inflation rate. A positive constant would reflect the forecasters' belief that the *net* effect of all other currently available and inflation-relevant information is to accelerate inflation. Finally, such a positive constant would imply a *negative* constant term, β_0, in equation 9.

Empirical Tests of the Alternative Inflation Forecast Model

Tables 3 and 4 report the results of estimating equations 6a and 6b, respectively, over various time periods. The first and perhaps most important observation is that the coefficients of determination (R^2) in table 3, are greater than 0.90 for four of the five periods. For longer periods, they exceed 0.94. This statistic indicates that over 90 percent of the variance of the inflation forecasts is explained by this relatively simple reduced form. Interestingly, these values for R^2 are quite close to those obtained when the forecasts are estimated in terms of more complicated Almon lags on past inflation rates and past money growth.[20] More importantly, the coefficients of determination adjusted for degrees of freedom ($\bar{R}^2$) are consistently greater than those obtained from estimates (not reported here) of the "naive" forecast equation given in 5a. The rejection of the naive model in favor of equation 6a is reinforced by F-tests (for the hypothesis that the two equations do not differ) conducted for the various sample periods. Results of these tests (based on comparisons of ordinary least squares estimates of the two equations) are reported in the last column of table 3.[21] The alternative model is favored

[20]The adjusted $\bar{R}^2$'s for equation 6a are similar to those obtained by Mullineaux. While the $\bar{R}^2$'s reported here generally exceed those of Mullineaux, his sample period differed from those estimated here, making direct comparison inappropriate. Other estimations by the author of the inflation forecasts based on more complicated Almon lags of past money growth and past inflation rates did not generate consistently higher $\bar{R}^2$'s than did the equations reported here.

[21]F-tests were made on the basis of OLS estimations of the two equations. Cochrane-Orcutt estimations would involve transforming all observations by some coefficient of autocorrelation. Unless each equation is characterized by the same degree of serial correlation, the two equations would not be directly comparable.

Table 4
Inflation Expectations: The Implied Forward Rate

$$f_{6,t} = \alpha_0 + \alpha_1 \pi^{e}_{6,t}$$

Period	Coefficients[a] α_0	α_1	$R^2/\bar{R}^2$	SEE	D.W.	Rho[b]
1953-78	.338 (3.478)	.967 (34.614)	.978/.978	.338	1.963	.266 (1.974)
1963-78	.525 (3.295)	.937 (26.087)	.980/.979	.275	2.083	.328 (1.934)
1953-71	.138 (1.530)	1.058 (21.589)	.928/.926	.384	1.553	
1963-71	.164 (1.486)	1.057 (24.331)	.974/.972	.186	2.369	
1953-78 (omitting 1972-74)	.163 (2.071)	1.037 (39.507)	.973/.972	.375	1.624	

[a]t-statistics are in parentheses.

[b]The autocorrelation coefficient is reported only for those equations which were estimated by the Cochrane-Orcutt technique because of evidence of serial correlation in the OLS estimates; t-statistics are in parentheses.

over the naive model at the 0.01 confidence level for all time periods.[22]

The estimated constants reported in table 3 reinforce the view that this forecast mechanism is more appropriate than the naive model. In estimates of that model, statistically significant, positive constant terms were consistently obtained, suggesting the importance of omitted variables. In contrast, estimates of the present model produced a significant (though negative) constant term in only one sample period — 1953-78. This constant could capture elements related to the era of the Nixon wage-price controls. When this three-year episode is deleted, the constant is no longer significant at standard confidence levels. Finally, it should be noted that, unlike the naive model, the present model shows no evidence of positive serial correlation, though the 1963-71 sample period shows some evidence of negative serial correlation.[23] The implied forward rate is also accurately described by equation 6b.[24] Taken together, these results provide favorable evidence that the underlying forecast process conforms quite closely to the one hypothesized here.

Although the R^2s remain high over the various sample periods, the variation in the estimated coefficients, especially those for the current inflation rate and the normal rate, suggest that the contribution of these variables in the forecasting process has changed.[25] For example, in periods ending with 1971, the current rate of inflation played virtually no independent role in the determination of next period's forecast. Apparently, current inflationary phenomena was largely discounted — at least until it became embedded in the past trend of inflation. As the sample period is extended toward the present, however, the most recent inflation rate assumes a dramatically different role. Both the magnitude and the significance of the a_2 term indicate that forecasters viewed the information reflected in the current inflation rate as more relevant.

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[22]In several OLS estimations of the naive model, the Durbin-Watson statistic was unacceptably low. While this result is usually interpreted as evidence of positive serial correlation, it may also indicate that important explanatory variables have been omitted. This interpretation seems appropriate here, since by including the two additional variables in equation 6a, evidence of positive serial correlation disappears.

[23]The Durbin-h statistic is appropriate for testing for serial correlation when lagged values of the dependent variable are included. The Durbin-h is normally distributed with a zero mean and a variance of σ^2. See J. Johnston, *Econometric Methods* (New York: McGraw-Hill, 1972), pp. 312-13.

[24]Equation 6b implies that the implied forward rate could alternatively be expressed in a form similar to that given in 6a. Estimating this version of the forward rate did not provide as good a fit in terms of R^2 as did the more simple form.

[25]Mullineaux, "Inflation Expectations and Money Growth," also observed a changing forecast structure over time. Mullineaux's work gives a thorough and detailed analysis of the behavior of the temporal coefficients on past inflation.

Table 5
Inflation Expectations: 12- and 18-Month Forecasts

$$\pi^e_{j,t} = a_0 + a_1 \pi^e_{j,t-1} + a_2 \pi_{6,t} + a_3 \pi^n_t;\ j = 12, 18$$

Period	Coefficients[a] a_0	a_1	a_2	a_3	$R^2/\bar{R}^2$	SEE	Durbin-h	Rho[b]
(12-month forecast)								
1953-78	−.266 (−1.496)	.734 (11.231)	.143 (3.529)	.146 (2.108)	.964/.962	.455	.691	
1963-78	−.149 (−.451)	.641 (7.087)	.212 (4.245)	.127 (1.135)	.952/.947	.455	−.109	
1953-71	−.082 (−.513)	.837 (11.099)	.030 (.619)	.113 (1.712)	.931/.925	.368	.828	
1963-71	−.114 (−.428)	.585 (3.315)	.080 (1.156)	.245 (1.290)	.934/.919	.296	−.376	−.574 (−2.888)
1953-78 (omitting 1972-74)	−.178 (−.936)	.794 (11.271)	.068 (1.307)	.141 (1.808)	.961/.958	.447	.012	
(18-month forecast)								
1953-71	−.151 (−1.341)	.809 (11.963)	.005 (.100)	.223 (4.841)	.955/.945	.282	.604	−.563 (−2.893)

[a]t-statistics are in parentheses.

[b]The autocorrelation coefficient is reported only for those equations which were estimated by the Cochrane-Orcutt technique because of evidence of serial correlation in the OLS estimates; t-statistics are in parentheses.

Examination of estimates for equation 6a over longer forecast horizons offers an additional perspective. Table 5 reports estimates of equation 6a for 12- and 18-month horizons.[26] Estimated coefficients for the 12-month horizon over various time periods show a pattern similar to that estimated for the 6-month horizon. As expected, all coefficients on the lagged dependent variable are larger for the 12-month horizon than for the 6-month horizon. This suggests that there is greater period-to-period persistence and a slower adjustment speed in the 12-month forecasts than in the 6-month forecasts. For the 18-month forecasts, however, the coefficient on the lagged dependent variable was slightly (but not significantly) lower than in the 12-month forecast horizon.

For those time periods in which the most recently observed 6-month inflation rate significantly affected the forecasts, its impact was greater on the short-run (6-month) forecasts than on the longer-run (12-month) forecasts. This observation provides further evidence that the most recently observed inflationary experience is incorporated only slowly into longer-run forecasts.

The specification given by equation 6a permits a useful interpretation of the coefficient for the normal rate. Essentially, the long-run tendency for the j^{th} horizon forecast to converge toward the normal rate can be represented by a long-run coefficient on the normal rate described as $a_3/(1-a_1)$.[27] Table 6 reports calculations of this parameter for the three forecast horizons over several periods. This long-run return-

[26]Note that estimated equations for these forecast horizons differ slightly from those described by equation 6a in that the most recent 6-month inflation rate, rather than the most recent 12- or 18-month inflation rates, is included. The reason for this is that the 12-month forecast, made six months ago, already incorporated all relevant information from past inflation. Only the most recent 6-month inflation rate is "news." (As noted in footnote 16, all forecasts, regardless of horizon, can be represented as a distributed lag on past 6-month inflation rates.) If the 12- and 18-month forecasts were made only every 12 and 18 months, then the exact specification given by 6a would be appropriate. (Equation 6a was estimated using this latter specification, despite the informational redundancy contained in the 12- or 18-month actual inflation rate. Those results did not differ notably from those reported here.)

[27]The presence of a lagged dependent variable makes equation 6a similar to a stock-adjustment type of equation. The coefficient, a_1, in 6a is interpreted as one minus the speed of adjustment of the forecast to the long-run "equilibrium" rate of inflation. The long-run coefficient for any other variable in the equation can then be described as a ratio of the estimated short-run coefficient to the speed of adjustment, i.e., $a_3/(1-a_1)$.

Table 6

Long-Run Response of Short-Term Expectations to Changes in the "Normal" Rate of Inflation[a]

Period	6-month forecasts[b]	12-month forecasts[b]	18-month forecasts[b]
1953-78	.538 (2.908)	.549 (2.614)	
1963-78	.291 (1.202)	.354 (1.326)	
1953-71	.687 (2.095)	.693 (1.868)	1.168 (2.649)
1963-71	.580 (2.275)	.590 (2.235)	
1953-78 (omitting 1972-74)	.667 (2.585)	.684 (2.206)	

[a]Due to rounding, the calculated coefficients may differ slightly from those calculated from results reported in tables 3 and 5.

[b]t-statistics are in parentheses. For a description of the methodology used to calculate the variance of $a_3/(1 - a_1)$ used in calculating the t-statistics, see Kmenta *Elements of Econometrics*, p. 444.

to-normality coefficient should be higher for longer forecast horizons, since long-run expectations would tend to converge to the normal rate of inflation. As expected, these long-run coefficients are larger for the 12-month than for the 6-month forecasts. While the differences between the coefficients for these horizons are not great, the long-run coefficient for the 18-month horizon is larger and, in fact, does not differ significantly from unity. Thus it appears that the forecasters do tend to form long-run expectations in a manner consistent with the return-to-normality hypothesis.[28]

The estimated magnitude of this long-run coefficient for both the 6- and 12-month horizons falls dramatically when the sample period includes only the 1960s and the 1970s.[29] This observation reinforces the view that the rapid acceleration in inflation experienced during the 1970s has had an important effect on the way inflation expectations are formed. Throughout this period, rapidly rising inflation may have simultaneously induced forecasters to revise the normal rate of inflation more frequently. Hence, the proxy measure for the normal rate used here may understate the correct value of the normal rate, when inflation is accelerating rapidly.[30] This possible measurement error could distort the evidence reflected in the long-run coefficient for this variable, especially during more recent periods.

In summary, several relevant observations emerge from the estimations of equations 6a and 6b. The inflation forecasting process employed by respondents to Livingston's survey of economists can be described in terms of both autoregressive elements and past money growth (interpreted here as a proxy for return-to-normality elements). Nevertheless, although the equation performs well over all subsamples of the period 1953-78, the relative roles played by the current and normal rates of inflation appear to have changed. Specifically, during the 1970s when inflation accelerated sharply, return-to-normality elements played a less important role while the most recent rate of inflation became more important. Finally, the emergence during the 1970s of a significant, positive constant in the implied forward rate equation provides some evidence that forecasters had begun to anticipate accelerating inflation.

Implications for Error-Learning Models

The relevant equation for examining the error-learning hypothesis is implied by the underlying expectations formation process. Equation 9 satisfies this criteria. In addition to the forecast error, it includes a lagged inflation forecast term and a return-to-normality element. Table 7 reports statistics obtained from estimating this equation.

When the error-learning hypothesis is examined from the perspective implied by the forecast mechanism underlying equation 9, evidence of error-learning is clearly present. The coefficient on the forecast error, β_2, differs significantly from zero at the 5 percent level (one-tailed test) over all sample periods except 1953-71. Recall that this coefficient reflects the relevance of the most recently experienced inflation. The results reported above reveal that the current rate of inflation only became important in samples that included the experience of the 1970s, during which inflation was accelerating sharply. Thus, Carlson's earlier conclusions about the relevance of past errors in ex-

[28]The calculated long-run coefficients for the normal rate are comparable to those obtained by Kane and Malkiel in their estimations based on cross-sectional data. For example, in equations using the CPI, their estimates of the return-to-normality coefficient ranged from about .52 for the 6-month horizon (in 1969) to about .63 for the 12-month horizon (in 1972).

[29]Note that the coefficient deteriorates only slightly in the subsample 1963-71.

[30]This view is reinforced by some results reported by Mullineaux. Using a two-period distributed lag on past 6-month money growth, Mullineaux found that both lagged coefficients increased dramatically during the 1970s. Thus, measures of "normal" inflation based on a fixed-weight average of past money growth would understate the "true" normal rate.

Table 7
Revisions in Inflation Expectations: The Implied Model

$$R_{6,t} = \beta_0 + \beta_1 \pi^e_{6,t-1} + \beta_2 E_{6,t} + \beta_3 \pi^a_t$$

Period	Coefficients[a] β_0	β_1	β_2	β_3	$R^2/\bar{R}^2$	SEE	D.W.	Rho[b]
1953-78	−.553 (−2.830)	−.174 (−2.932)	.215 (4.775)	.169 (2.256)	.402/.365	.493	1.708	
1963-78	−.145 (−.446)	−.030 (−.394)	.312 (6.178)	−.052 (−.489)	.585/.541	.448	2.393	
1953-71	−.444 (−2.711)	−.349 (−4.931)	.050 (1.039)	.245 (3.595)	.431/.381	.366	1.674	
1963-71	−.153 (−.731)	−.289 (−1.826)	.116 (2.137)	.130 (.906)	.564/.463	.251	2.006	−.729 (−4.395)
1953-78 (omitting 1972-74)	−.544 (−2.860)	−.254 (−4.256)	.091 (1.790)	.238 (3.069)	.376/.331	.434	1.622	

[a]t-statistics are in parentheses.

[b]The autocorrelation coefficient is reported only for that equation which was estimated by the Cochrane-Orcutt technique because of evidence of serial correlation in the OLS estimates; t-statistic is in parentheses.

plaining forecast revisions is, in one sense, reaffirmed. The error-learning hypothesis, however, appears to have greater validity when recent, unexpectedly rapid inflation has invalidated prior forecasts.

Equation 9 requires that the estimated coefficients conform to restrictions implied by the underlying forecast process. These restrictions, which are listed below equation 9, were confirmed for all sample periods in the estimates of the revision equation. In no case did the coefficients from equation 9 differ significantly from the restricted values for those coefficients derived from the independent estimates of the underlying forecasting process.

SUMMARY AND CONCLUSIONS

The foregoing analysis and discussion has presented evidence concerning the nature of the inflation forecasting process implicit in the Livingston price expectations data. Although earlier conclusions about the relevance of the error-learning hypothesis may have been valid for certain periods over the past 25 years, they do not appear to be valid for the decade of the 1970s.

More important, however, is the information revealed about the nature of the inflation forecasting mechanism. Evidence reported here indicates that when inflation has been accelerating, recent inflationary experience becomes more important in the expectations process. This result suggests that policies which can successfully lower *current* inflation could reap important longer-run dividends by simultaneously inducing a reduction in inflation expectations.[31] The results, however, also suggest that once the economy moves from high inflation to lower inflation, return-to-normality elements may become more important. Under a regime where planned, gradual reductions in the growth rate of money are announced and pursued, inflation expectations would seemingly adapt only slowly. On the other hand, if during periods of decelerating inflation, expectations become more responsive to current experience — as they were during periods of accelerating inflation — expectations may well adapt more rapidly. Evidence of strong persistence effects over all time periods suggests that breaking the inflation psychology necessarily involves a long-term commitment by policymakers to an anti-inflation policy. Once such a policy is announced and undertaken, any decelerating inflation actually experienced should reinforce the adaptation to lower inflation expectations.

[31]This observation should not be interpreted as supporting incomes-policies since the adoption of price and wage controls could be expected to alter the structure of expectations formation.

Money, Inflation, and Economic Growth: Some Updated Reduced Form Results and Their Implications

KEITH M. CARLSON

THE economic experience of the United States during the 1950s and 1960s provided an opportunity to develop and test a number of hypotheses relating to the performance of the macroeconomy. One such hypothesis that received empirical support during this period held that monetary actions, as measured by movements in the monetary aggregates, have lasting effects on only nominal variables. This proposition is an important element in a body of thought called "monetarism."[1]

In contrast to the relative economic tranquility of the 1950s and 1960s, the decade of the 1970s was marked by extensive experimentation with wage and price controls, large supply shocks, proliferation of government regulations, and worldwide inflation. These events and developments prompted economists to question whether or not the performance of the United States economy during this period was consistent with prior hypotheses relating to the lasting impact of monetary actions. This article is addressed to that question.

The article focuses on the magnitude of the response of GNP, output, and the price level to changes in the money stock, defined as currency plus private checkable deposits.[2] The magnitudes of these responses are derived by estimating reduced form equations; that is, equations in which observations of the rates of change of economic variables are regressed on current and lagged values of the rate of change of money and other suitably chosen exogenous variables. The sum of the coefficients on the money variable is interpreted as a measure of the magnitude of response during the sample period from which the observations are drawn.[3]

THE QUANTITY EQUATION OF EXCHANGE AND REDUCED FORMS

The underlying framework for the analysis is the quantity equation of exchange. This equation is an identity that states the value of all spending for goods and services in two ways: the product of the stock of money times its velocity of circulation, and the

[1]For an extensive discussion of monetarism, see Thomas Mayer, et. al., *The Structure of Monetarism* (New York: W. W. Norton and Company, 1978).

[2]The regressions were run before data were available for the new definitions of the monetary aggregates. Data for "old" M1 were used, and ATS and NY NOW accounts were added after III/78.

[3]Whether or not this magnitude of response can be interpreted statistically as a "long-run" result depends on the length of the lag relative to the number of observations in the sample period. A reliable estimate of the long-run response of a variable that adjusts quickly and completely to an exogenous shock does not require as many observations as does a slowly adjusting variable.

price level times the quantity of aggregate output. In symbols, this identity is:

$$(1)\ MV \equiv PX \equiv Y,$$

where

- M = nominal money stock,
- V = velocity of circulation,
- P = price level,
- X = output, and
- Y = nominal GNP.

As an identity, the quantity equation of exchange means little. When combined with assumptions relating to the determination of the variables, however, the equation assumes behavioral content. Writing the equation in rate of change form, where each of the variables is allowed to be influenced by money, yields the following:

$$(2)\ \overbrace{\varepsilon(M,M)\dot{M}}^{\dot{M}} + \overbrace{\varepsilon(V,M)\dot{M} + a}^{\dot{V}} = \overbrace{\varepsilon(P,M)\dot{M} + b}^{\dot{P}} + \overbrace{\varepsilon(X,M)\dot{M} + c}^{\dot{X}},$$

where ε is the elasticity of the first variable in parentheses with respect to the second. A dot over a variable indicates its compounded annual rate of change. The constants, a, b, and c, represent the effect of nonmonetary influences on $\dot{V}$, $\dot{P}$, and $\dot{X}$, respectively.

The total differential of equation 2 results in an expression that relates the elasticities to each other:

$$(3)\ 1 + \varepsilon(V,M) = \varepsilon(P,M) + \varepsilon(X,M),$$

or

$$(4)\ 1 + \varepsilon(V,M) = \varepsilon(Y,M).$$

Equations 3 and 4 indicate the constraints that must be considered when attempting to estimate these elasticity parameters. An estimate of either $\varepsilon(V,M)$ or $\varepsilon(Y,M)$ implies the other. Given one of these elasticities, only one of the remaining elasticities — $\varepsilon(P,M)$ or $\varepsilon(X,M)$ — can be estimated. Alternatively, estimates of $\varepsilon(P,M)$ and $\varepsilon(X,M)$ imply both $\varepsilon(V,M)$ and $\varepsilon(Y,M)$.

The elasticity parameters and the constants in equation 2 can be estimated in a variety of ways. Reduced form equations could be estimated for $\dot{Y}$ and $\dot{P}$, $\dot{Y}$ and $\dot{X}$, $\dot{P}$ and $\dot{X}$, $\dot{V}$ and $\dot{P}$, or $\dot{V}$ and $\dot{X}$. The choice is arbitrary only if the error terms for each of these reduced form equations have exactly the same serial correlation properties.[4] Monetarists researching the U.S. economy have generally concentrated on $\dot{Y}$ and $\dot{P}$, although not always in combination.[5] Nelson recently developed justification for this choice of variables by testing the hypothesis that the structure of the United States economy is recursive, with disturbances from GNP flowing to the price level and not the reverse.[6] Consequently, this article focuses on reduced form estimates of $\dot{Y}$ and $\dot{P}$.[7]

REDUCED FORM RESULTS

The empirical analysis of the impact of monetary actions on GNP, output, and the price level uses previous specifications by monetarists as a starting point and modifies these specifications in light of the experience of the 1970s.[8] After the equations are summarized and the variables are defined, the equations are first estimated using data from 1955 through 1969. They are then estimated with data from the 1970s. Of primary interest is the stability of the relationships when data from the 1970s are incorporated into the estimates.

Specifications and Definitions of Variables

The GNP equation is specified as follows:

$$(5)\ \dot{Y} = a_0 + \sum_{i=0}^{5} m_i \dot{M}_{-i} + \sum_{i=0}^{5} e_i \dot{E}_{-i},$$

where

- $\dot{Y}$ = compounded annual rate of change of nominal GNP,
- $\dot{M}$ = compounded annual rate of change of M1 (plus ATS deposits and NY NOW accounts after III/78), and
- $\dot{E}$ = compounded annual rate of change of high employment federal expenditures.

This equation is essentially the same as that estimated

[4] See Yash P. Mehra, "An Empirical Note on Some Monetarist Propositions," *Southern Economic Journal* (July 1978), pp. 154-67.

[5] For example, see Leonall C. Andersen and Keith M. Carlson, "A Monetarist Model for Economic Stabilization," this *Review* (April 1970), pp. 7-25, and William G. Dewald and Maurice N. Marchon, "A Modified Federal Reserve Bank of St. Louis Spending Equation for Canada, France, Germany, Italy, the United Kingdom and the United States," *Kredit and Kapital* (1978), pp. 194-212.

[6] Charles R. Nelson, "Recursive Structure in U.S. Income, Prices, and Output," *Journal of Political Economy* (December 1979), pp. 1307-27.

[7] Additional justification for the $\dot{Y}$-$\dot{P}$ combination is found in Thomas A. Gittings, "A Linear Model of the Long-Run Neutrality of Money," *Staff Memoranda*, Federal Reserve Bank of Chicago (1979).

[8] The specifications summarized here are the "preferred" results of estimating a variety of specifications.

Table 1

Estimates of Reduced Form Equations with Pre-1970 Data (Sample Period: I/55-IV/69)[1]

$$\text{GNP equation: } \dot{Y} = \underset{(3.557)}{3.575} + \Sigma m_i \dot{M}_{-i} + \Sigma e_i \dot{E}_{-i}$$

m_0	.275 (1.653)	e_0	.066 (1.148)
m_1	.430 (5.082)	e_1	.070 (2.001)
m_2	.345 (3.486)	e_2	.024 (.661)
m_3	.139 (2.038)	e_3	–.039 (1.678)
m_4	–.067 (.837)	e_4	–.086 (3.265)
m_5	–.154 (1.679)	e_5	–.084 (2.788)
Σm_i	.966 (4.054)	Σe_i	–.051 (.561)

R^2 = .438; S.E. = 3.361; and D.W. = 1.934.

$$\text{Price equation: } \dot{P} = \underset{(.133)}{-.049} + \Sigma n_i \dot{M}_{-i} - \underset{(.509)}{.030} (\dot{P}_F - \dot{P}) + \Sigma f_i (\dot{P}_E - \dot{P})_{-i},$$

n_0	.042 (1.077)	n_{11}	.062 (4.321)	f_0	–.002 (.062)
n_1	.036 (1.365)	n_{12}	.065 (4.433)	f_1	.004 (.230)
n_2	.033 (1.811)	n_{13}	.068 (4.293)	f_2	.007 (.358)
n_3	.032 (2.220)	n_{14}	.068 (4.014)	f_3	.007 (.381)
n_4	.033 (2.318)	n_{15}	.067 (3.703)	f_4	.005 (.262)
n_5	.035 (2.309)	n_{16}	.063 (3.414)	f_5	.003 (.149)
n_6	.039 (2.400)	n_{17}	.057 (3.164)	Σf_i	.024 (.279)
n_7	.043 (2.631)	n_{18}	.048 (2.953)		
n_8	.048 (2.995)	n_{19}	.036 (2.777)		
n_9	.053 (3.463)	n_{20}	.020 (2.629)		
n_{10}	.058 (3.954)	Σn_i	1.008 (7.420)		

R^2 = .559; S.E. = 1.094; and D.W. = 1.996.

[1]All polynomial distributed lags are third degree with tail constraint only; figures in parentheses are absolute values of t-statistics; a dot over a variable indicates compounded annual rate of change.

by Andersen and Jordan in 1968,[9] but modified so that the coefficients are constrained on a third degree polynomial distributed lag with t — 6 = 0.

The price equation is specified as follows:

$$(6)\ \dot{P} = b_0 + b_1D_1 + b_2D_2 + b_3(\dot{P}_F - \dot{P}) + \sum_{i=0}^{20} n_i\dot{M}_{-i} + \sum_{i=0}^{5} f_i(\dot{P}_E - \dot{P})_{-i},$$

where

$\dot{P}$ = compounded annual rate of change of the GNP deflator,

D_1 = wage and price control dummy,

D_2 = decontrol dummy,

$\dot{P}_F$ = compounded annual rate of change of the food deflator,

$\dot{M}$ = compounded annual rate of change of M1 (plus ATS deposits and NY NOW accounts after III/78), and

$\dot{P}_E$ = compounded annual rate of change of producer prices for fuels, related products, and power.

This specification builds on one developed by Karnosky except that it introduces variables designed to capture the influence of nonmonetary shocks on the

[9]Leonall C. Andersen and Jerry L. Jordan, "Monetary and Fiscal Actions: A Test of Their Relative Importance in Economic Stabilization," this *Review* (November 1968), pp. 11-24.

price level.[10] The polynomial distributed lag is third degree for both money and energy prices with constraints of $t - 21 = 0$ and $t - 6 = 0$, respectively.

Results Using Pre-1970 Data

Table 1 summarizes the estimated equations using data prior to the onset of the shocks of the 1970s. For the 1955-69 period, GNP was dominated by movements in the money stock, and the adjustment to these changes was essentially complete after five quarters. The elasticity of GNP with respect to the money stock, as measured by the sum of the coefficients on money, was not significantly different from one at the 5 percent level and implied that the elasticity of velocity with respect to money was zero. With the sum of the coefficients on high employment expenditures not significantly different from zero, the constant term was an estimate of the trend growth of velocity. Based on these estimates, the equilibrium growth rate of GNP during the 1955-69 period was equal to the growth rate of money plus the trend rate of change of velocity.

According to the estimated price equation, the rate of change of the price level was also dominated by the growth rate of the money stock in the 1955-69 period. Other factors, namely food and energy prices, were not significant in explaining overall price movements during this period, thus confirming Karnosky's estimate for essentially the same period. The pattern of the estimated coefficients indicated that prices adjust to a monetary shock very slowly, but the total effect after 20 quarters was an elasticity of the price level equal to one. Since neither the constant term

[10]Denis S. Karnosky, "The Link Between Money and Prices — 1971-76," this *Review* (June 1976), pp. 17-23.

Table 2
Estimates of the GNP Equation[1]

$$\dot{Y} = a_0 + \Sigma m_i \dot{M}_{-i} + \Sigma e_i \dot{E}_{-i}$$

	I/55-IV/69			I/70-IV/79			I/55-IV/79		
	Coeff.	t	Cum.[2]	Coeff.	t	Cum.[2]	Coeff.	t	Cum.[2]
m_0	.275	1.653	.275	.657	2.358	.657	.407	2.968	.407
m_1	.430	5.082	.704	.376	2.279	1.033	.407	5.344	.815
m_2	.345	3.486	1.049	.169	.986	1.201	.282	3.271	1.096
m_3	.139	2.038	1.187	.031	.243	1.232	.104	1.782	1.200
m_4	–.067	.837	1.120	–.040	.242	1.193	–.052	.752	1.148
m_5	–.154	1.679	.966	–.049	.282	1.144	–.111	1.415	1.037
Σm_i	.966	4.054		1.144	2.350		1.037	6.115	
e_0	.066	1.148	.066	.039	.544	.039	.053	1.211	.053
e_1	.070	2.001	.136	.068	1.041	.106	.055	1.805	.107
e_2	.024	.661	.159	.079	1.248	.186	.023	.768	.130
e_3	–.039	1.678	.120	.076	1.491	.261	–.021	1.008	.109
e_4	–.086	3.265	.033	.060	1.067	.321	–.054	2.203	.056
e_5	–.084	2.788	–.051	.034	.627	.355	–.054	2.064	.001
Σe_i	–.051	.561		.355	1.613		.001	.014	
a_0	3.575	3.557		–1.078	.262		3.159	3.437	
R^2		.438			.272			.410	
S.E.		3.361			3.934			3.620	
D.W.		1.934			2.331			1.924	

[1]All polynomial distributed lags are third degree with tail constraint only; t-statistics are absolute values; a dot over a variable indicates compounded annual rate of change.

[2]Numbers are the cumulative sum of coefficients.

Table 3
Estimates of the Price Equation[1]

$$\dot{P} = b_0 + b_1D_1 + b_2D_2 + b_3(\dot{P}_F - \dot{P}) + \Sigma n_i\dot{M}_{-i} + \Sigma f_i(\dot{P}_E - \dot{P})_{-i}$$

	I/55-IV/69			I/70-IV/79			I/55-IV/79		
	Coeff.	t	Cum.[2]	Coeff.	t	Cum.[2]	Coeff.	t	Cum.[2]
n_0	.042	1.077	.042	.056	1.087	.056	.061	1.969	.061
n_1	.036	1.365	.078	.087	2.183	.143	.064	3.006	.125
n_2	.033	1.811	.112	.110	3.095	.253	.067	4.360	.192
n_3	.032	2.220	.144	.126	3.419	.379	.068	5.300	.260
n_4	.033	2.318	.177	.134	3.322	.513	.069	5.303	.329
n_5	.035	2.309	.212	.137	3.076	.650	.069	4.967	.397
n_6	.039	2.400	.251	.134	2.794	.784	.068	4.717	.465
n_7	.043	2.631	.295	.127	2.505	.910	.066	4.625	.531
n_8	.048	2.995	.343	.116	2.211	1.026	.064	4.668	.596
n_9	.053	3.463	.396	.102	1.909	1.128	.061	4.790	.657
n_{10}	.058	3.954	.454	.086	1.600	1.215	.058	4.889	.715
n_{11}	.062	4.321	.516	.069	1.284	1.284	.054	4.806	.770
n_{12}	.065	4.433	.582	.052	.967	1.335	.050	4.422	.820
n_{13}	.068	4.293	.649	.034	.655	1.370	.046	3.804	.866
n_{14}	.068	4.014	.717	.018	.355	1.388	.041	3.139	.907
n_{15}	.067	3.703	.784	.004	.074	1.391	.036	2.554	.942
n_{16}	.063	3.414	.848	–.008	.185	1.383	.030	2.085	.972
n_{17}	.057	3.164	.905	–.017	.419	1.366	.024	1.718	.996
n_{18}	.048	2.953	.953	–.021	.627	1.345	.018	1.432	1.015
n_{19}	.036	2.777	.989	–.020	.811	1.326	.012	1.208	1.027
n_{20}	.020	2.629	1.008	–.013	.971	1.312	.006	1.030	1.033
Σn_i	1.008	7.420		1.312	1.706		1.033	11.459	
f_0	–.002	.062	–.002	–.001	.060	–.001	.008	.909	.008
f_1	.004	.230	.003	.019	3.490	.019	.024	5.151	.031
f_2	.007	.358	.009	.025	4.195	.044	.026	5.105	.058
f_3	.007	.381	.016	.021	3.916	.064	.020	4.971	.078
f_4	.005	.262	.021	.012	1.835	.076	.011	2.179	.089
f_5	.003	.149	.024	.003	.523	.079	.002	.469	.091
Σf_i	.024	.279		.079	3.064		.091	5.274	
b_0	–.049	.133		–1.522	.345		–.018	.052	
b_1	—	—		–2.193	3.487		–2.256	3.801	
b_2	—	—		–1.655	1.846		–.316	.407	
b_3	–.030	.509		.130	1.833		.060	1.273	
R^2		.559			.802			.819	
S.E.		1.094			1.262			1.268	
D.W.		1.996			2.180			1.735	

[1]All polynomial distributed lags are third degree with tail constraint only; t-statistics are absolute values; a dot over a variable indicates compounded annual rate of change; D_1 and D_2 are wage and price control and decontrol dummies, respectively.

[2]Numbers are the cumulative sum of coefficients.

Table 4
Results of Chow Test (I/55-IV/69 vs. I/70-IV/79)

	Critical F	Calculated F	Conclusion
GNP equation	$F_{.05\ (7,86)} = 2.12$	1.20	Cannot reject H_0[1]
Price equation	$F_{.05\ (8,80)} = 2.05$	3.23	Reject H_0

[1]H_0 is the null hypothesis that the regression equations are equal for the two sample periods.

nor the effect of nonmonetary shocks were significantly different from zero, the equilibrium rate of change of the price level during this sample period was equal to the rate of monetary growth.

These two estimated equations implied that the equilibrium rate of output growth was independent of the rate of monetary expansion during the 1955-69 period. This implication was derived from an examination of the elasticity estimates in conjunction with equations 3 and 4; $\varepsilon(Y,M) = 1$ and $\varepsilon(P,M) = 1$ together implied that $\varepsilon(X,M) = 0$. In other words, these estimated reduced form equations substantiated the hypothesis that monetary actions have lasting effects on only nominal variables.

Updated Results

Tables 2 and 3 present the results using data from the 1970s. For purposes of comparison, the pre-1970 estimates are also summarized. The Chow test was used to check the equations for stability.

Estimated Equations — Updated estimates for the GNP equation are shown in table 2 and for the price equation in table 3. Results are shown both for the 1970s (I/70-IV/79) and for the extended sample period (I/55-IV/79).

The sum of the coefficients on money in the GNP equation was not significantly different from one at the 5 percent level, either for the 1970-79 period or for the fully extended sample period 1955-79. Estimates of the constant, however, indicated a decline in the trend growth of velocity when data for the 1970s were included. For the 1970-79 sample period, the estimated constant was negative but not significantly different from zero at the 5 percent level. For the fully extended sample period, however, the constant was positive and significantly different from zero, but the point estimate was less than that for the 1955-69 period.

The estimate of the price equation for the 1970-79 period showed an increase in the sum of the coefficients on money. However, this sum was not significantly different from zero at the 5 percent level. For the fully extended sample period, the sum of the money coefficients was significantly different from zero, although not significantly different from one at the 5 percent level.

Estimates of the remaining coefficients indicate that nonmonetary factors, namely energy prices and wage and price controls, influenced price level movements during the 1970s, and to such an extent that they were also significant over the full sample period. Estimates of the constant term for both the 1970-79 and 1955-79 periods were not significantly different from zero at the 5 percent level.

Tests for stability — The updated results suggest some conflicting conclusions. The Chow-test of stability was used to investigate further the appropriateness of simply extending the sample period to include the 1970s.[11] Table 4 summarizes the results of applying this test to the GNP and price equations.

The test results show that the hypothesis of stability for the GNP equation for the two sample periods was not rejected. However, the hypothesis of stability was rejected for the price equation. The interpretation of these results is that the GNP equation, as estimated over the full sample period, can be used to summarize that relationship. However, the choice of the estimated price equation depends on the period that is chosen for analysis.[12]

Implications of the Results for the Relationship between Money and Output

One implication of the reduced form results using data prior to 1970 was that the equilibrium rate of

[11]Gregory Chow, "Tests of Equality Between Sets of Coefficients in Two Linear Regressions," *Econometrica* (July 1960), pp. 591-605.

[12]These price equations should not be interpreted as long-run equations, however, because the sample periods are so short. See footnote 3.

output growth was independent of monetary growth. In other words, trend output was determined by real factors: namely, growth of the labor force, capital stock, and technology.

When the reduced form equations were updated with data from the 1970s, the implication for equilibrium output was modified. In a strict statistical sense, the hypothesis that monetary actions have lasting effects only on nominal variables was not rejected when data from the 1970s were included in estimating the relationships. However, when the estimated GNP equation for the full sample period was combined with the price equation for the 1970-79 period, the growth of money appeared to influence the rate of growth of output. Although $\varepsilon(Y,M)$ was still approximately one, the point estimate of $\varepsilon(P,M)$ was 1.31. Consequently, based on the experience of the 1970s, the point estimate of $\varepsilon(X,M)$ was —.31.

The nature of this result, although statistically tentative, is summarized in table 5. Underlying the calculations in this table is the assumption that nonmonetary shocks equal zero. These results, although they do not demonstrate causality, provide indirect support for the view that there is a negative relation between the trend rate of monetary growth (and inflation) and the trend rate of economic growth.

This contention that inflation adversely affects output has received increasing emphasis in the recent literature.[13] One view is that inflation slows growth by discouraging investment and saving via the existing tax structure.[14] The inflation process increases effective tax rates for both individuals and firms and lowers after-tax rates of return, thereby reducing incentives to invest and save.

Another argument stresses the uncertainty associated with inflation.[15] If higher and higher inflation rates also mean greater risks associated with investment planning, saving and investment will be discouraged because a given expected rate of return will be accompanied by a greater variance.

Table 5

Relationship between Trend Output and Money Growth

Rate of growth of money	Rate of growth of output based on: Pre-1970 results[1]	Updated results[1]
0%	3.62%	4.68%
2	3.54	4.13
4	3.46	3.58
6	3.37	3.03
8	3.29	2.48

[1]These calculations are based on the point estimates of the parameters in the GNP and price equations and assume that nonmonetary influences are equal to zero except for the constant terms.

Still another explanation of the inflation-growth connection is that the inflation process introduces "noise" into the price signals that are transmitted from consumers to producers.[16] As a result, the general efficiency of the price system in allocating resources is reduced. Such a reduction must be manifested in a reduced growth rate of output.

SUMMARY

This article presents updated reduced form results relative to the hypothesis that monetary actions have a lasting impact on only nominal variables. When data from the 1970s were included in the sample, this hypothesis could not be rejected for either the 1970-79 period or the 1955-79 full sample period.

When the reduced form equations were tested for stability over the entire period, the hypothesis of stability for the GNP equation could not be rejected; but the null hypothesis for the price equation was rejected. When the GNP equation for the fully extended sample period was combined with the price equation for the 1970-79 period, the point estimates of the coefficients suggested that the rate of growth of output was negatively related to the growth rate of money during the 1970s. Even though only suggestive, the results provide tentative evidence to support the notion that real economic gain can be achieved by reducing the trend growth of money.[17]

[13]For general discussions of possible factors contributing to the slowdown of productivity in the 1970s, see Edward F. Denison, "Explanations of Declining Productivity Growth," *Survey of Current Business* (August 1979), pp. 1-24; and John A. Tatom, "The Productivity Problem," this *Review* (September 1979), pp. 3-16.

[14]A recent study providing evidence relating to the effect of inflation on corporate rates of return is reported in Martin Feldstein and Lawrence Summers, "Inflation and the Taxation of Capital Income in the Corporate Sector," *National Tax Journal* (December 1979), pp. 445-70.

[15]See Stephen L. Able, "Inflation Uncertainty, Investment Spending, and Fiscal Policy," Federal Reserve Bank of Kansas City *Economic Review* (February 1980), pp. 3-13.

[16]Milton Friedman, "Nobel Lecture: Inflation and Unemployment," *Journal of Political Economy* (June 1977), pp. 451-72.

[17]Laurence H. Meyer and Robert H. Rasche, "On the Costs and Benefits of Anti-Inflation Policies," this *Review* (February 1980), pp. 3-14.