because the trends are masked by cyclical and other temporary random fluctuations. In chart 1 we have plotted the correlation coefficient calculated between M-1B growth in period t and each of the changes in the GNP deflator in period t and the 16 quarters following. Few of the correlation coefficients are greater than two standard deviations. Only the correlations calculated at 7, 8, 9, and 10 quarters are significant at a 95 percent confidence level.

We have included some results using regression analysis in the appendix. To summarize briefly—regardless of the definition of the money supply used—the best fitting specifications are those including 16 lagged quarters of money supply growth. The most significant impacts of money growth on inflation occur in the sixth through the twelfth lagged quarters. These results are consistent with the correlations presented in chart 1.

Conclusion

The evidence indicates that we should expect to wait a substantial period of time between the achievement of slower money growth and subsequent reports of lower inflation rates. Precisely how long will depend on the speed with which people recognize the change in money supply growth and adjust their expectations. If slower money growth results in rapidly changing expectations, reported inflation will fall more quickly. Past inflation is embodied in contracts that may tend to slow the inflation-suppressing effects of reduced money growth. Even the most optimistic estimates indicate a lag well in excess of one year before reduced money supply growth has a significant effect on inflation. It may be as long as four years before the full effect is felt. It is possible that the negative short-run output and unemployment effects of the slower money growth will be substantial. However, these short-run effects are both less certain and less enduring than the adverse long-run price effects of fast money growth.

Appendix

Using regression analysis, we have estimated the relationship between the growth rate of the GNP deflator and various definitions of the money supply. Both theory and the evidence suggest that the short-term (quarter-to-quarter) change in the aggregate price level depends on many factors other than the money supply. However, the non-monetary shocks have only a temporary effect unless they are accommodated by an increasing money supply.

The model used to generate the results in table 2 is given in equations 1 and 2:

$$(1)\ P_t = \sum_{i=0}^{n} m_i M_{t-i} + U_t .$$

$$(2)\ U_t = \rho U_{t-1} + \epsilon_t .$$

In equation 1, the GNP deflator (P) was regressed on past values of the money supply (M). All variables were transformed by taking the first difference of the logarithm (approximating continuous rates of change). Various lags (n = 8, 12, 16, and 20) were used on the money supply, defined alternatively as the St. Louis base, M-1A, M-1B, and M-2. Preliminary results indicated the presence of positive autocorrelation in the residuals (U), so the Cochrane-Orcutt technique was used to estimate the autocorrelation coefficient (ρ) in equation 2. To preserve degrees of freedom and to adjust for multicollinearity in the money growth series, the pattern of the weights (m_i) was constrained to fit a third-order polynomial with no endpoint constraints. Summary statistics are given in table 2. Some interesting results emerged. For every monetary variable the lowest standard error (SE) of the regression was in the equation with 16 lagged quarters; that is, the full effect of a change in money supply growth on inflation occurs over a four-year period.

Using the smallest standard error of the regression as the criterion, M-1B best "explains" this measure of inflation. Other criteria that might be used include the sum and the distribution of the lagged coefficients. A sum equal to one implies that a steady growth rate of money will lead to an inflation rate equal to the money growth rate. Coefficients greater than one reflect growth in velocity.[2] We can reject the hypothesis that the sum of the coefficients is equal to zero in all cases.

The autocorrelation parameter was significant in every instance. This systematic behavior of the error term suggests that there are variables missing from equation 1. This is a quarterly model of inflation. All of the non-monetary variables that affect price indexes through demand or supply in the short run have been omitted. The point here is not to forecast or "explain" short-run growth in the GNP deflator; rather, it is to show a long-term relationship between money growth and this inflation index.

Table 2 Estimates of the Price Equation
1964:IIQ – 1980:IIIQ

n	Σm_i	H_o: Σm_i=1 t	H_o: Σm_i=0 t	SE	ρ
St. Louis Base					
20	0.883	−1.36	10.27	1.474	0.637
16	0.905	−1.20	11.46	1.473	0.639
12	0.885	−1.60	12.29	1.480	0.637
8	0.864	−1.81	11.52	1.474	0.657
M-1A					
20	1.136	1.60	13.36	1.449	0.562
16	1.140	1.82	14.81	1.429	0.553
12	1.130	1.73	15.07	1.448	0.558
8	1.078	0.73	10.07	1.533	0.685
M-1B					
20	1.089	1.17	14.33	1.417	0.512
16	1.105	1.52	16.01	1.403	0.508
12	1.097	1.49	16.88	1.416	0.514
8	1.047	0.57	12.77	1.486	0.619
M-2					
20	0.707	−5.33	12.85	1.432	0.618
16	0.712	−5.33	13.19	1.429	0.613
12	0.700	−5.17	12.07	1.475	0.639
8	0.639	−3.80	6.73	1.608	0.768

NOTE: Reject H_o with a critical region of 5 percent if the absolute value of t is greater than or equal to 1.96.

2. For a discussion of the aggregates and economic activity, see John B. Carlson and Theresa Gwazdauskas, "The New Aggregates, Economic Activity, and Monetary Policy," *Economic Commentary,* Federal Reserve Bank of Cleveland, March 10, 1980.

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Inflation, Interest Rates, and Monetary Growth

by William T. Gavin

On October 6, 1979, the Federal Reserve System changed its operating procedures for monetary policy. The period following that change has been one of turbulence in the money and capital markets. Not only have interest rates risen to unprecedented heights, but both interest rates and money supply growth have been unusually volatile. During this period, the objectives of the Federal Reserve have remained constant—to reduce inflationary pressures and eventually the level of interest rates by gradually lowering the growth of the money stock. In principle, the growth of the money stock could be constrained by controlling either interest rates or bank reserves. Under the former operating procedure, the Federal Reserve estimated the relationship between interest rates and the money supply, then "targeted" the interest rate on federal funds in a narrow range that was estimated to be consistent with desired monetary growth. This procedure proved to be unsatisfactory, because the relationship between interest rates and the money supply changed as inflation accelerated and because changes in interest rates were often not large enough to control money supply growth. In this environment adherence to interest-rate targets caused money growth to deviate further and further from desired targets.

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The opinions stated herein are those of the author and not necessarily those of the Federal Reserve Bank of Cleveland or of the Board of Governors of the Federal Reserve System.

Under the new procedure, the relationship between the supply of reserves and money is estimated, and operating targets are set for reserves. The relationship between reserves and the money supply may be no less likely to change in the short run than the relationship between interest rates and the money supply. However, if there is a change, the operation of the new procedure initiates adjustments in bank reserves and subsequently market interest rates that tend to return the money supply growth to its desired path.[1] The desired paths, or, more accurately, the target ranges for each of the monetary aggregates, are chosen by the Federal Open Market Committee (FOMC). Each year the FOMC must report its plans to Congress pursuant to the Full Employment and Balanced Growth Act of 1978 (the Humphrey-Hawkins Act). Because the Federal Reserve has selected targets that are low enough to slow inflation, we can expect continued pressure in the credit markets. To see why this pressure is necessary, it is important to understand the basic relationships between inflation, interest rates, and the money supply—the topic of this *Economic Commentary.*

Inflation

Inflation is defined as "an increase in the volume of money and credit relative to available goods resulting in a substantial and

1. For a detailed discussion of the mechanics of the new operating procedure, see E.J. Stevens, "The New Procedure," *Economic Review,* Federal Reserve Bank of Cleveland, forthcoming.

continuing rise in the general price level" (*Webster's New Collegiate Dictionary,* 1973 ed.). More precisely, inflation is a *substantial and continuing* increase in the volume of money and credit relative to available goods, resulting in a substantial and continuing rise in the general price level. There is an important distinction between this definition and a popular misconception that results from our attempts to measure the general price level. By necessity, the general price level is measured by assessing prices of individual goods and services and constructing indexes, such as the consumer price index (CPI), the wholesale price index (WPI), and the GNP deflator. Through this procedure, we tend to think of inflation as an increase in the price indexes so that any increase in an index is labeled "inflation." Yet many individual price increases that affect the CPI or the WPI are not truly inflationary. As an example, the drought in 1980 decreased the supply of many farm products. As food prices rose, so did all the price indexes that include food. In one sense, the increased prices of food caused inflation. In another and more important sense, they did not. If we do not have a drought in 1981 and if everything else is unchanged, the price of the farm-product component of food will return to its previous level.

Inflation causes a continuing increase in the general price level. Such an increase is not likely to occur unless it causes or is accompanied by a substantial and continuing increase in the volume of money and credit relative to available goods. Moreover, inflation is generally reflected in corresponding movements in the prices of all goods and services, as even the most cursory examination of the upsweep in prices in the past two decades demonstrates. The average annual inflation rate for the United States since 1961 is shown in table 1, column 2. In 20 years, the rate of increase in the GNP deflator has grown rather steadily from 1 percent in 1961 to 9.9 percent in 1980. The low rates in 1971-72 probably reflect the Nixon administration's wage and price controls. The high reported inflation rates in 1973 through 1975 reflect the relaxation of those controls and the temporary increase accompanying the quadrupling of world oil prices.

Table 1 Long-Run Trends in Prices, Money, and Interest Rates

Year	Inflation rate[a]	Money supply growth[b]	Corporate bond interest rate, percent[c]	*Ex post* real interest rate
1961	1.0	1.9	4.7	3.7
1962	2.0	1.2	4.6	2.6
1963	1.5	2.5	4.5	3.0
1964	1.4	3.2	4.6	3.2
1965	2.4	3.8	4.6	2.2
1966	3.7	4.0	5.3	1.6
1967	3.2	4.3	5.8	2.6
1968	4.6	5.2	6.5	1.9
1969	5.2	5.5	7.4	2.2
1970	5.0	5.2	8.5	3.5
1971	4.6	5.4	7.9	3.3
1972	4.0	5.9	7.6	3.6
1973	7.2	6.8	7.8	0.6
1974	10.5	6.0	9.0	−1.5
1975	7.2	5.5	9.6	2.4
1976	4.7	4.8	9.0	4.3
1977	6.1	5.8	8.4	2.3
1978	7.9	6.8	9.1	1.2
1979	8.5	7.9	10.1	1.6
1980	9.9	7.2	12.8	2.9

a. The inflation rate is measured as the average annual percent change in the GNP deflator.
b. This is a moving average of the past three years of M-1B growth. For example, the 1980 figure, 7.2, represents the average annual growth in M-1B for 1978, 1979, and 1980.
c. This interest rate is a simple average of the interest rates on Moody's Aaa, Aa, A, and Baa corporate bonds.

To illustrate the connection between past money growth and current inflation, the average money supply growth over the three previous years is shown in table 1, column 3. As is evident, there is no clear relationship between short-run changes in the money supply and the price level. However, the trends over time are clearly correlated.

The long-run relationship between the money supply and the price level is well understood and not a subject of controversy among economists. To understand why this relationship has been ignored in so many policy recommendations, we shall include a discussion of interest rates in our analysis.

Interest Rates and Inflation

Interest rates are determined in markets for loanable funds. Like other prices, interest rates fluctuate with changes in supply and demand. The market interest rate has two components—a premium for expected inflation and the real interest rate. The premium for expected inflation is the amount that borrowers must pay lenders so that the real value of the funds lent is maintained over the life of the contract. The real interest rate is the market interest rate minus the expected inflation premium.

Open market operations of the Federal Reserve System are a major determinant of the short-run supply function for loanable funds. A purchase of government securities by the Federal Reserve adds reserves to the banking system and leads to an increase in the amount of loans that banks can make. In the short run, this increase in the supply of reserves will cause interest rates to fall. In the long run, the opposite may be the case. If the supply of reserves continues to expand, inflation will accelerate and the expected inflation premium in the interest rate will rise (see table 1, column 4). The trend in the corporate bond interest rate corresponds to the trends in inflation and past money supply growth.

In column 5, the *ex post* real interest rate is calculated as the average corporate bond rate minus the increase in the GNP deflator. Viewed in this way, it is evident that real interest rates have not been high by historical standards. In the long run, the real interest rate is independent of both reported inflation and money supply growth. There is no trend in the real interest rate series, as there is in the other series.

The Money Supply

The money supply is a difficult variable to define empirically, because the word *money* has many meanings. The way the money supply is calculated depends on the way the calculations will be used. As a measure of transaction balances, the money supply usually is defined as currency plus checkable deposits (M-1B). As a measure of the store-of-value function, savings and various time deposits also are included (M-2). As a measure of the money supply in theoretical economic models, the monetary base is often used, because it represents government supply of fiat money and a control variable of the monetary authorities. The monetary base is the sum of currency in circulation plus bank reserves on deposit with the Federal Reserve System.

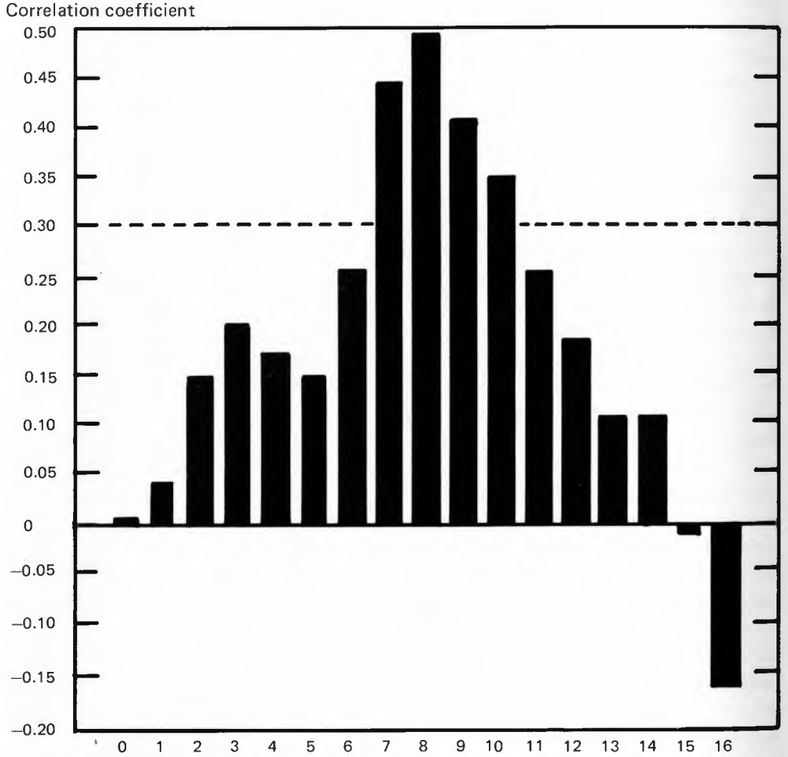
Practical problems in defining money have led the Federal Reserve to adopt multiple targets. Each aggregate moves differently over seasonal and cyclical periods. Even in the long run, the trends in each of the aggregates can vary, as many of the individual components respond differently with respect to technology, interest rates, and income. However, differences in long-run trends can be observed and incorporated into the target-setting stage in policy formulation. High inflation today reflects the fact that all of the aggregates have grown too rapidly in the past. Reversing this trend will cause interest rates to rise in the short run, but it will not have an immediate effect on prices. The lag between decreases in money growth and decreases in inflation is lengthy and variable. Moreover, it depends on how quickly people recognize the reduction in money supply growth and come to believe that it will persist. In other words, inflation expectations will not drop until a substantial and continual decrease is recognized. When money supply growth is reduced in the face of continuing inflation, interest rates rise and marginal credit demands are crowded out of the marketplace. This may lead to increased unemployment, which represents the temporary adjustment cost of an anti-inflationary policy. The benefits of this policy will come gradually as inflation begins to decrease.

Even though policy may be committed to slowing the long-run inflation rate by lowering the growth rates of the monetary aggregates, all of the theoretical and empirical evidence suggest that slowing money growth will not immediately slow growth in the aggregate price level. With the supply of funds to credit markets reduced, interest rates will rise in the short run. If the Federal Reserve persists in slowing money growth, however, we can expect inflation to slow and interest rates to fall as the expected inflation premium becomes smaller.

How long should we expect to wait before reduced money growth will lower reported inflation rates? While there is no definitive answer to this question, recent experience suggests that significant deflationary effects of slower money supply growth will show up in lower reported inflation rates in the second and third years following the deflationary policy. Changes in trend are difficult to discern from the data in table 1,

Chart 1 Correlations between M-1B Growth and Future Inflation Rates

1964:IQ – 1975:IIIQ



NOTE: The standard deviation is calculated as one over the square root of the sample size. The dotted line is drawn at two standard deviations.