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THE IMPACT OF MONETARY TARGETING IN THE UNITED STATES: 1976-1984

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ABSTRACT

This paper attempts to assess empirically the impact on output and inflation of monetary policy in the U.S. during the period of M1 targeting from 1976 to 1984. The impact of policy shocks on output and inflation, and the impact of aggregate demand, aggregate supply and money demand shocks on M1 and the Fed's target path, are examined through the use of impulse response functions. These response functions are based on an orthogonalization of VAR residuals derived from an estimated structural model. The VAR specification reflects the finding that M1 and the Fed's target for M1 are cointegrated.

The evidence suggests that money supply shocks and shocks to M1 target have accounted for little of the observed volatility of output or inflation. However, the induced policy response to aggregate demand and supply shocks has contributed to subsequent inflation.

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I. Introduction

From the first quarter of 1985 to the fourth quarter of 1986, M1 grew at a 14 percent annual rate while nominal GNP growth averaged only 5.1 percent. This divergent behavior has been interpreted by many as a breakdown in the relationship between money and nominal income, and it has led the Federal Reserve to at least temporarily abandon M1 targeting as a guide to monetary policy. This brings to an end a period during which monetary policy in the U.S. was generally framed in terms of M1 growth targets. It would seem, then, that now would be an opportune time to examine the impact of monetary targeting on both monetary policy and the economy during the 1976 to 1984 period of M1 targeting. During these years, the Fed was criticized both for adhering too closely to strict monetarist policies and for not adhering sufficiently tightly to such policies. It has even been questioned whether the monetary targets established by the Fed had any impact on the actual conduct of monetary policy at all. The frequent deviations from target paths that the Fed tolerated, as well as the Fed's practice of always using actual M1 as the base for establishing new target paths no matter how far from the old path actual M1 might be, led many to blame the Fed for excessive average inflation and inflation volatility.

The purpose of this paper is to assess empirically the impact of the Fed's monetary policy on real output and inflation during the period of M1 targeting. After briefly reviewing some aspects of the Fed's targeting procedures, section II discusses the criticisms the Fed's procedures have received. This discussion suggests ways in which empirical evidence can be used to determine whether monetary policy contributed to economic instability.

The basic approach to determining the impact of monetary policy involves an examination of impulse response functions and variance decompositions obtained by using an estimated structural model to orthogonalize VAR residuals. A general description of this approach is contained in section III, together with a discussion of the structural model and the estimation procedure. Section IV presents the empirical results, while section V contains a brief summary of the paper.

Several interesting conclusions emerge from the analysis. First, neither shocks to money supply growth nor to the target path seem to account for much output growth or inflation volatility during this period. This implies that what contribution monetary policy made to the volatility of these two variables was not due to autonomous policy shocks. Second, the induced response of monetary policy to economic shocks does seem to have contributed to higher inflation.

These conclusions must be viewed as very tentative because of several limitations from which the empirical analysis suffers. Most important of these is the shortness of the sample period. This has prevented an adequate treatment of the possible policy regime shifts that occurred during the 1976 to 1984 period. This is potentially a serious problem since several empirical relationships seem to have shifted in response to changes in Fed policy procedures. For example, Roley and Walsh [1985] report that the response of interest rates to weekly money supply announcements changed in response to changes in the Fed's operating procedures, and Huizinga and Mishkin [1986] find that the stochastic process describing real interest rates shifted in October 1979 and October 1982, both dates of monetary policy shifts.[1/]

Sufficient evidence exists to question the estimation of a single model over the entire 1976-1984 period. The scarcity of observations combined with the plethora of regimes, implies that one must be cautious when drawing conclusions from the empirical results presented in this paper. Hopefully, a model estimated over the entire period can still provide some useful information about the average impact of policy during this period.

II. Monetary Targeting

The Federal Open Market Committee (FOMC) of the Federal Reserve System has publicly announced target growth ranges for monetary aggregates since the passage of House Concurrent Resolution 133 in 1975. From the first quarter of 1976 until the passage of the Full Employment and Balanced Growth Act of 1978,[2/] the practice of the FOMC was to announce every quarter a target growth rate range for each monetary aggregate that would apply over a four quarter period. Thus, in February 1976, the FOMC set a target range of 4½% - 7% for M1 growth to apply to the period from 1975:4 to 1976:4. This target range was calculated from a base equal to the actual level of M1 during 1975:4. Three months later, the FOMC announced a four quarter target range, again 4½% - 7% to apply to the period 1976:1 to 1977:1. The base for this target range was the actual level of M1 during 1976:1.

This method of calculating the growth targets for M1 and the broader monetary aggregates resulted in quarterly base drift: each quarter, the base for the new growth ranges shifted to equal the actual level of money in the previous quarter. The effect of such base drift is to make permanent any deviations of actual money from the target path and introduce a unit root into the money supply process.

Under the Humphrey-Hawkins Act of 1978, the FOMC was required to establish target growth ranges every February for the calendar year. The FOMC would establish target ranges to apply from the fourth quarter of the previous year to the fourth quarter of the current year, calculated from a base equal to the actual value of the aggregate in the fourth quarter of the previous year. Thus, in February 1979, the FOMC announced a target range of 1½% - 4½% growth for M1 starting from the actual value of M1 in 1978:4. This new procedure replaced automatic quarterly base drift with automatic annual base drift.

The FOMC also reviewed its target ranges at mid-year and occasionally adjusted either the base or the target growth rate ranges. For example, in July of both 1983 and 1985 the FOMC responded to rapid M1 growth during the first six months of the year by using second quarter M1 as its new base for calculating growth paths and by adjusting the growth rate ranges.[3/]

The behavior of the log of M1 during the 1976 to 1984 period is shown by the solid line in Figure 1. The average annual growth rate from the fourth quarter of 1975 to the fourth quarter of 1984 was 7.4%.The dashed line in the Figure illustrates a hypothetical path for M1 derived from the successive midpoints of the target ranges set by the FOMC but maintaining the base at the actual level of M1 in 1975:4. This "no drift" series for M1 grew at an average annual rate of 5.5% from 1975:4 to 1984:4. The cumulative gap between these two lines represents one measure of the effect on the money supply of allowing base drift to occur. This measure is shown in Figure 2 as the dashed line. By the fourth quarter of 1984, M1 was roughly 15% higher than it would have been if it had always grown at the midpoint of the FOMC's successive growth rate ranges.

The solid line in Figure 2 plots the difference between actual M1 and the value implied for M1 by the midpoint of the then current target range.

Positive values reflect quarters when actual M1 was above the target midpoint; the series is negative when M1 was below the target midpoint. M1 exceeded the target midpoint in every quarter except one from 1976:4 through 1981:1. Another string of positive deviations occurred between 1982:2 and 1984:2, including the two largest target overshoots of the period in 1982:4 and 1983:1. Under the FOMC's policy of automatic base drift, each quarter's deviation prior to 1979:1 permanently affected the subsequent M1 path. After 1979:1, only fourth quarter deviations were impounded automatically into the target path.

The FOMC has frequently been criticized for allowing M1 to deviate from the midpoint growth rate implied by the target ranges -- particularly when M1 ended a target period outside the ranges altogether - and for then allowing target deviations to become permanent by using actual M1 as the base for subsequent target paths.[4/] Automatic base drift implies that the money stock will follow a random walk process, and such a process would seem to be inconsistent with a policy of price stabilization. It has also been claimed that, since base drift makes permanent any short-run deviations from target, it hinders the achievement of both stable money growth and stable prices over longer periods. Broaddus and Goodfriend [1984] discuss three major objections to base drift. First, it reduces the public's confidence in the Fed's commitment to maintaining stable, steady expansion of the money supply over the long-run. Second, by automatically "forgiving" any target misses, base drift greatly reduces the incentives for the Fed to hit its targets. Missing a target in one year imposes no penalty on the Fed in subsequent years since each year automatically starts on target. Third, temporary disturbances that cause money to deviate from target are allowed to permanently affect the money stock and, therefore, the price level. This leads to increased uncertainty about the future price level and reduces one of the advantages of monetary targeting.[5/]

Goodfriend [1986] has recently argued that the non-trend stationarity of both the money supply and the price level arises from the Federal Reserve's attempts to smooth nominal interest rates.[6/] The manner in which an interest rate smoothing objective by the monetary authority leads to a non-trend stationary price level can be illustrated by considering the impact of a random price level shock that leaves the real rate of interest unchanged.[7/] Any attempt to move the price level back to its initial level will generate non-zero expected inflation, thereby leading to nominal interest rate movements. The monetary authority can prevent nominal rates from moving by keeping the expected rate of inflation equal to zero. Hence, in this example, smoothing nominal interest rates is similar to smoothing expected inflation. In such an environment, the monetary authority can keep expected inflation always equal to zero as long as all price level movements are expected to be permanent. Thus, a disturbance that would otherwise result in a temporary price fluctuation will end up having a permanent effect on the price level because of the induced effect of monetary policy. In contrast, Goodfriend shows that, with price level smoothing objectives alone, the optimal price level is trend stationary.

The implications of Goodfriend's analysis can be illustrated in the following simple stochastic model:[8/]

$$R_t = E_t\, p_{t+1} - p_t + r; \tag{1}$$

$$m_t - p_t = \alpha_t - \beta R_t; \tag{2}$$

$$\alpha_t = \theta\alpha_{t-1} + a_t, \quad 0 \leq \theta \leq 1; \tag{3}$$

$$m_t = \delta_1\alpha_t + (e_t - \delta_2 e_{t-1}), \quad 0 \leq \delta_2 \leq 1; \tag{4}$$

$$e_t = e_{t-1} + \varepsilon_t. \tag{5}$$

The ex-ante real rate of interest is assumed to be equal to a constant, r, so the nominal rate R_t is given in equation (1) as r plus the expected rate of inflation. Equation (2) gives the demand for real money balances as a function of the nominal interest rate and a stochastic component, α_t, whose generating process is specified by equation (3). a_t is assumed to be a white noise disturbance term. For $0 \leq \theta < 1$, α_t follows a stationary stochastic process with finite unconditional variance $\sigma_a^2/(1 - \theta^2)$; for $\theta = 1$, α_t follows a random walk. A simple policy rule for the nominal money supply that assumes m_t can contemporaneously respond to the stochastic component of money demand is given by equation (4). e_t is a random walk control error where ε_t in (5) is a white noise disturbance assumed to be uncorrelated with a_t. The parameter δ_2 is taken to be a choice variable of the monetary authority (as is δ_1) that allows the policymaker to affect the degree of persistence the control error has on the level of the nominal money supply.

If bubble solutions are ruled out, it is straightforward to show that the equilibrium price level is given by

$$p_t = \frac{(\delta_1 - 1)}{1 + \beta(1-\theta_1)}\alpha_t + (1-\delta_2)e_t + \frac{\delta_2}{1 + \beta}(e_t - e_{t-1}) \tag{6}$$

and the nominal interest rate is equal to

$$R_t = \frac{(\delta_1-1)(\theta-1)}{1+\beta(1-\theta)}\alpha_t - \frac{\delta_2}{1+\beta}(e_t - e_{t-1}) + r. \tag{7}$$

Equations (6) and (7) show the potential conflict that exists between interest rate smoothing and price level stationarity. It is clear that money demand disturbances should always be completely accomodated ($\delta_1 = 1$) since that reduces the one step ahead forecast error variances of both p_t and R_t. However, interest rate smoothing also requires that $\delta_2 = 0$, while price level stationarity requires that $\delta_2 = 1$.

A choice of $\delta_2 = 0$ implies that m_t is non-trend stationary, so one could characterize the nonstationarity of p as caused by the nonstationarity of m. However, nonstationarity of m is neither necessary nor sufficient to generate price level nonstationarity. For example, if $\theta = 1$ but $\delta_1 = 0$, p will be nonstationary whether or not m is.

An alternative perspective that will prove useful in the empirical analysis is to note that if the unit root in p is induced by the unit root in m when $\delta_2 = 0$, then real money balances should be stationary. From (4) and (6),

$$m_t - p_t = \frac{1+\delta_1\beta(1-\theta)}{1+\beta(1-\theta)}\alpha_t + \frac{\beta\delta_2}{1+\beta}(e_t - e_{t-1})$$

$$= \frac{1+\delta_1\beta(1-\theta)}{1+\beta(1-\theta)}\alpha_t + \frac{\beta\delta_2}{1+\beta}\epsilon_t \tag{8}$$

Equation (8) shows that $\theta \neq 1$ is both necessary and sufficient for real money balances to be stationary. This result holds regardless of the values taken by the policy parameters δ_1 and δ_2.

If $\theta < 1$ and $\delta_2 = 0$, both p and m are nonstationary while m - p will be cointegrated (Engle and Granger [1986]).[9/] This is a testable hypothesis and will be examined in Section II. Evidence that cointegration can be rejected would indicate that the real demand for money is subject to permanent shocks ($\theta = 1$). In this case, a policy of steady growth in the money supply would still generate a random walk component to the price level as prices adjust to keep the real supply of money equal to real demand in the face of permanent shifts in demand. Nonstationarity of p would arise in this case even if the monetary authority placed no weight on interest rate smoothing as an objective of policy, and, instead, followed a constant growth rate rule for the money supply.

While the Fed's toleration of frequent target misses and its procedure of introducing a unit root into the money stock would certainly seem to create at least _a priori_ grounds for attributing inflation volatility, price level uncertainty and the non-trend stationarity of the price level to Federal Reserve policy, a non-trend stationary money stock can also arise even when the central bank's only concern is price stability if real money demand is nonstationary. Minimizing price forecast error variance requires that $\delta_1 = \delta_2 = 1$. In this case, p is stationary, but the nominal money supply, and real money balances will be nonstationary if $\theta = 1$. The money stock will itself follow a difference stationary process. However, the unit root in money, rather than inducing a unit root in prices, would in this case, prevent prices from having a random walk component.[10/] Evidence that Fed policy has introduced a unit root into the money supply process is not, therefore, sufficient to support the view that base drift has contributed to inflation volatility and price level uncertainty.

The joint behavior of money, the Fed's target for M1, and major macro variables can provide evidence on the impact of monetary policy during the targeting period. If the Fed has introduced a unit root into money in an attempt to limit the price adjustment required by persistent velocity and income shocks, money and prices will not be cointegrated. In addition, both velocity and output shocks should lead to adjustments in the target path and the actual money stock only to the extent that such shocks are persistent. Thus, evidence that temporary velocity or output shocks produce permanent movements in the target path would provide evidence that the FOMC's targeting practices have contributed to price instability.

Because a monetary policy concerned with price stability should offset money supply control errors ($\delta_2 = 1$), a finding that money supply shocks lead to persistent money supply and price movements would also indicate that Fed policy has contributed to price instability. Further evidence that the FOMC has, through its policy actions, contributed to inflation uncertainty would be a finding that either innovations to the target path or to the money supply itself account for a significant fraction of inflation volatility.

In assessing the impact of monetary policy, an important distinction must be made between the effects of policy shocks and the effects of induced policy responses. For example, a monetary authority might maintain perfect control over the money supply and eliminate all unpredicted money supply movements (i.e., no money shocks are allowed to occur), but still contribute to output and inflation volatility through its systematic reaction to economic disturbances. The opposite extreme would be a policy that allows no money supply movements in response to economic events but which, because of poor control techniques, permits frequent random shocks to the money supply. In judging an historical episode, it is useful to know whether the major effects of monetary policy arose through the systematic reaction of the monetary authorities to movements in income, inflation and interest rates or through unpredicted shifts in the monetary targets or the money supply itself.

This discussion suggests that a Vector Autoregression (VAR) incorporating the FOMC's monetary target, the actual money supply, and the aggregate price level, plus other macro variables, can shed light on the validity of the criticisms of FOMC procedures. Impulse response functions derived from an estimated VAR system can indicate whether the FOMC has allowed temporary output shocks or money demand shocks to produce persistent movements in money and prices. The contribution of money shocks and policy target shocks to inflation volatility can be assessed by examining the variance decomposition of inflation forecast errors.

To provide really useful information, however, it is necessary to identify orthogonalized money supply shocks, policy target shocks, etc. from the VAR residuals. The method by which a structural interpretation for the orthogonalized innovations is achieved is discussed in the next section, together with a description of the variables included in the VAR system and a discussion of the implications of cointegration for the specification of the variables in the VAR.

III. Empirical Specification

A. Cointegration and Stationarity

In order to investigate the impact of the FOMC's target paths, the approach to structural estimation used recently by Blanchard and Watson [1985], Bernanke [1985], Sims [1986], and Blanchard [1986] is adopted.

This approach combines a Vector Autoregression with restrictions imposed by a structural model in order to avoid the assumption, implicit in the standard calculations of variance decompositions and impulse response functions, that the variables in the system are related by a recursive structure.

Quarterly, seasonally adjusted data on five variables are incorporated in the empirical work: the natural log of real GNP (Y), the log of the GNP Price Deflator (P), the three-month Treasury bill rate (R), log M1 (M), and the log of a measure of the Fed's target for M1 (T). T_t is defined as the midpoint of the target range for log $M1_{t+1}$ as calculated from information known at time t. T is thus a forward looking measure of the target path, and it is constructed by applying the midpoint of the target range for t+1 in effect during t to the target base then in effect. For example, suppose the FOMC in February of year t announces a target range for M1 of 4% - 7% from a base of actual M1 in the fourth quarter of year t-1. Then, in July, suppose they revise the range to 3% - 6% for the rest of the year, but do not revise the base. Then, in the second quarter of year t, T would equal log M1 for the fourth quarter of year t-1 plus .04125 (the midpoint of 4%-7% growth for nine months expressed at a quarterly rate). For the third quarter, T would equal log M1 for the fourth quarter of year t-1 plus .0275 (six months growth at the midpoint of 4% - 7% plus .0225 (six months growth at the midpoint of the new 3% - 6% range). Refering to Figure 2 the solid line is equal to $M_t - T_{t-1}$.

A number of recent empirical studies have suggested that most macroeconomic variables are better represented as difference stationary, and not trend stationary, processes.[11/] It has become common, therefore, to specify VAR's in first difference form. However, Engle and Granger

[1986] point out that such a specification is incorrect if the system is cointegrated. A vector x is said to be cointegrated of order (1,1) if all elements of x are stationary in their first difference and there exits a nonzero vector α such that $\alpha'x$ is stationary.[12/] Before specifying the form of the VAR, it is necessary to consider the possibility that such a cointegrating vector α exists.

Three pairwise comparisons involving likely candidates for cointegration were examined - real money balances (M-P), the real value of the target variable (T-P), and the difference between the target and the current money stock (T-M). For each pair, the null hypothesis that the two variables are not cointegrated is tested.

The testing procedure can be illustrated with respect to M and P. If real money balances are stationary, then M and P are cointegrated with known cointegrating vector $\alpha' = (1,-1)$. A test of the null of no cointegration can be obtained by regressing the change in M-P on a constant and the lagged level of M-P. The test statistic is just the F-statistic for the joint significance of the two estimated coefficients. Under the null hypothesis of no cointegration, this test statistic does not have an F distribution, but Dickey and Fuller [1981] provide significance levels based on Monte Carlo results. A high value of the test statistic indicates rejection of no cointegration.

The Dickey-Fuller test statistics for M-P, T-P, and T-M are reported in part I of Table 1. At a 5% significance level, we cannot reject the null hypothesis that M-P and T-P are not cointegrated. This result casts doubt on the argument that the Fed generates non-trend stationarity of P and M while M-P is stationary. In contrast, the hypothesis that T-M is not cointegrated can be rejected. This reflects the fact that next quarter's target for M1 can never stray too far from the current level of M1. Note that this is consistent with a policy that keeps the target path fixed and returns M to the target path whenever it deviates from it, and with a policy that employs base drift so that the target is adjusted to ensure that it never gets too far from the actual money supply. The latter interpretation would seem to more closely describe Fed behavior.

As a check on these results, cointegration was tested under the additional hypothesis that the cointegration vector is unknown. That is, the null hypothesis is that, for example, M-αP is not cointegrated, with α unknown. Engle and Granger [1986] discuss several alternative tests based on the regression of M on P. This regression is called the cointegrating regression by Engle and Granger. Part II.A of Table 1 shows that for each of the three cointegrating regressions, the estimated α is essentially equal to one.13/

Three of Engle and Granger's test statistics are reported. The first, reported in part II.A, is just the Durbin-Watson statistic from the cointegrating regression. Under the null of no cointegration, the residuals will be nonstationary and the D-W will approach zero. Thus, a large D-W implies rejection of no cointegration. Based on Monte Carlo results, Engle and Granger report a 5% critical value for the D-W of 0.386. Only for T-M can the null be rejected. The second test regresses the change in the residuals from the cointegrating regression on their lagged level, and the test statistic is the t-statistic for the coefficient on the lagged residual term. This is reported in the row headed ξ_2 in part II.B of Table 1. The null can again be rejected only for T-M. Finally, the row headed ξ_3 reports the t-statistic on the lagged residual from the cointegrating regression in a regression with the change in the residual as the dependent variable and that includes, in addition to the lagged level, four lagged changes in the residual. This statistic provides the only conflicting results as it suggests the null cannot be rejected for any of the three cases.

The evidence clearly indicates that real money balances and the real value of the target variable are nonstationary. The pairs (M, P) and (T,P) are not cointegrated. However, three of the four tests indicate that T and M are cointegrated, and, for the subsequent analysis, this will be assumed to be the case.

It can be argued that the apparent non-trend stationarity of real money balances results from the positive income elasticity of the demand for real balances. The presence of a unit root in real income then induces nonstationarity in real money balances.[14/] This suggests that M-P and Y should be cointegrated with cointegrating vector $(1 -\alpha)$ where α is the income elasticity of real money demand. The estimate of α obtained from the cointegrating regression of M-P on Y, together with three test statistics for the null hypothesis of no cointegration are given in Table 2. The evidence appears consistent with the null of no cointegration.[15/]

These results have interesting implications for interpreting the implications for the prive level process of a policy that makes M follow a trend stationary process. The evidence that neither real money balances nor real balances adjusted for income are stationary suggests the demand for money is nonstationary. Therefore, the price level will be non-trend stationary even if the nominal money supply were to follow a constant growth rate path.[16/]

As previously mentioned, it has become common to enter variables in VAR systems in first differenced form in order to ensure stationarity. The evidence that T and M are cointegrated suggests specifying the VAR in terms of the first differences of the logs of output, the price level, the interest rate, and the money supply and the level of the target minus the money supply. Table 1 has provided evidence that T-M is stationary. Tests were also conducted for the presence of a unit root in the first differences of Y, P, R, and M.[17/] The null hypothesis of a unit root can be rejected at the 5% level for Y_t-Y_{t-1}, R_t-R_{t-1}, and M_t-M_{t-1}. However, this hypothesis is not rejected for the first difference of the price level. This evidence of a possible second unit root in the price level (a unit root in the rate of inflation) may explain the failure to reject the absence of cointegration for M and P since the tests were based on the assumption that M_t-M_{t-1} and P_t-P_{t-1} were stationary. Economic theory, however, would not imply a unit root in inflation if the growth rates of money and output are stationary. Regressing the inflation rate on a constant, a time trend and four lagged values of the inflation rate yielded a coefficient on the time trend with a marginal significance level of .062. Since neither money growth nor output growth have trends, this result is also hard to reconcile with standard aggregate models.[18/] It is worth noting, however, that all these tests may have little power, given the shortness of the sample period.

B. VAR Specification

On the basis of the tests for cointegration and stationarity reported in Section III.A, two alternative specification for the VAR system are suggested. One specification would include the first differences of Y, R, M and the rate of inflation and the <u>level</u> of T - M. The second would include the first differences of Y, R, M and P, the level of T-M, and a time trend. Only the empirical results obtained using this second specification will be presented, since it provides a more natural parallel treatment of all the variables. However, the VAR estimation and the structural model estimation (to be discussed below) were repeated using the second difference of p and excluding a time trend. The results obtained from this specification are presented in the appendix.[19/]

Define $Z'_t = (\Delta Y_t, \Delta P_t, \Delta R_t, \Delta M_t, T_t - M_t)$ where Δ denotes the first difference. It will be assumed that these five variables are linked by a set of structural equations of the form

$$AZ_t = B(L)Z_{t-1} + u_t \tag{9}$$

where A is an invertable 5 x 5 matrix, and B(L) is a 5 x 5 matrix of polynomials in the lag operator L. The vector u_t is a vector of independently distributed, serially uncorrelated "structural" disturbance terms with diagonal covariance matrix Σ_u. In the present context, the equations in (9) can be thought of as an aggregate demand equation, an aggregate supply equation, a money demand equation, a money supply equation, and a target setting equation.

Premultiplying both sides of (9) by A^{-1} yields

$$Z_t = D(L)Z_{t-1} + v_t \tag{10}$$

where $D(L) = A^{-1}B(L)$ and $v_t = A^{-1}u_t$. Equation (10) is in the standard form of a VAR, and it can be estimated by OLS to obtain consistent estimates of the VAR residuals v_t. In the present application, the estimation period for the VAR was 1977:1 -1984:4. A lag length of four was used, and a constant and time trend were included in each regression equation.[20/] In addition, a dummy variable equal to one from 1979:4 to 1982:3 and zero otherwise was included in a crude attempt to represent the effects of the period during which the Fed employed a nonborrowed reserve operating procedure.

The objective, however, is to obtain estimates of the response of each variable in Z to innovations in the structural disturbances u. The VAR residuals are equal to a linear combination of the structural disturbances given by $Av_t = u_t$. The now standard procedure for generating impulse response functions and variance decompositions involves orthogonalizing the VAR residuals using the Choleski decomposition of the sample covariance matrix $M = (1/T)vv'$. If S is a lower triangular matrix such that $SS' = M$, the transformed orthogonalized residuals with unit variance are given by $S^{-1}v$. If Q is the unique positive diagonal matrix such that $QQ' = \Sigma_u$ (i.e., the diagonal elements of Q are just the standard errors of the u_i's), then the structural model implies that the VAR residuals should be orthogonalized and scaled by premultiplying v by $Q^{-1}A$. $Q^{-1}A$ will generally not be lower triangular unless the structural relationships represented by the matrix A imply a recursive structure, so variance decompositions and impulse response functions derived from a Choleski decomposition will not give the effects of the structural shocks (the u_i's) on the variables of the system.[21/]

In order to use a decomposition that allows for a structural interpretation, it is necessary to estimate the unknown elements of A and Σ_u. From (9) and (10), $vv' = A^{-1} uu' A'^{-1}$. Equating population moments with sample moments,

$$M_l = A^{-1}\sum_u A'^{-1}. \tag{11}$$

Since M contains 5*6/2 = 15 bits of sample information, equation (11) gives 15 nonlinear simultaneous equations in the unknown elements of A and $\sum_u$. Thus, if there are 15 or fewer elements to estimate in A and $\sum_u$, the information in (11) can potentially be used to obtain estimates of the structural parameters of the model. Since there are 5 variances in $\sum_u$, there must be 10 or fewer nonzero elements of A.

Given a specification of the zeros in A, the actual estimation procedure employed is that of Generalized Method of Moments (GMM).[22/] Let θ be the 15 x 1 vector consisting of the stacked elements of M on and below the diagonal. Let $\bar{\theta}(\beta)$ be the corresponding vector of elements of $A^{-1}\sum_u A'^{-1}$, where β denotes the k x 1 vector of unknown parameters in A and $\sum_u$. Parameter estimates are obtained by minimizing the quadratic form

$$(\theta-\bar{\theta}(\beta))'W(\theta-\bar{\theta}(\beta))$$

with respect to the elements of β, where the weighting matrix W is given by

$$W = \{(1/T)\sum[(\theta_t-\theta)(\theta_t-\theta)']\}^{-1}$$

In this notation, the typical element of θ would be of the form $(1/T)\Sigma v_{it}v_{jt}$, while the corresponding element of θ_t is $v_{it}v_{jt}$. The asymtotic covariance matrix of the parameter estimates is estimated by

$$\{[\partial(\theta-\bar{\theta})/\partial\beta]'W[\partial(\theta-\bar{\theta})/\partial\beta]\}^{-1}$$

Under fairly general assumptions, the GMM estimators are consistent and asymtotically efficient.

In order to implement this procedure it is necessary to impose a priori restrictions on the elements of A and $\sum_u$. The covariance matrix $\sum_u$ is taken to be diagonal. The elements of A are chosen to represent a fairly standard, ad-hoc aggregate model. Let v' = (y, p, r, m t-m) be the residuals from the VAR system. By definition, $Av_t = u_t$. These five equations, reflecting the contemporaneous relationships in the structural relationships, are assumed to take the following form:

$$y_t - \alpha_1(r_t - {}_tp'_{t+1} + p_t) = u_{1t} \tag{12}$$

$$p_t - \alpha_2 y_t = u_{2t} \tag{13}$$

$$r_t - \alpha_3 y_t - \alpha_4(m_t - p_t) = u_{3t} \tag{14}$$

$$m_t - \alpha_5 y_t - \alpha_6 r_t - \alpha_7 p_t = u_{4t} \tag{15}$$

$$t_t - m_t - \alpha_8 y_t - \alpha_9 p_t - \alpha_{10} m_t = u_{5t}. \tag{16}$$

Equation (12) gives aggregate demand as a function of the expected real rate of interest. In the definition of the expected real interest rate, ${}_tp'_{t+1}$ denotes the effect of the current realization of v_t on expectations of p_{t+1}. This can be calculated using the coefficients from the estimated VAR.[23/]. The structural disturbance u_{1t} has the interpretation of an aggregate demand shock. Equation (13) is a Phillips Curve type relationship, with u_{2t} equalling an aggregate supply shock.[24/]

Equation (14) is a simple inverted money demand equation. Suppose the basic money demand equation takes the form $M - P = a_3Y + a_4R$, ignoring lagged terms and the disturbance term. The resulting relationship among the VAR residuals takes the form $a_3y + a_4r - (m-p) = \psi_t$. Normalizing on the interest rate yields equation (14) with $\alpha_3 = -a_3/a_4$, $\alpha_4 = 1/a_4$, and $u_3 = \psi_t/a_4$. u_3 is interpreted as a money demand shock.

Equations (15) and (16) capture the actions of the Federal Reserve in setting monetary policy. Equation (15) represents a money supply relationship that assumes the Fed allows nominal money supply growth to respond to income growth, nominal interest rate changes and inflation with u_4 equal to a money supply shock. The money target set for period t+1 is assumed to depend on current money growth, income growth, and inflation. u_5 has the interpretation of a shock to next quarter's money target.

It may appear that the model structure is recursive with respect to the target variable, since t only occurs in equation (16). However, this is not the case. Variations in t_t, the target for m_{t+1}, can, in principle, influence the expected rate of inflation. Through the real rate channel in equation (12), t_t can contemporaneously affect y_t, p_t, r_t and m_t.

IV. Empirical Results

It is useful to recall the questions motivating this study before the empirical results are examined. A major criticism of targeting as practiced by the FOMC is that monetary volatility contributed to output and price instability, and that allowing base drift let temporary control errors have permanent effects on prices. Evidence relevant for an evaluation of this critique would be provided by estimates of the impact of innovations in the target path and in the money supply on the subsequent path of money and prices, by estimates of the contribution of target uncertainty and money uncertainty to the volatility of output and prices, and by evidence on the induced policy response to aggregate demand shocks, money demand shocks and aggregate supply disturbances.

The first step in estimating the impact of target and money disturbances involves the estimation of the structural model outlined in the previous section using the residual covariance matrix obtained from the unrestricted VAR estimates. The residual covariance and correlations are reported in Table 3. The significant cross correlations indicate that impulse response functions and variance decompositions derived from a standard Choleski decomposition of the residual covariance matrix are likely to be sensitive to the chosen ordering. In order to employ an orthogonalization that allows a structural interpretation, equations (12) - (16) were estimated.

The GMM estimates obtained for the parameter of the structural model are presented in Table 4. In general, the estimates are relatively imprecise as judged from their asymptotic standard errors. However, several are statistically significant (9 of 15) and the signs of the estimates accord with a priori expectations.

The estimated contemporaneous effect of the expected real interest rate on output is essentially equal to zero. This implies that real output is predetermined with respect to the other contemporaneous variables of the system. In particular, there will be no contemporaneous effect of money or target shocks on output via the channel of expected future inflation.

A zero value for α_1 has two important implications for the current analysis. First, it implies that the model has a block recursive structure in which y is exogenous with respect to p, r, m, and t-m, while p is exogenous with respect to r, m, and t-m. In turn, this implies that the variance decompositions and impulse response functions derived by using the structural estimates to orthogonalize the VAR residuals will show effects of y and p shocks equivalent to those obtained using a standard Choleski decomposition with y and p placed first and second in the ordering. However, the Choleski decomposition assumes a recursive structure among all the variables of the system, while the exogeneity of y in the present model is estimated from the data. Table 4 gives the estimated matrix used to orthogonalize the VAR residuals and it shows that r and m are simultaneously related.[25/]

Second, $\alpha_1 = 0$ implies that the expectations channel by which the future money target might affect current output is nonoperative. Changes in next quarter's M1 target may influence expected inflation and real interest rates, but there is no contemporaneous output effect.

The estimated equation for the money supply shows a strong response to nominal interest rate movements ($\hat{\alpha}_6 = 3.01$). This seems consistent with the general perception that, even while expressing its goals in terms of monetary targets, the Fed has attempted to smooth interest rate movements.[26/] Money supply growth also appears to show little response to real output changes, but an increase in inflation tends to reduce it. The target variable seems to depend mainly on actual money and inflation. The negative coefficient on m_t might indicate some attempt by the FOMC to offset monetary control errors by adjusting down the target for money relative to m_t if current money growth has been high.

Of particular interest are the estimated variances of the structural disturbance terms, since these disturbances each have an intuitive interpretation.

Aggregate demand shocks are estimated to have the largest variance, although the asymptotic standard error is huge (886.0). The variance of aggregate supply shocks is only one eighth that of aggregate demand shocks, while the other variances are even smaller. Of particular interest is the fact that money supply shocks have a relatively small variance even though Table 3 shows that the variance of the one-step ahead forecast error for money in the VAR is second only to that for output. This implies that most of the one-step ahead forecast error in M1 growth is due, not to money supply shocks, but to the endogenous response of money to output, inflation, and interest rates.

The finding of a small variance for money demand shock would seem to contrast with the usual Fed emphasis on the importance of such disturbances. However, σ_3^2 is defined in terms of an equation normalized on the interest rate (equation (14)). The implied variance of the money demand function written with real money balances as the dependent variable is 0.4.[27/] This approaches the variance of aggregate demand shocks in magnitude and is more consistent with the standard Fed view.

The impact of monetary policy and monetary targeting on output and inflation will be studied in two steps. First, the effect of independent money supply shocks and disturbances to the target path will be examined. Second, the effect of the endogenous policy response to macro disturbances will be estimated. This distinction between policy disturbances and induced policy actions is important in assessing monetary policy.

A. Money Supply and Target Shocks

Using the estimated structural parameters, together with the VAR system, it is possible to examine the role played by money supply shocks and shocks to the target path in the determination of output growth and changes in the rate of inflation. Information on the importance of these disturbances can be gained from an examination of the variance decompositions implied by the model. The variance decompositions show the fraction of the forecast error variance of a variable attributable to each of the innovations in the system at various forecast horizons. As the forecast horizon approaches infinity, these equal the proportion of the unconditional variance of the variable due to each innovation source. The variance decompositions are presented in Table 5.

The variance decompositions indicate that independent money supply and target disturbances account for little of the forecast error variance of either output or inflation. These two disturbances explain less than 15 percent of the output growth forecast error variance at 24 quarters, and little more than 1 percent at a forecast horizon of 2 quarters. Interestingly, shocks to the target for future money seem more important than money supply shocks. Money supply and target shocks account for even less of the forecast error variance of inflation changes. Again, however, target shocks accounts for more of the inflation forecast error than do money supply shocks.

The variance decompositions for money and the target produce some interesting results. The Fed usually attributes deviation of money from target to the presence of money demand shocks, and Table 5 shows that money demand disturbances are important in explaining the variance of money forecast errors. In fact, almost 40 percent of the one-step ahead forecast error in money growth is attributed to money demand disturbances. But aggregate demand disturbances are even more important. The structural model attributes little of the target variance to money supply shocks and much more to aggregate demand, aggregate supply, money demand, and target disturbances.

The impulse response functions showing the effects of money supply and target shocks are shown in Figure 3. Panels 3a and 3b illustrate the impact on the levels of Y, P, M and T of a one-standard deviation realization of u_4. In 3a, a positive money supply shock tends to produce an output expansion with a three quarter lag. This is very quickly reversed, however, and output appears to cycle around the no-shock path. In contrast, the price level begins to rise after 8 quarters. The positive slope of the price level path after 2 years indicates that money supply shocks have permanent effects on the rate of inflation.

Panel 3b shows why a money supply shock tends to raise the rate of inflation. Money supply shocks during the period of monetary targeting were not subsequently reversed. As 3b shows, there is some initial offset to the shock so that the level of M moves back towards its no-shock value. However, after four quarters, this offset ends, and the rate of growth of M seems to be left permanently higher.[28/] The target path appears to follow the upward trend in money, although it exhibits large cycles around an upward trend.

Panel 3c shows that target shocks, like money supply shocks, initially generate a positive output response, followed by cycles in the level of output around the no-shock level. In contrast, the price level is above the no-shock path for five quarters following the shock to the target variable. Then, however, the price level appears to drift downward, suggesting a permanently lower rate of inflation. As shown by panel 3d, the lower rate of inflation is paralleled by a reduction in the rate of growth of the money supply. Somewhat paradoxically then, during this period of monetary targeting, upward shocks to the level of the target path ultimately were followed by a reduced rate of growth of the money supply and a fall in the rate of inflation.

Two general conclusions seem to emerge from this empirical analysis. First, innovations to the target path and to money growth explain little of the forecast error variance of output and prices. Second, positive money supply shocks do seem to generate higher rates of inflation. In contrast, positive target shocks lead to a somewhat lower subsequent rate of inflation.

These conclusions, however, do not shed light on the criticism that the Fed's induced response to economic disturbances has contributed to output and inflation volatility. Aggregate demand shocks, for example, may account for a large fraction of inflation forecast error variance precisely because of the Fed's attempt to dampen interest rate movements. It is necessary, therefore, to examine the induced effects of disturbances on money supply growth and the target growth rate.

B. Endogenous Policy Responses

In order to determine whether output, inflation, and money demand disturbances have induced monetary policy responses that have contributed to price instability, impulse response functions from the structural model are presented in Figures 4 - 6.

The estimated effect of an aggregate demand shock is shown in Figures 4a and 4b. An aggregate demand shock has a strong positive impact on output growth that is subsequently only partially reversed. The contemporaneous response of money growth is positive, but after one quarter money growth turns negative, reflecting perhaps a delayed attempt at stabilization policy. There appears to be no systematic long-run effect on either the growth rate of money or the level of M. The rate of inflation is also not permanently affected, but the price level is left higher by the aggregate demand shock.

The impact of an aggregate supply (inflation) shock, shown in Figure 5, provides evidence that the induced monetary policy response contributed to the inflationary impact of such shocks. Panel 5a shows that an aggregate supply shock causes the price level to grow at a roughly constant rate relative to the no-shock path. This permanent effect on the rate of inflation is mirrored by a permanent positive effect on the rate of money growth. Panel 5b shows that the money supply initially falls in response to the supply shock, but after 4 quarters, M has returned to its no-shock level and then exhibits a sustained increase in its rate of growth. The target reacts in a similar fashion, although the initial fall in the level of the path is larger than the fall in the actual money supply.

Figure 6 shows that money demand shocks are initially accommodated by a rise in the money supply. This is only partially offset; M and T are left permanently higher. Panel 6a shows that output reacts positively to a money demand shock. This may reflect the persistent positive money supply response to a temporary money demand disturbance. Initially, the money demand shock is offset by accommodative monetary policy. However, because the expansion in M is not subsequently reversed, there is a net expansionary effect on output. In addition, the price level rises and remains at a level slightly above the no shock path.

In the case of inflation shocks and money demand shocks, the evidence that emerges from these impulse response functions suggests that the induced response of the money supply contributed importantly to subsequent price and output movements. Only in the case of aggregate demand shocks was there no long-run response of the money supply. In all cases, the target path tends to follow the path of actual money. This reflects the fact the two variables are assumed to be cointegrated.

V. Summary and Conclusions

This paper represents a first step towards an evaluation of the conduct of monetary policy during the decade of monetary targeting. The empirical analysis found that neither money supply nor monetary target shocks seemed to account for much of the forecast error variances of output growth and inflation. The induced response of money growth to aggregate demand shocks also did not appear to contribute to higher inflation but the response to aggregate supply shocks did. The response of monetary policy to money demand shocks led to a permanently higher price level with no long-run effect on the rate of inflation.

While the results suggest that the Fed's response to economic disturbances contributed to inflation, this does not imply that steady money growth during this period would have induced stationary behavior in the price level. The failure to reject the null hypothesis that M1 and prices are not cointegrated indicates that the real demand for money is nonstationary. Thus, a nonreactive monetary policy that keeps M1 growing at a constant rate would also have produced nonstationary behavior in the price level.

It may be prudent to conclude by reviewing the limitations of the analysis that force any results to be viewed as preliminary in nature. The chief limitations arise from the shortness of the sample period together with the changes in Federal Reserve operating procedures which occurred in

October 1979 and October 1982. Even without such policy shifts, the empirical analysis relies on identifying restrictions imposed on the contemporaneous relations between the one-step-ahead forecast errors of the variables in the VAR system. These exclusion restrictions may be questioned, and the results might change if an alternative structure is imposed.

Despite the fact that there were changes in operating procedures, the period under study was one in which M1 targeting did provide a conceptual framework that guided monetary policy. For this reason, it is hoped that the empirical results obtained here may provide some indication of the impact of monetary policy between 1976 and 1984.

Footnotes

1. Walsh [1987a] discusses a potential problem with Huizinga and Mishkin's method of identifying real rate shifts.
2. This Act is better know as the Humphrey-Hawkins Act.
3. Each year, the Federal Reserve Bank of St. Louis publishes in its Review a useful analysis of the FOMC deliberations on setting targets during the previous year.
4. In one of the earliest attacks on base drift, Poole [1976] suggested, as an alternative procedure, that the midpoint of the previous year's target range, and not actual M1, be used as the new base. This recommendation was also proposed in the 1985 Economic Report of the President. In Figure 1, the dashed line is derived by applying this procedure. Deviations from target would no longer have permanent effects on the path of the money stock if this recommendation were adopted.
5. The Shadow Open Market Committee [1985] has recommended the elimination of base drift. See also M. Friedman [1982, 1985] and McCallum [1984].
6. For evidence that most macroeconomic time series are difference stationary, and not trend stationary, see Nelson and Plosser [1982].
7. The intuition behind this example differs somewhat from that developed by Goodfriend.
8. The main difference between this model and Goodfriend's are the simplier form of the policy rule used here, the assumption that p_t is contemporaneously observed, and the assumption about the stochastic properties of α_t. Barro [1987] uses a similar model to analyze interest rate smoothing policies.

9. Two variables x and y are said to be cointegrated of order (1,1) if the first difference of both are stationary and there exists a nonzero α such that $x + \alpha y$ is stationary. Cointegration is discussed in Section II.A below.

10. This point is developed more fully in Walsh [1986], and the optimal degree of base drift is derived as a function of the stochastic properties of income and velocity.

11. For example, see Gould, Miller, Nelson and Upton [1978], Nelson and Plosser [1982], Kim [1985], and Campbell and Mankiw [1986].

12. A useful summary of the theory of cointegration can be found in Campbell and Shiller [1986].

13. Engle and Granger also suggest estimating α from the error-correction regression of ΔM or ΔP on lagged changes in M and P and lagged levels of M and P. The estimated values for α are obtained as the ratio of the coefficient on lagged M to that on lagged P (when ΔM is the dependent variable).

The following results were obtained from the error-correction regressions:

Model	Dependent Variable	$\hat{\alpha}$
$M - \alpha P$:	ΔM	0.985
$M - \alpha P$:	ΔP	2.38
$T - \alpha P$:	ΔT	1.025
$T - \alpha P$:	ΔP	2.38
$T - \alpha M$:	ΔT	1.011
$T - \alpha M$:	ΔM	0.998

14. In terms of of the model of Section I, income would be one of the factors giving rise to a nonstationary process for α_t.

15. Since the income elasticity of real money demand is often assumed to equal one, the null hypothesis of no cointegration among M, P, and Y with known cointegration vector (1 -1 -1) was also tested and the null could not be rejected. This agrees with ealier studies that have found velocity to be non-trend stationary. See the references cited in footnote 9.

16. The nonstationarity of velocity may in part be attributable to monetary policy induced volatility so that under a steady growth rate rule velocity would no longer be nonstationary. However, technological shocks and shifts in tastes that produce non-trend stationary behavior of real output are generally assumed to be invariant with respect to the money supply process. A constant growth rate rule for the money supply with no base drift would, in this case, still result in nonstationary price level behavior.

17. The test statistic is the F-statistic for the null hypothesis that $\beta_0 = \beta_1 = 0$ in the regression $x_t - x_{t-1} = \beta_0 + \beta_1 x_t$, where x is the first difference of Y, R, P and M. The 5% critical value, interpolated from Dickey and Fuller [1981], is 5.1, and the values of the test statistics were 7.9 for Y, 1.6 for P, 12.7 for R, and 14.9 for M.

18. Stock and Watson [1987] find that the rate of inflation is stationary around a time trend during the 1960 - 1979 period. However, for the longer 1960 - 1985 period, they find that no trend is necessary to induce stationarity in the rate of inflation.

19. In a previous version of this paper, only the results using the first difference of the inflation rate were presented. While the paper's basic conclusions hold using either specification, I have used the model that enters P in first difference form and includes a time trend for two reasons. First, the structural model has a more easily interpreted form when all variables are differenced in the same degree. Second, the impulse response functions in the model using the first difference of the rate of inflation often show permanent effects of shocks on the rate of inflation even in the absence of any long-run effect on the rate of money growth. Such seemingly implausible results did not arise when the first difference of the price level and a time trend were used.

20. Because of the shortness of the sample, a longer lag length was not tried. A lag length of three was rejected when tested against a lag length of four ($\chi^2(25) = 45.7$, marginal significance level = 0.007).

21. For a discussion of the problems in drawing structural conclusions from VARs, see Cooley and LeRoy [1985].

22. For a discussion of these estimators, see Hanson and Singleton [1982] or Chamberlain [1983].

23. See Bernanke [1986]. If b' is the 1x5 vector of estimated coefficients on Z_{t-1} in the VAR equation for ΔP_t, then $b'v_t$ gives the revision in the expectation of ΔP_{t+1} due to the observation of v_t.

24. Note that (3) is consistent with either a Lucas-type supply curve or with the type of aggregate supply curve implied by the presence of overlapping wage contracts as in Fischer [1977] and Taylor [1979], since p_t is equal to a one step ahead forecast error.

25. By way of comparison, the matrix used to orthogonalize the residuals using a Choleski decomposition with ordering y, p, r, m, t-m is equal to

0.0215	0.0	0.0	0.0	0.0
0.0040	0.0030	0.0	0.0	0.0
0.0037	0.0043	0.0063	0.0	0.0
0.0078	0.0051	-0.0025	0.0054	0.0
0.0011	-0.0033	-0.0004	-0.00	0.0042

26. The coefficient α_6 is the one most likely to have shifted over the sample period in response to changes in Fed operating procedures. Consequently, the estimated value may not adequately reflect the true response during any particular policy regime. Barro [1987] finds evidence that the stochastic process followed by the monetary base in the U.S. during the postwar period is consistent with interest rate smoothing behavior by the Fed.

27. To be comparable with Table 4, this has been multiplied by 1000.

28. In Walsh [1986], it is noted that base drift is positively correlated with the subsequent midpoint of the growth rate range the FOMC sets for M1. That is, positive target overshoots tended to be followed by upward revisions in the target growth rate range.

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FIGURE 1

M1 - THE EFFECT OF DRIFT

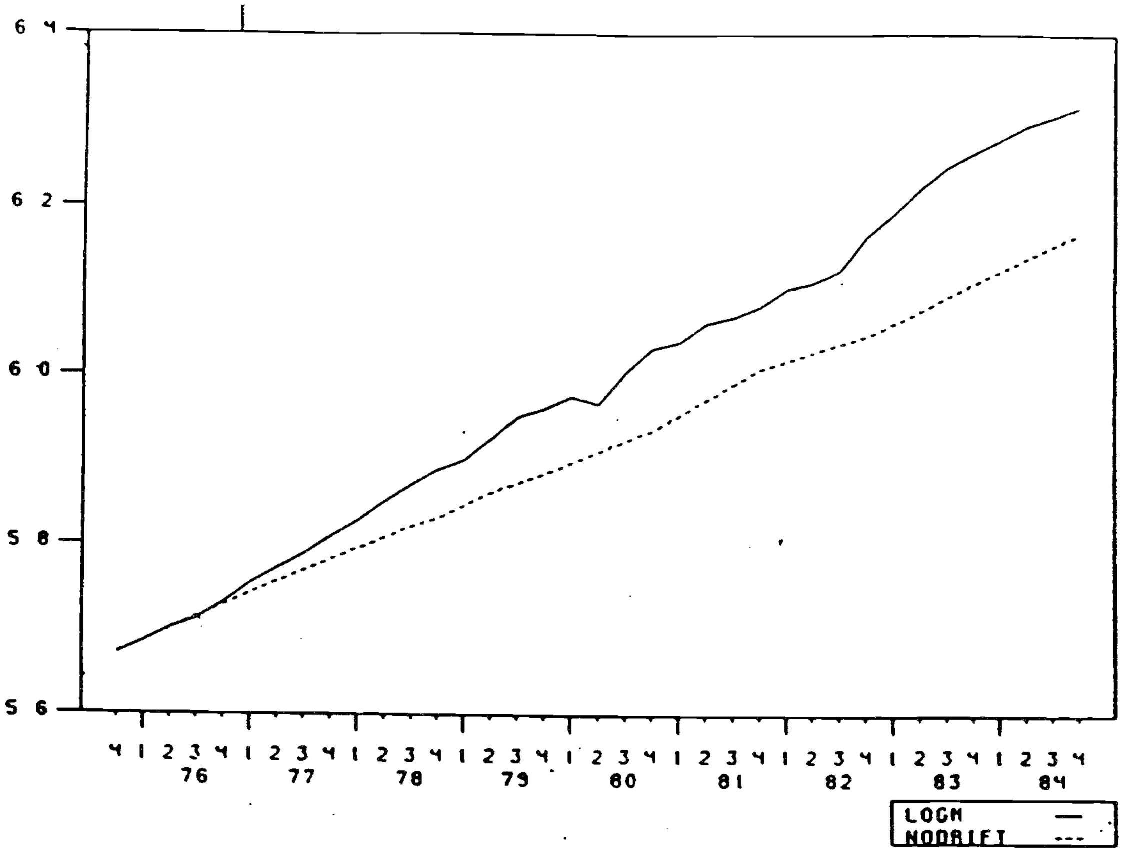


FIGURE 2

MEASURES OF BASE DRIFT

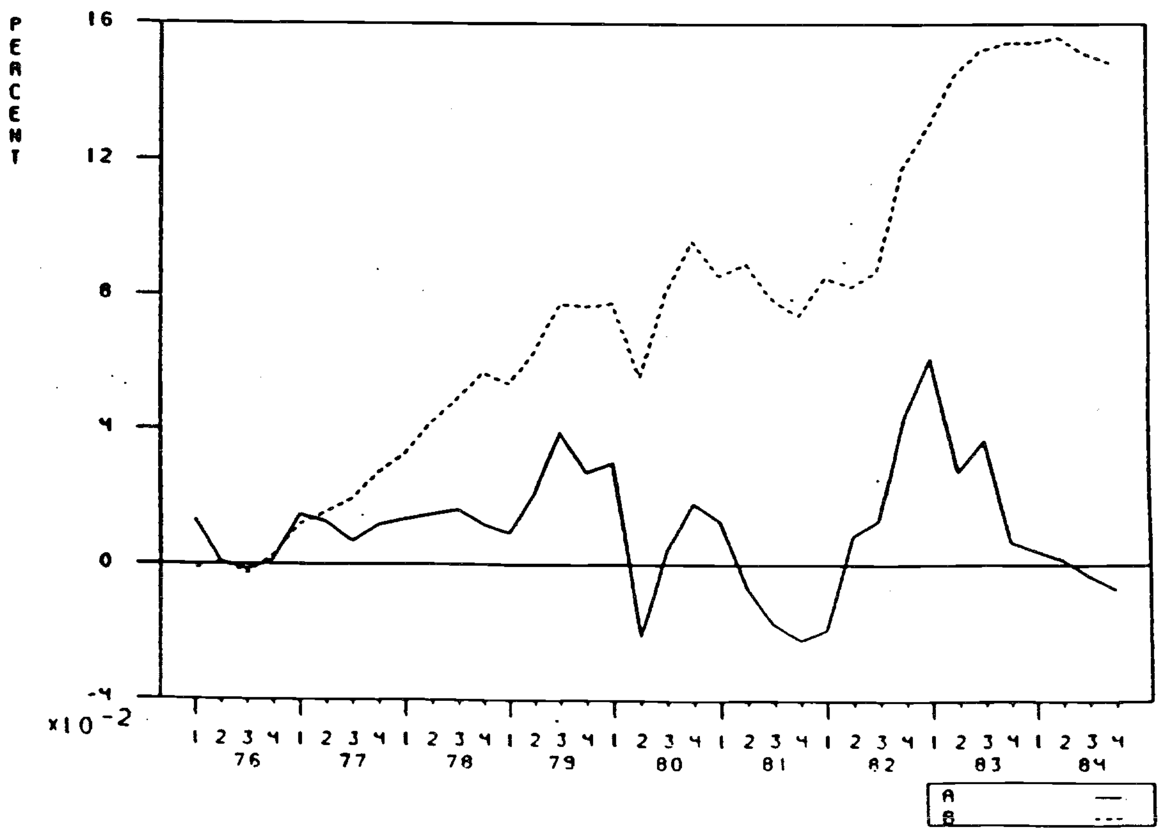


FIGURE 3

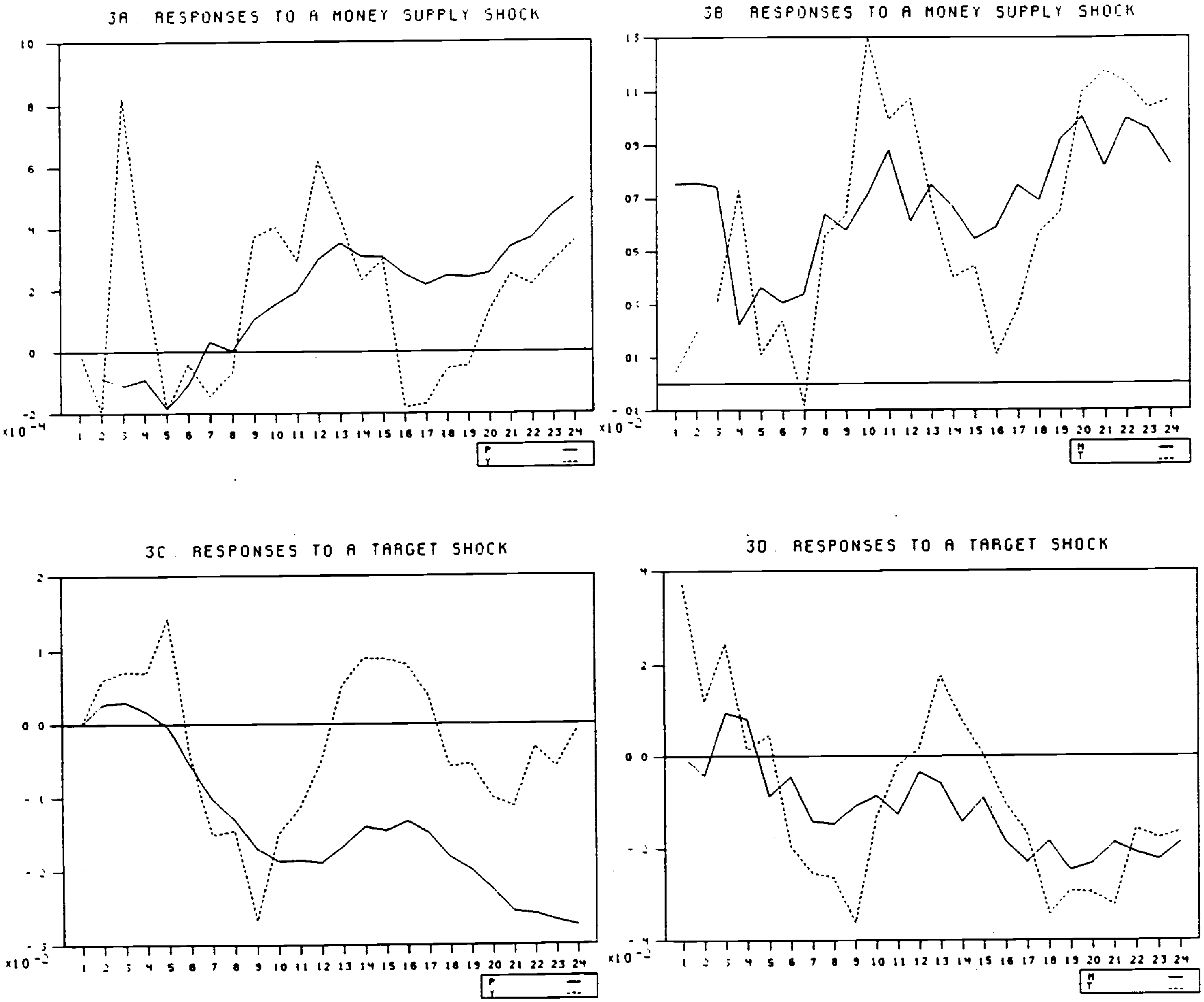
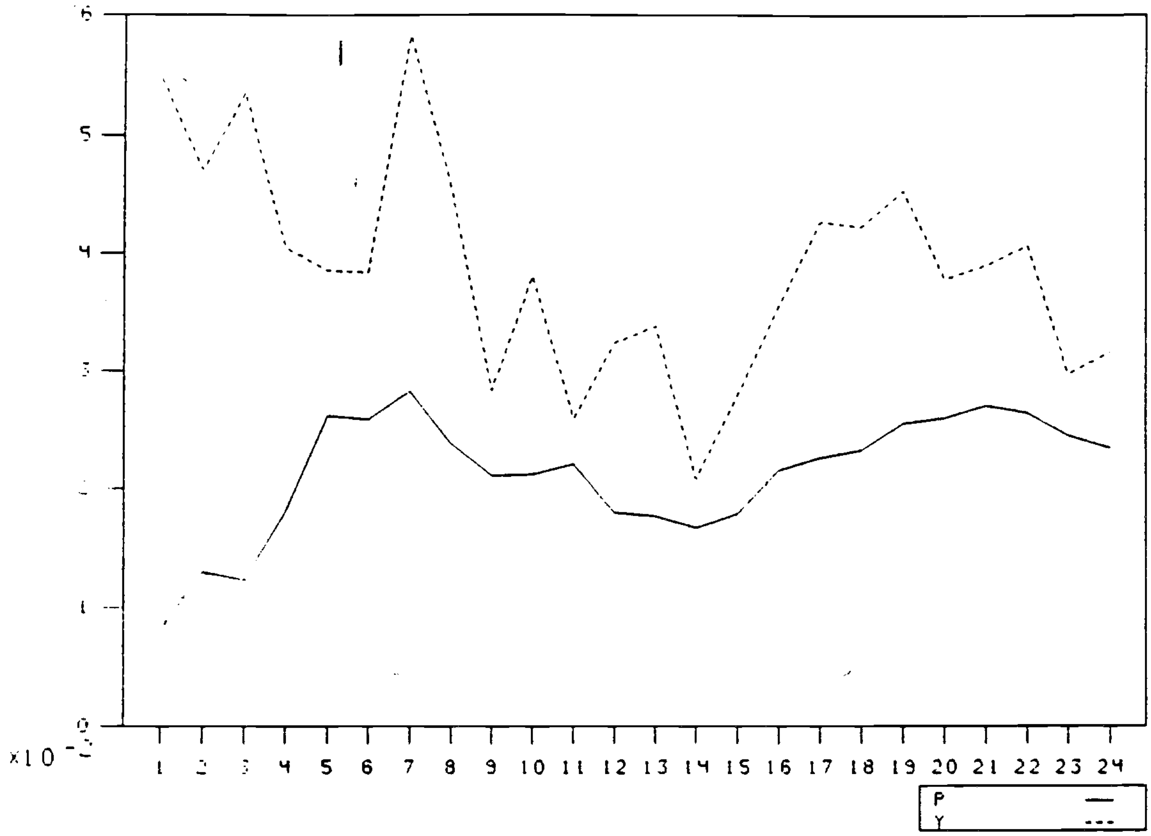

3A. RESPONSES TO A MONEY SUPPLY SHOCK
P
Y
3B. RESPONSES TO A MONEY SUPPLY SHOCK
M
T
3C. RESPONSES TO A TARGET SHOCK
P
Y
3D. RESPONSES TO A TARGET SHOCK
M
T

FIGURE 4

4A RESPONSES TO AN AGGREGATE DEMAND SHOCK



4B RESPONSES TO AN AGGREGATE DEMAND SHOCK

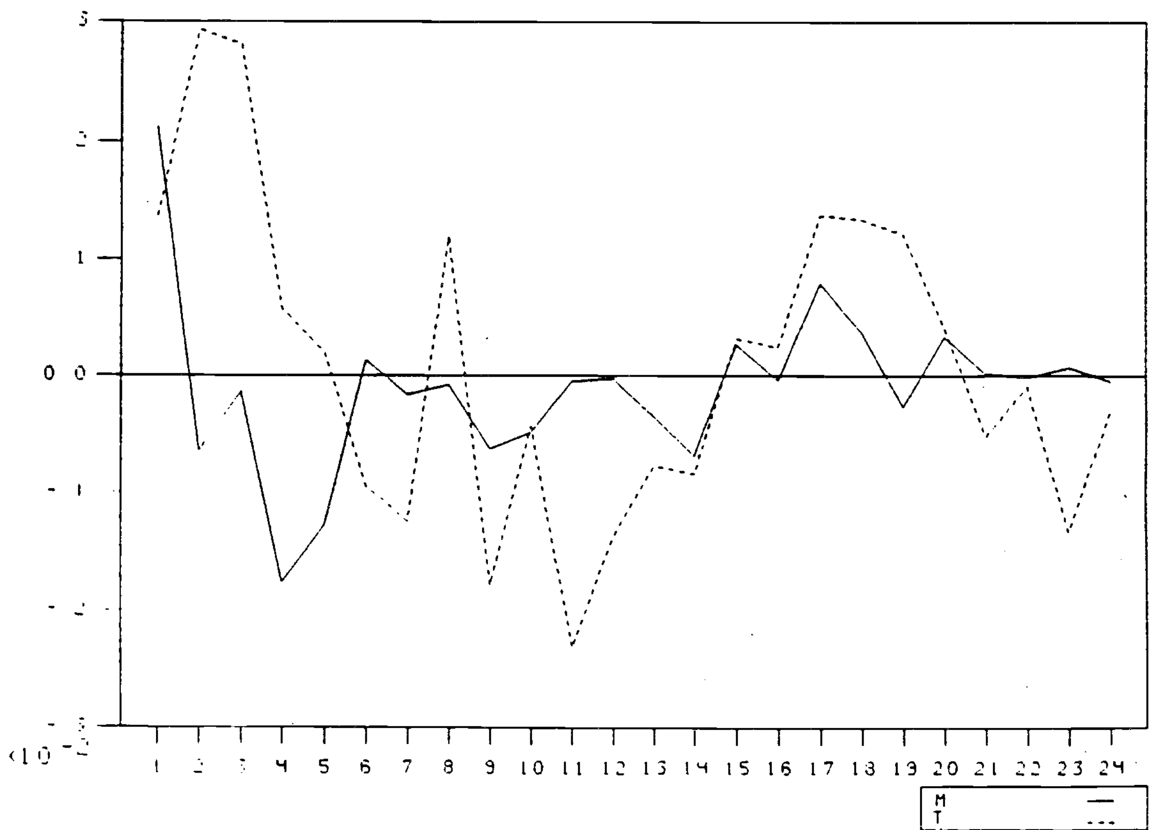
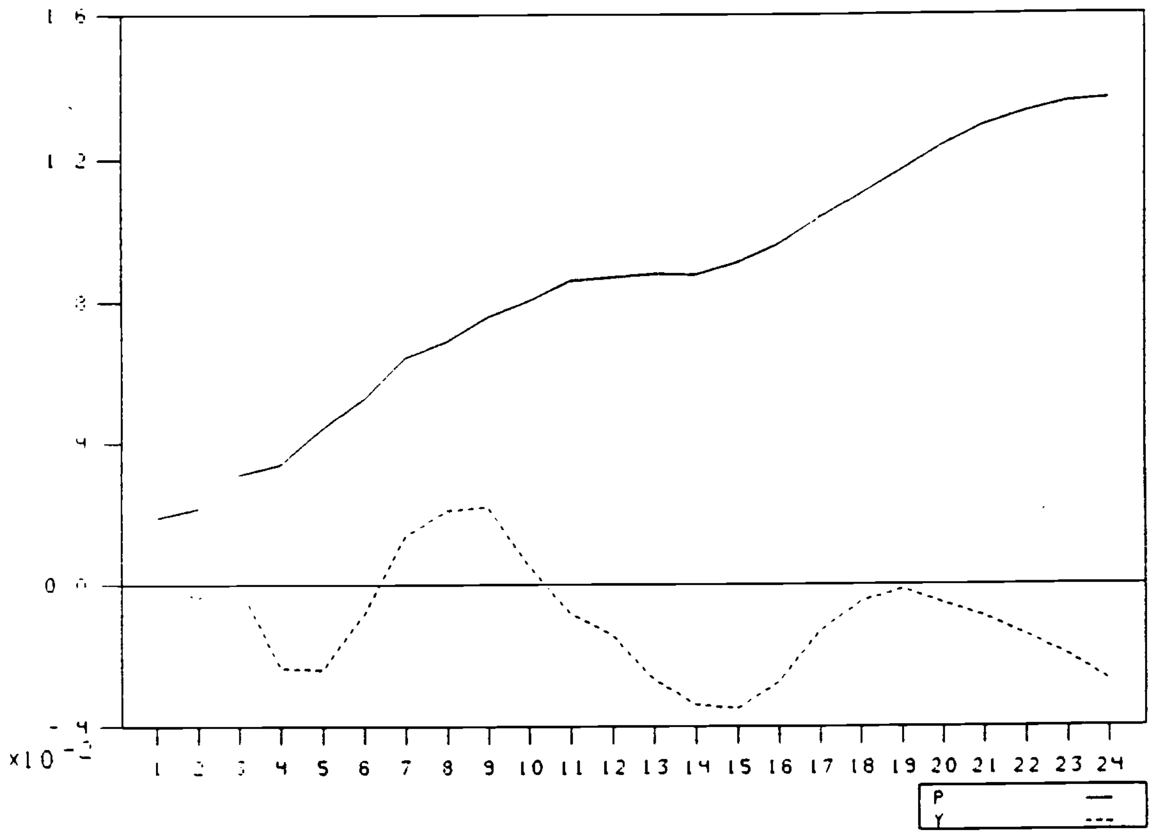


FIGURE 5

5A RESPONSES TO AN AGGREGATE SUPPLY SHOCK



5B RESPONSES TO AN AGGREGATE SUPPLY SHOCK

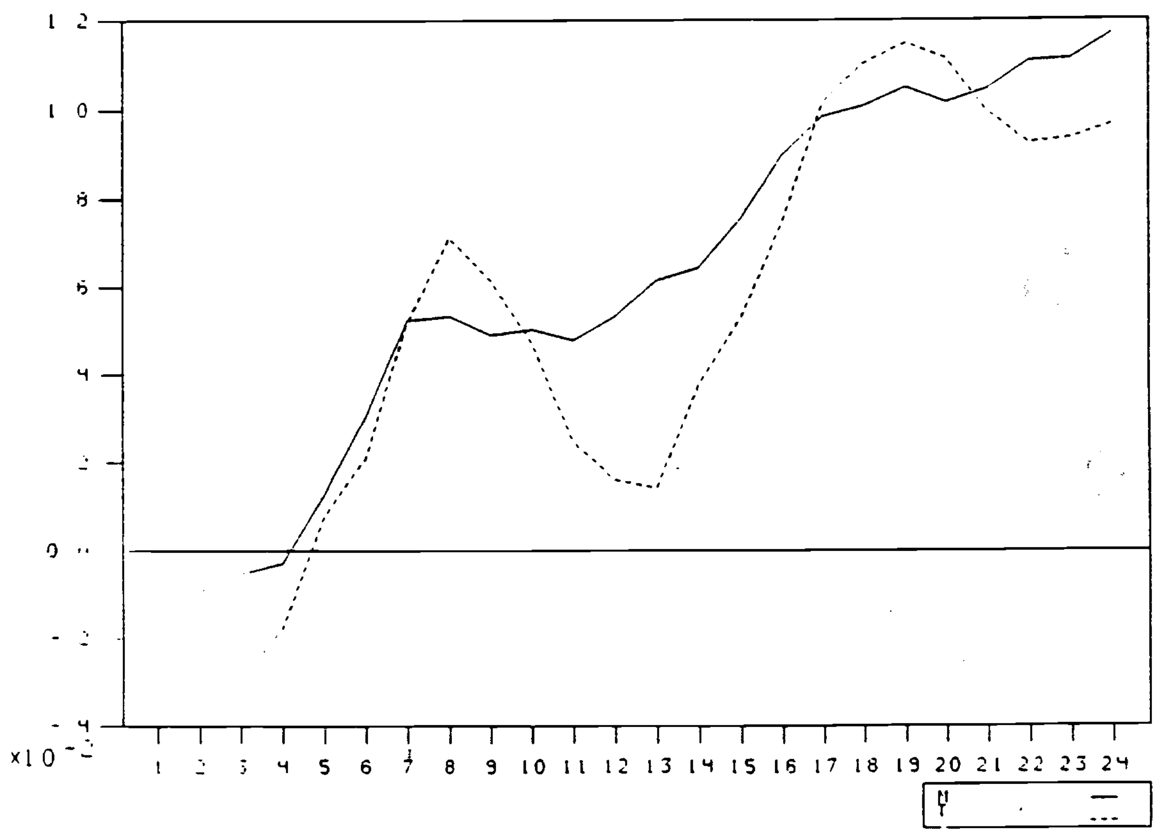
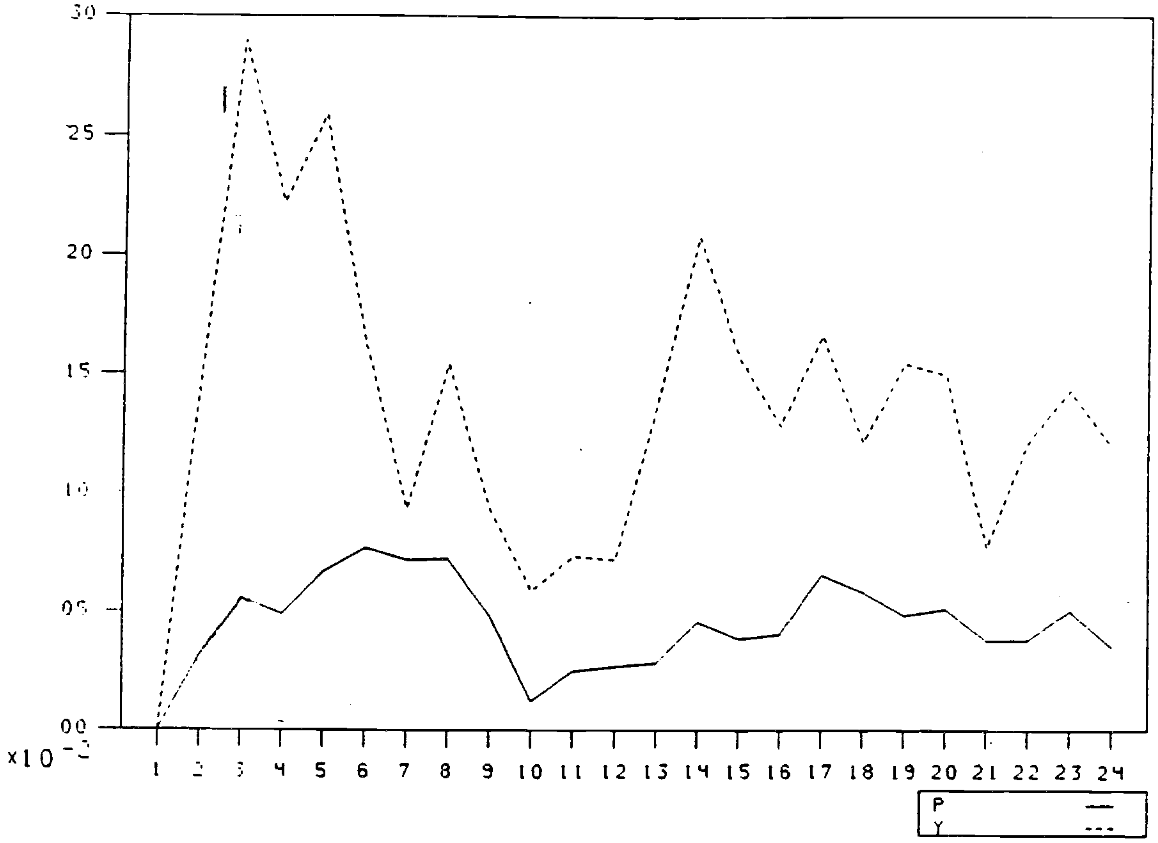


FIGURE 6

6A RESPONSES TO A MONEY DEMAND SHOCK



6B RESPONSES TO A MONEY DEMAND SHOCK

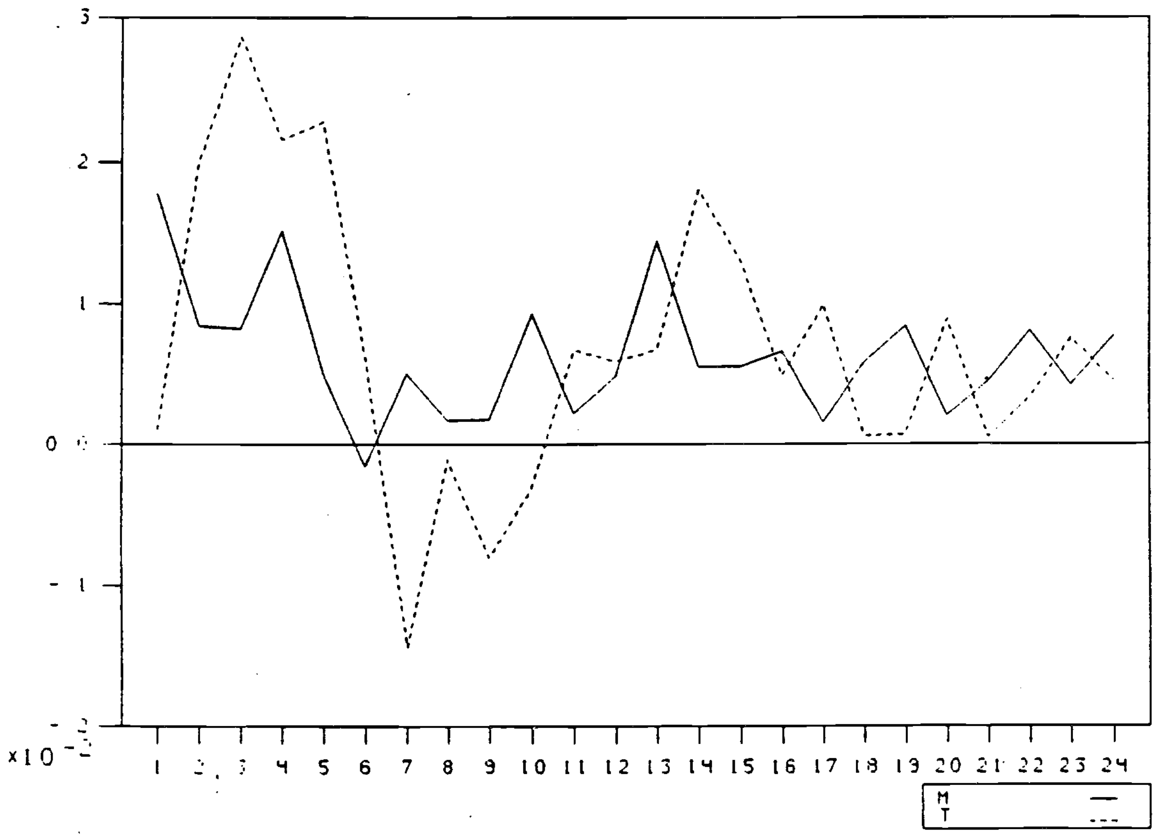


Table 1

Tests for Cointegration: 1976:1 — 1984:4

I. Cointegrating Vector: (1 - 1)'.

$$x_t - x_{t-1} = \alpha_0 + \alpha_1 x_{t-1}; \quad H_0 : \alpha_0 = \alpha_1 = 0$$

	Variable			
	M-P	T-P	T-M	5% Critical Value
Test Statistic:	0.44	0.36	5.97*	5.1

II. Unknown Cointegrating Vector: (1 -α)'

A. Cointegrating Regression $x_t = \alpha_0 + \alpha y_t + \epsilon_t$

	Variable Pair			
	M and P	T and P	T and M	5% Critical Value
$\hat{\alpha}$	1.01	1.01	1.00	
Test Statistic (DW):	0.13	0.20	1.07*	0.39

B. $\hat{\epsilon}_t - \hat{\epsilon}_{t-1} = \beta\hat{\epsilon}_{t-1} + \sum_1^q \gamma_i (\hat{\epsilon}_{t-i} - \hat{\epsilon}_{t-i-1})$

	Residuals from Cointegrating Regression			
Test Statistic	M and P	T and P	T and M	5% Critical Value
ξ_2 (q=0)	0.29	0.51	3.52*	3.37
ξ_3 (q=4)	1.84	0.90	2.33	3.17

* Significant at the 5 percent level.

Table 2

Tests for Cointegration between (M-P) and Y

A. Cointegrating Regression: $M-P = \alpha_0 + \alpha Y + \varepsilon$

$\hat{\alpha}$	DW	5% Critical Value
0.14	0.13	0.39

B. $\hat{\varepsilon}_t - \hat{\varepsilon}_{t-1} = \beta\hat{\varepsilon}_{t-1} + \sum_1^q \gamma_i (\hat{\varepsilon}_{t-i} - \hat{\varepsilon}_{t-i-1})$

	ξ_2 (q=0)	ξ_3 (q=4)
Test Statistic	0.71	1.86
(5% Critical Value)	(3.37)	(3.17)

Table 3

Residual Covariances from VAR*

	y	r	p	m	t-m
y	0.462	0.086	0.079	0.167	-0.024
r		0.025	0.028	0.046	-0.014
p			0.072	0.035	-0.021
m				0.122	-0.025
t-m					0.030

Residual Correlations

	y	r	p	m	t-m
y	1.00	0.80	0.43	0.70	-0.20
r		1.00	0.65	0.84	-0.52
p			1.00	0.37	-0.46
m				1.00	-0.41
t-m					1.00

* Entries multiplied by 1000.

Table 4

Parameter Estimates for the Structural Model

$\alpha_1 = 0.000$	$\alpha_6 = 3.010$
$\alpha_2 = 0.157$	$\alpha_7 = -0.482$*
$\alpha_3 = 0.225$	$\alpha_8 = 0.086$
$\alpha_4 = -0.187$*	$\alpha_9 = -0.186$*
$\alpha_5 = -0.083$	$\alpha_{10} = -0.235$*

Estimated Variances of Structural Disturbances**

$\sigma_1^2 = 0.480$	$\sigma_4^2 = 0.022$*
$\sigma_2^2 = 0.057$*	$\sigma_5^2 = 0.014$*
$\sigma_3^2 = 0.014$*	

$$\hat{A}^{-1}\hat{\Sigma}_u^{\frac{1}{2}} = \begin{matrix} 0.0219 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0034 & 0.0075 & 0.0 & 0.0 & 0.0 \\ 0.0040 & 0.0013 & 0.0024 & -0.0006 & -0.0000 \\ 0.0085 & 0.0004 & 0.0071 & 0.0030 & -0.0000 \\ -0.0008 & -0.0017 & -0.0017 & -0.0007 & 0.0037 \end{matrix}$$

* Asymptotic t-statistic greater than 1.96.

** Times 1000.

Table 5

Variance Decomposition

(Decomposition Based on Structural Model)

Innovation to:	Money Supply(M)	Target(T)	Aggregate Demand(Y)	Money Demand(R)	Aggregate Supply(p)
Output Growth					
Quarter: 2	0.11	1.10	91.80	6.57	0.41
4	3.13	0.84	72.88	10.38	12.77
8	2.48	8.49	58.34	10.00	20.70
12	2.40	11.08	54.76	8.77	22.98
24	2.33	12.56	49.74	9.69	25.68
Inflation					
2	0.16	1.59	19.76	2.11	76.39
4	0.14	1.55	20.52	2.67	75.12
8	0.39	6.19	19.64	1.88	71.89
12	0.54	6.83	19.05	3.25	70.33
24	0.57	8.09	16.42	3.53	71.38
Money Growth					
2	3.17	0.98	67.47	22.56	5.82
4	3.53	8.72	63.33	19.12	5.30
8	2.24	14.17	40.79	15.41	27.39
12	2.33	15.69	38.79	16.70	26.49
24	2.10	16.90	33.94	17.58	29.48
Future Target - Current Money					
2	2.10	42.09	33.95	10.59	11.27
4	1.84	27.91	39.83	12.68	17.74
8	1.61	27.60	35.69	17.43	17.67
12	1.55	25.26	31.13	14.19	27.87
24	1.36	24.07	22.27	11.37	40.93

Appendix

An alternative specifications of the VAR system was estimated based on the potential presence of a second unit root in the price level. If π_t denotes the rate of inflation from t-1 to t, the alternative specification included the first differences of Y, π, R, M and the level of T - M. A constant and the dummy for 1979:4 - 1982:3 were included in each equation, but a time trend was not included.

Letting (y, π, r, m, t-m) denote the residuals from the VAR system, the structural model corresponding to equations (12) - (16) took the form:

$$y_t = \alpha_1(r_t - {}_t\pi_{t+1}) + u_{1t}$$

$$\pi_t = \alpha_2 y_t + u_{2t}$$

$$r_t = \alpha_3 y_t + \alpha_4(m_t - \pi_t) + u_{3t}$$

$$m_t = \alpha_5 y_t + \alpha_6 r_t + \alpha_7 \pi_t + u_{4t}$$

$$t_t - m_t = \alpha_8 y_t + \alpha_9 \pi_t + \alpha_{10} m_t + u_{5t}.$$

In the definition of the expected real interest rate, ${}_t\pi_{t+1}$ denotes the effect of the current realization of v_t on expectations of π_{t+1}. In addition, equation (14) requires some explanation. Suppose the demand for real money balances is given, in levels, by $M_t - P_t = a_3 Y_t + a_4 R_t$, or $P_t = M_t - a_3 Y_t - a_r R_t$. In order to express this in terms of the variables incorporated in the VAR, premultiply by $(1-L)^2$ where L is the lag operator: $(1-L)^2P_t = (1-L)M_t - (1-L)M_{t-1} - a_3(1-L)Y_t + a_3(1-L)Y_{t-1} - a_4(1-L)R_t + a_4(1-L)R_{t-1}$. This implies that one of the equations in (9) takes the form $a_3(1-L)Y_t + a_4(1-L)R_t + (1-L)^2P_t - (1-L)M_t = a_3(1-L)Y_{t-1} + a_4(1-L)R_{t-1} - (1-L)M_{t-1}$. Note that because money demand is a demand for real money balances, restrictions are placed on the coefficients of the lagged first differences of Y, R, and M. These restrictions on the lag were ignored in the VAR estimation.

Parameter estimates are given in Table A.1, and the variance decompositions are reported in Table A.2.

The impulse response functions tend to imply conclusions similar to those reported in the text with one important exception that is best illustrated by Figure A.1. This figure shows the impact on the level of Y and M and the rate of inflation of an aggregate supply shocks. The effect on π is similar to that implies by Figure 5a; inflation shocks leave the rate of inflation permanently above the no-shock path. However, Figure A.1 shows no long-run increase in the rate of money growth. Only the level of M appears to be left higher. Similar results were found in response to money demand and supply shocks. In each case, the specification using the first difference of the inflation rate implied the somewhat implausible result that permanent increases in the inflation rate were not accompanied by any changes in the growth rate of money.

Table A.1

Parameter Estimates for the Structural Model

α_1	= 0.000	α_6	= 2.911*
α_2	= 0.0149	α_7	= -0.558*
α_3	= 0.088	α_8	= 0.143
α_4	= -0.151*	α_9	= -0.285*
α_5	= -0.053	α_{10}	= -0.272*

Estimated Variances of Structural Disturbances**

σ_1^2	= 0.711	σ_4^2	= 0.008*
σ_2^2	= 0.074*	σ_5^2	= 0.015*
σ_3^2	= 0.028*		

$\hat{A}^{-1} \hat{\Sigma}_u^{\frac{1}{2}} =$

0.0267	0.0	0.0	0.0	0.0
0.0040	0.0086	0.0	0.0	0.0
0.0025	0.0015	0.0036	-0.0003	0.0001
0.0028	-0.0010	0.0113	0.0020	-0.0008
0.0036	0.0015	-0.0032	-0.0006	0.0041

* Asymptotic t-statistic greater than 1.96.

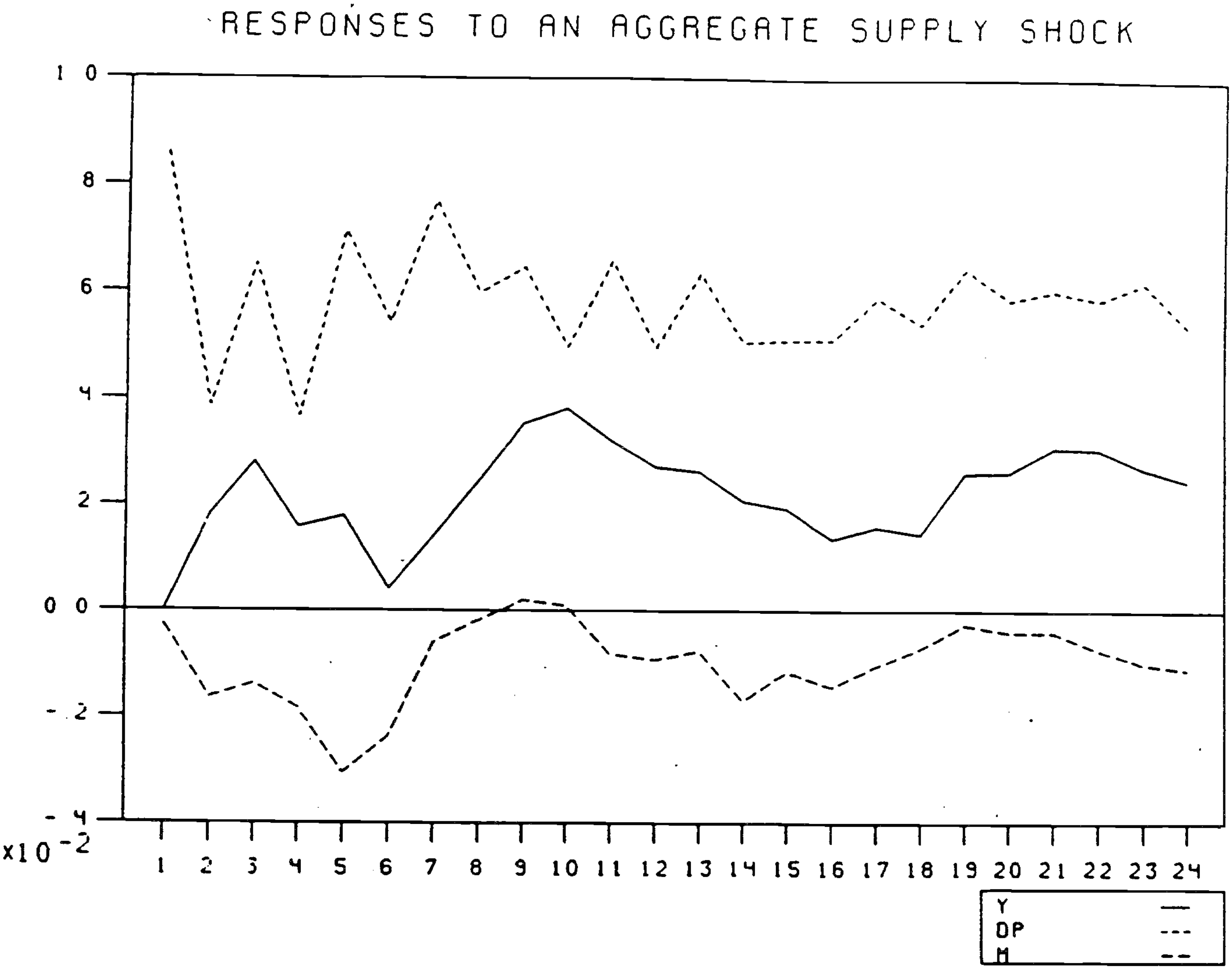
** Times 1000.

Table A.2

Variance Decomposition
(Decomposition Based on Structural Model)

Innovation to:	Money Supply(M)	Target(T)	Aggregate Demand(Y)	Money Demand(R)	Aggregate Supply(π)
Output Growth					
Quarter: 2	0.00	0.95	91.75	0.50	6.79
4	0.86	1.56	82.79	4.22	10.57
8	0.65	8.58	72.66	5.40	12.71
12	0.58	10.26	71.56	5.00	12.61
24	0.55	11.02	69.14	5.48	13.81
Inflation Change					
2	0.02	1.29	14.51	0.92	83.26
4	0.02	1.64	27.93	0.78	69.63
8	0.13	1.88	37.25	1.04	59.71
12	0.15	1.82	37.38	1.95	58.70
24	0.16	2.58	37.11	2.78	57.36
Money Growth					
2	1.05	0.40	53.03	37.29	8.24
4	0.92	5.20	55.11	32.39	6.38
8	0.66	12.50	48.72	24.11	14.02
12	0.63	12.96	48.57	23.38	14.45
24	0.59	12.93	50.14	21.51	14.82
Future Target - Current Money					
2	0.53	19.35	66.72	10.86	2.54
4	0.43	14.83	73.88	8.28	2.58
8	0.37	14.18	70.27	8.90	6.28
12	0.36	15.91	67.90	8.56	7.28
24	0.35	16.55	65.74	8.70	8.66

FIGURE A.1


RESPONSES TO AN AGGREGATE SUPPLY SHOCK
1 0
8
6
4
2
0 0
-.2
-4
x10 -2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Y
DP
M