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USING MEASURES OF EXPECTATIONS TO IDENTIFY THE EFFECTS OF A MONETARY POLICY SHOCK

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ABSTRACT

This paper considers an alternative econometric approach to the VAR methodology for identifying and estimating the effects of monetary policy shocks. The alternative approach incorporates available measures of market participants' expectations of economic variables in order to calculate economic innovations to those variables. In general, expectations measures should provide important additional information relative to a standard VAR analysis, since market participants presumably use a much richer information set than that assumed in a typical VAR model. The resulting innovations are easily incorporated in a VAR-like framework.

The empirical results are quite surprising. First, when expectations are incorporated, the variance of all innovations is reduced substantially. Second, innovations to the federal funds rate derived using the alternative approach are only somewhat correlated with their VAR counterparts, while innovations to other economic variables are essentially uncorrelated. Still, monetary policy *shocks* derived using the two approaches are also somewhat correlated, since innovations to prices and economic activity explain only a small fraction of innovations to the federal funds rate. As a consequence, the impulse responses of economic variables to the two sets of monetary policy shocks have remarkably similar properties.

Using Measures of Expectations to Identify the Effects of a Monetary Policy Shock

Allan D. Brunner[1]

I. Introduction

Vector autoregressive (VAR) models, popularized by Sims (1980), have been used widely and extensively by economists to study the dynamic behavior of economic variables. The appeal of VAR models is likely due to several attractive features relative to other econometric modeling approaches. These features include a minimum number of identifying restrictions, few exogenous variables, and an ease of implementation. Still, the use of a VAR model requires a few strong assumptions about the availability of information to economic agents, some of which are also common to other more-overidentified econometric models. This paper considers an alternative approach that address some possible shortcomings of the VAR approach, while maintaining many of its appealing features.

The estimation of a structural VAR model generally requires two steps. First, a vector of economic variables, X_t, is regressed on several lags of itself. The set of lagged variables (dated t-1 and earlier) is assumed to be a good proxy for the information set that is available to economic agents just prior to the determination of X_t. As a consequence, VAR residuals are interpreted as economic *innovations*, new information about X_t that becomes available at time t. In the second step of estimation, the innovations are decomposed into orthogonal *shocks* using one of several methods. These shocks are often given a structural or behavioral interpretation.

This paper is concerned primarily with two implicit assumptions that are made in the first step

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of the VAR methodology that may not accord well with reality. First, since many economic data for a particular period are not released until subsequent periods, the information set that is typically used by VAR models contains information that is not yet available to some economic agents. Second, there is an assumption that the appropriate information set contains only lagged values of X_t. In actuality, the correct information set likely contains lags of many other economic variables not contained in X_t.

In this paper, the first problem is addressed by simply dropping from the information set those data that are not actually available to economic agents. The second problem is mitigated by incorporating market participants' expectations of economic variables. These expectations measures should bring important additional information into the analysis, since market participants presumably use a much richer information set (relative to a standard VAR model) to make their forecasts. Importantly, the expectations measures serve as an efficient and convenient way to expand the implied information set beyond that used by a typical VAR model.

In order to illustrate the alternative econometric methodology, this paper considers the task of identifying monetary policy shocks and estimating their effects on various macroeconomic variables. Indeed, there has been a great deal of recent interest in this topic. For example, Christiano and Eichenbaum (1992) and Leeper and Gordon (1992) examined the "liquidity effects" of monetary policy shocks, the immediate reaction of economic variables to unexpected changes in the stance of monetary policy. More recently, Bernanke and Blinder (1992), Strongin (1992), Gordon and Leeper (1995), Christiano, Eichenbaum, and Evans (1994) and Brunner (1994) have explored alternative ways of identifying monetary policy shocks and tracing out their effects on the macroeconomy. Importantly, much of this research was conducted using vector-autoregressive (VAR) models.

The empirical results are quite surprising. First, when expectations are incorporated, the variance of all innovations is reduced substantially. Second, innovations to the federal funds rate using the two methodologies -- using a VAR model and using market expectations -- are only somewhat correlated. The correlation between the two is .56 -- enough so that the VAR approach cannot be rejected out of hand, but not so large that the approach is validated. Innovations to other economic variables (prices and indicators of economic activity) are essentially uncorrelated. Still, monetary policy *shocks* derived using the two approaches are also somewhat correlated, since innovations to prices and economic activity explain only a small fraction of innovations to the federal funds rate. As a consequence, the impulse responses of economic variables to the two sets of monetary policy shock have remarkably similar properties.

The remainder of the paper proceeds as follows. Section II demonstrates how the VAR methodology can be replaced with an alternative approach that incorporates measures of expectations. Section III examines whether selected measures of market expectations are, in fact, accurate predictions of actual economic outcomes. It also compares economic innovations calculated with both the VAR and alternative approaches. Similarly, section IV computes structural shocks using both methods, and it examines their effects on several economic variables. Section V provides some concluding remarks.

II. Using Measures of Expectations

This section has two objectives. The first objective is to review the traditional VAR approach, popularized by Sims (1980), and to describe some potential problems with that modeling strategy. The second objective is to outline an alternative approach that addresses the possible shortcomings of the VAR approach. The main advantage of the alternative approach is that it incorporates measures of market participants' expectations in the estimation of economic innovations, while maintaining many of the appealing features of the VAR modeling strategy. This approach is illustrated by outlining the necessary steps to identify monetary policy shocks and to trace out their effects on selected economic variables. This particular application is pursued further in subsequent sections of the paper.

The VAR Approach

Suppose that an economist is interested in studying the dynamic behavior of an nx1 vector of economic variables, X_t. One modeling strategy is to estimate a structural VAR(p) model of X_t:

$$A_0 X_t = \mu + A(L) X_{t-1} + \eta_t \tag{1}$$

where μ is an nx1 vector, $A(L) = A_1 + A_2L + ... + A_pL^{p-1}$, A_i is an nxn matrix, L is the lag operator, and η_t is a nx1 vector of structural (orthogonal) shocks.

The estimation of a structural VAR model generally requires two steps. The first step is to estimate the reduced-form representation of X_t, where X_t is regressed on p lags of itself:

$$X_t = \mu' + B(L) X_{t-1} + u_t \tag{2}$$

where μ' is an nx1 vector, $B(L) = B_1 + B_2L + ... + B_pL^{p-1}$, B_i is an nxn matrix, and u_t is a nx1 vector containing the reduced-form VAR innovations. Note that, by assumption, u_t contains all new information about X_t that becomes available during period t, and the only new information that is obtained during period t is about variables dated at time t.

In the second step, the VAR innovations (u_t) are used to estimate A_0 and to recover the structural shocks (η_t). Equating equations (1) and (2) implies the following relationship between the reduced-form innovations and the structural shocks:

$$A_0 u_t = \eta_t \tag{3}$$

In order for A_0 and η_t to be identified, A_0 must contain at least n(n-1)/2 zero-restrictions. Sims (1980) assumed that A_0 was lower-triangular in order to orthogonalize the innovations. With this assumption, A_0 and the ηs can be estimated with OLS, simply by regressing each innovation on other appropriate innovations. In contrast, Sims (1986) and Bernanke (1986) considered alternative decompositions, where sufficient zero-restrictions were imposed on A_0 based on economic theory. In this case, more sophisticated estimation methods, such as instrumental variables or maximum likelihood are required.[2]

Once A_0 and the ηs have been estimated, the remaining structural parameters are calculated by observing that equations (1) and (2) also imply $A_i = A_0^{-1}B_i$ (i=1,...p). The structural model can then be used to study the time-series properties of the data in a number of ways. Often economists are interested in examining impulse response functions, which capture the dynamic responses of X_t to the set of structural shocks (η). The impulse response functions can be obtained by inverting the VAR, yielding the vector-moving-average (VMA) representation:

$$\begin{aligned} X_t &= [A_0 - A(L)]^{-1}\mu + [A_0 - A(L)]^{-1}\eta_t \\ &= \mu'' + C(L)\,\eta_t \end{aligned} \tag{4}$$

where μ'' is an nx1 vector, $C(L) = C_0 + C_1L + ...$, and C_i is an nxn matrix. The impulse response of any element of X_t to a particular structural shock corresponds to the appropriate elements of C(L). In addition, the VMA representation can also be used to decompose the forecast errors or the variance of X_t into components attributable to individual elements of η_t.

There are a number of attractive features of the VAR methodology that have led to its popularity. First, the identification of the structural VAR model in equation (1) is achieved with a minimum number of identifying restrictions. Indeed, restrictions are often placed only on A_0, leaving A(L) unrestricted. In contrast, other structural approaches often involve large numbers of restrictions on A(L) that are often not tested and that may or may not be guided by economic theory. Since the parameters of a VAR model are relatively unconstrained, some economists consider a VAR model to

[2] See Blanchard and Quah (1989) for an alternative identification scheme that places restrictions on the long-run effects of η_t.

be a relatively atheoretical approach, allowing for a (possibly) richer set of dynamics than a more-overidentified model would allow.

Second, there are often no exogenous variables in the VAR model other than constants, seasonal dummies, and deterministic time trends. As a consequence, the emphasis is placed on the effects of structural disturbances within the context of a fully-articulated system of endogenous variables, rather than on the effects of certain economic variables (endogenous or exogenous) on other variables. Finally, since each structural equation in the VAR model is treated symmetrically with respect to explanatory variables, the VAR methodology is easily and quickly implemented, often with only a few lines of computer code.

Potential Problems with VARs

The estimation of A_0 and η_t in equation (3) depends critically on estimates of the VAR innovations (u_t), the "first-stage" regressions shown in equation (2). There are at least two reasons why the VAR innovations in equations (2) may be poor proxies for the true innovations to X_t. First, there is good reason to believe that the information set implied by a typical VAR contains information that is not yet available to economic agents. For example, the VAR methodology assumes that all lagged values of X_t are publicly observable at the end of period t-1. Unfortunately, most economic data for a particular period are not available until subsequent periods and may be subject to revisions for months, weeks, or even years after their initial release. As a consequence, if some variables on the right-hand side of the regression in equation (2) are not actually observable at time t-1, the innovations will be improperly estimated.

Similarly, the VAR methodology assumes that the set of information available to economic agents at time t-1 contains only lags of X_t. In all likelihood, the appropriate information set is much richer than the one implied by a typical VAR model. If there exists additional information at time t-1 that helps predict X_t and that is omitted from the regression in equation (2), the resulting estimated innovations are not true innovations and are inappropriate for identifying structural shocks to X_t.

Importantly, either of these two problems can be overcome with proper modifications to the structural VAR in equation (1). In the first case, the structural model could be constructed so that only information that is actually available is used as an explanatory variable. In the second case, X_t could be expanded to include any necessary additional explanatory variables. Unfortunately, increasing the dimensions of X_t is often undesirable or simply infeasible. Since even small VAR models typically require the estimation of a large number of parameters, adding more variables to the VAR system would only further exacerbate any problems with few degrees-of-freedom.

An Alternative Approach

This paper considers an alternative econometric approach to the VAR methodology that attempts to gauge the importance of the shortcomings described above. First, the problem of assuming too much in agents' information set is addressed by reconstructing X_t so that only information that is actually known at time t-1 is used to calculate innovations. Second, the problem of excluding information that agents do have available is addressed by including available measures of market expectations in the estimation of economic innovations. These measures serve as a convenient and efficient way to include all relevant information necessary to calculate innovations.

In order to illustrate the alternative approach, consider the task of identifying monetary policy shocks and of tracing out their effects on various economic variables of interest (X_t). Suppose that the Federal Reserve's policy instrument is the federal funds rate -- one of the variables in X_t -- and that the Fed's reaction function -- analogous to one of the structural equations in equation (1) -- can be written as follows:

$$FFR_t = \phi + \gamma \, [\, X'_{1,t} \; X'_{2,t-1} \,]' + \ldots + \eta_t^{MP} \qquad (5)$$

where ϕ is a constant, γ is a nx1 vector, $X_{1,t}$ is a vector of variables describing period t and observable at time t, $X_{2,t}$ is a vector of variables describing period t and observable at time t+1, and η^{MP}_t denotes a monetary policy shock. Note that with this specification, the federal funds rate responds contemporaneously to new information about $X_{1,t}$ and $X_{2,t-1}$. Finally, γ contains some zero elements for identification purposes, analogous to the zero-restrictions on A_0.

As with the VAR methodology, the first step is to calculate innovations to the federal funds rate, $X_{1,t}$ and $X_{2,t-1}$:

$$\begin{aligned} FFR_t &= \alpha_1 + \beta_1(L)[\, X'_{1,t-1}\; X'_{2,t-2}\,]' + \delta_1 E[\, FFR_t \mid \hat{I}_{t-1}] + u_t^{FFR} \\ X_{1,t} &= \alpha_2 + \beta_2(L)[\, X'_{1,t-1}\; X'_{2,t-2}\,]' + \delta_2 E[\, X_{1,t} \mid \hat{I}_{t-1}] + u_t^{X1} \\ X_{2,t-1} &= \alpha_3 + \beta_3(L)[\, X'_{1,t-1}\; X'_{2,t-2}\,]' + \delta_3 E[\, X_{2,t-1} \mid \hat{I}_{t-1}] + u_t^{X2} \end{aligned} \qquad (6)$$

where $\beta_i(L)$ is a matrix polynomial, $E[\cdot \mid \hat{I}_{t-1}]$ represents an observable measure of market participants' expectations of a particular variable, and $\hat{I}_{t-1}$ is an unobservable information set that is implied by the observed expectations measure. There are a few interesting aspects of equation (6) that are worth discussing. First, it could be the case that using only lags of $X_{1,t}$ and $X_{2,t-1}$ are required to calculate innovations to the federal funds rate, to $X_{1,t}$ and to $X_{2,t-1}$. That is, the inclusion of the expectations measures adds no additional explanatory power to the regressions in equation (6). This possibility corresponds to the testable hypothesis that δ_i is equal to zero. On the other hand, it could be the case that market participants' forecasts of these variables are unbiased and efficient. That is, including the expectations measures in the regressions in equation (6) actually preclude using lags of other variables, if market participants use all *useful* information to make their forecasts. This possibility corresponds to the testable hypotheses that δ_i is equal to one (a test of unbiasedness) and that $\beta_i(L)$ are equal to zero (a test of efficiency).

In the second step of the alternative approach, innovations to the federal funds rate are regressed on innovations to all necessary variables in the Fed's reaction function:

$$u_t^{FFR} = \gamma_1 u_t^{X1} + \gamma_2 u_t^{X2} + \eta_t^{MP} \tag{7}$$

Analogous to equation (3) for the VAR approach, the regression in equation (7) yields a set of structural monetary policy shocks.

Finally, analogous to the inversion process in equation (4), X_t -- the original variables of interest -- can be regressed on contemporaneous and lagged values of the structural shocks:

$$X_t = \mu'' + \rho(L)\,\eta_t^{MP} \tag{8}$$

where $\rho(L)$ is a matrix polynomial. The estimate of $\rho(L)$, along with estimates for the structural shocks, can be used to calculate impulse response functions, forecast error decompositions, and variance decompositions in the usual ways.

Of course, this alternative approach is not without some potential pitfalls, some which it shares with the traditional VAR approach. First, as with a conventional VAR model or any other structural model, the econometrician must specify which economic variables in the Fed's reaction function contain newly-available information (X_{1t} and X_{2t-1} above). Any important variable that is omitted from the analysis will bias the estimates of the structural shocks. In addition, as illustrated in the above example, there must be available and reliable measures of market participants' expectations for the federal-funds rate and for each relevant variable in the Fed's reaction function. Finally, as with a conventional VAR model or any other structural model, there could be simultaneity between the federal funds rate and variables that are in the Fed's reaction function. In that case, one must find additional innovations to use as instruments to estimate γ in equation (7). This requires still more assumptions about which innovations to use as instruments and additional expectations measures in order to derive the required instruments.

III. Economic Innovations

The previous section of the paper described an alternative econometric approach to identifying monetary policy shocks and calculating their effects on economic variables. This section proceeds with the first step of that approach -- the derivation of the economic innovations using available measures of expectations, as well as lags of traditional macroeconomic variables. These innovations are contrasted with those derived from a traditional VAR model, and they are used in the next section to calculate monetary policy shocks, as well as impulse response functions for several variables with respect to a monetary policy shock.

A Benchmark VAR

In order to contrast results from the alternative approach with those from a traditional VAR, a benchmark VAR model is required. There has been a great deal of recent debate concerning the appropriate monetary policy instrument and the appropriate set of economic indicators to include in the Federal Reserve's reaction function -- see, for example, Bernanke and Blinder (1992), Strongin (1992), Gordon and Leeper (1995), Christiano, Eichenbaum, and Evans (1994), and Brunner (1994). Although the recent consensus appears to be that the federal funds rate best represents the Fed's operational instrument, there is little agreement on a reasonable set of economic indicators to include in the Fed's reaction function. The following set of economic variables, however, is representative of variables used in that literature, and they will serve as a benchmark for subsequent analysis:

$$X_t = [\ Y_t \quad CPI_t \quad PCOM_t \quad FFR_t \quad NBR_t \quad TOTR_t \quad M1_t\ ] \tag{9}$$

where Y is some measure of economic activity, CPI is the consumer price index, PCOM is a price index of sensitive commodities, FFR is the federal funds rate, NBR is non-borrowed reserves, TOTR is total reserves, and M1 is the M1 monetary aggregate.[3] It is also assumed that structural shocks can be identified with a triangular decomposition based on the ordering in equation (9) and that monetary policy shocks are associated with structural shocks to the federal funds rate. This benchmark VAR model corresponds to one of the monthly models studied by Christiano, Eichenbaum, and Evans (1994). As they discuss, this identification scheme is somewhat defensible when using monthly data, as will be the case in this paper.[4]

With these assumptions, the Fed is assumed to respond to: i) contemporaneous changes in output, consumer prices, and commodity prices, ii) lagged values of all variables, and iii) a monetary policy shock:

$$FFR_t = \phi + \gamma_1 Y_t + \gamma_2 CPI_t + \gamma_3 PCOM_t + ... + \eta_t^{MP} \tag{10}$$

That is, using equation (3), innovations in the federal funds rate are assumed to respond contemporaneously to innovations in output, consumer prices and commodity prices:

$$u_t^{FFR} = \gamma_1 u_t^{Y} + \gamma_2 u_t^{CPI} + \gamma_3 u_t^{PCOM} + \eta_t^{MP} \tag{11}$$

As in equation (2), all VAR innovations are derived by regressing each variable in X_t on several lags of X_t:

$$X_t = \mu' + B(L) X_{t-1} + u_t \tag{2}$$

As discussed in the previous section, there are at least two worrisome aspects of the decomposition of the federal funds rate in equation (11). First, neither the CPI nor most broad measures of

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[3] With the exception of the federal funds rate, all variables are expressed as log levels.

[4] The primary purpose of this paper is to illustrate an alternative estimation strategy that incorporates expectations measures. It is not to argue the merits of any particular set of economic variables or any particular identification scheme.

economic activity for a given period are publicly observable during that period. This means that the innovations used as regressors in equation (11) have been derived using information that is not yet available to the Fed or to other market participants. Second, all innovations have been derived by assuming a limited information set for the Federal Reserve. Even if the Fed responds only to innovations in Y, CPI, and PCOM, its expectations of those variables are likely based on a much richer information set than just lags of X_t. Accordingly, there is a compelling case to be made for: i) excluding Y_{t-1} and CPI_{t-1} from the list of regressors when calculating the innovations to FFR_t and $PCOM_t$, ii) deriving innovations to Y_{t-1} and CPI_{t-1} rather than Y_t and CPI_t for use in equation (11), and iii) deriving all innovations with an assumed richer information set for the Fed by incorporating available measures of expectations. This is the focus of the next subsection of the paper.

Deriving Innovations

As shown in Table 1, there are several available options for measuring market participants' expectations of the federal funds rate, economic activity, and the consumer price index. First, there are several available market readings on the expected federal funds rate. Banks can contract to borrow or lend federal funds for 1-month intervals at the term-federal-funds rate. Thus, if markets are forward-looking, the 1-month term-federal-funds rate observed on the last day of a month ($TFFR_{t-1}$) should be a good predictor of the month-average federal funds rate for the following month. Similarly, there are other forward-looking interest rates, including the 1-month Treasury bills rate (TBR_{t-1}), the 1-month CD rate (CDR_{t-1}), and the 1-month Eurodollar rate (EDR_{t-1}). Finally, if the Fed is pursuing a funds-rate targeting strategy, then the federal funds rate should reflect all economic information available to the Fed, and the lagged federal funds rate (FFR_{t-1}) can also serve as a forecast of the current federal funds rate. The federal funds rate is plotted against each measures in Figure 1.

For the remaining variables, Money Market Services (MMS) provides frequent forecasts for upcoming economic releases for CPI inflation and for several monthly indicators of economic activity growth, including the unemployment rate (UR), retail sales (RSLS), and industrial production (IP). Actual and forecasted values for each of these variables are shown in Figures 2 and 3.

An important question concerns whether these measures of expectations are, in fact, efficient and unbiased estimators of future values of the variables. Table 2 examines this question for the forward-looking interest rates. The table summarizes regression results based on:

$$FFR_t - E[FFR_t \mid \hat{I}_{t-1}] = \alpha + \beta(L)[X'_{1,t-1} X'_{2,t-2}] + (\delta - 1) E[FFR_t \mid \hat{I}_{t-1}] + u_t^{FFR} \quad (12)$$

where $X_{1,t}$ = [$PCOM_t$ FFR_t NBR_t $TOTR_t$ $M1_t$]' and $X_{2,t}$ = [Y_t CPI_t]', and where E[·] represents a forward-looking interest rate. In particular, the table presents significance levels for four Wald tests and the R^2 for each regression. The Wald tests corresponds to the following hypotheses: i) that there is not a time-invariant risk premium (α=0), ii) that the forward-looking interest rate is an efficient estimator (βs=0), iii) that the forward-looking interest rate is an unbiased estimator (δ=1), and iv) that the forward-looking interest is both efficient and unbiased. An R^2 of zero would also be a general indicator that additional information (other than the forward-looking interest rate) provides no additional predictive power.

The results are generally disappointing. Although the term federal funds rate, the CD rate, and the Eurodollar rate appear to be unbiased estimators of the federal funds rate, none of the forward-looking interest rates are efficient estimators. Other than the obvious explanation -- that banks make systematic forecast errors -- these results could be interpreted in two ways. First, the additional information could be capturing a time-varying risk premium. This argument is most plausible for the Treasury bill rate, which shows evidence of a time-invariant risk premium (α not equal to zero). A second explanation might be that banks exhibit some habitat persistence, preferring not to always arbitrage away any predictable differences between current market rates and expected future federal funds rates. Still, the R^2s in these regressions seem somewhat large to be associated with a time-varying risk premium or habitat persistence. In any case, while the market interest rates provide additional useful information (δ=0 is rejected in all cases), they do not by themselves provide complete information for forecasting the federal funds rate.

The ability of market participants to make accurate predictions of economic activity -- as measured by MMS forecasts -- are evaluated in Table 3 using the following regression:

$$Z_t - E[Z_t \mid \hat{I}_{t-1}] = \alpha + \beta(L)[X'_{1,t-1} X'_{2,t-2}]' + (\delta - 1)E[Z_t \mid \hat{I}_{t-1}] + u_t^Z \qquad (13)$$

where Z_t corresponds to the variables listed in the first column of the table.

These results are somewhat more promising than those for the federal funds rate. First, only forecasts of retail sales appear to be inefficient. Importantly, this result is consistent with the previous conjecture that the inefficiency of the forward-looking interest rates is due to the presence of a time-varying risk premium rather than because banks make systematic forecast errors. On the other hand, MMS forecasts of two variables -- retail sales and the unemployment rate -- are biased, tending to follow the actual values down when the variable is falling and vice versa. Similarly, the joint hypothesis of efficiency and unbiasedness can be rejected at conventional significance levels for retail sales and the unemployment rate. In summary, as before, while the MMS forecasts provide additional useful information for forecasting these variables, they do not by themselves provide complete information.

Although these expectations measures appear to include important additional information on a statistical basis for forecasting these economic variables, another important question is whether these measures are important in an economic sense. This question is explored in Table 4, which presents the variances and cross-correlation matrix for several sets of innovations for the variables described above. Panel (i) lists the variances and the cross-correlation matrix for three sets of innovations to the federal funds rate. The first set was derived using the standard VAR methodology, by regressing the federal funds rate on 12 lags of each variable in X_t.[5] The second set was derived in a similar fashion, except that the first lag of UR and CPI were excluded from the regression, since they are not observable by the Fed at time t-1. Since some information is deleted from the assumed information set, the variance of these innovations is a bit larger, although they are highly correlated with the standard VAR innovations. The third set was calculated by excluding the first lag of UR and CPI but including the term federal funds rate ($TFFR_{t-1}$) as a regressor. Interestingly, the variance of these innovations is substantially smaller than for the other two sets of innovations, although the innovations are still somewhat correlated with the other sets.

Panels (ii) and (iii) provide similar information for innovations to the unemployment rate and to the consumer price index. It should be noted, however, that the standard VAR innovations are to UR_t and CPI_t, while the other two sets of innovations are to UR_{t-1} and CPI_{t-1}, since it is assumed in the alternative approach that the Fed responds contemporaneously to the latter innovations. There are several important features of these results. First, innovations derived using the alternative approach are essentially uncorrelated with the standard VAR innovations. Second, as before, including expectations measures substantially reduces the variance of the innovations. Still, the innovations to UR_{t-1} and CPI_{t-1} -- derived with and with the expectations measures -- are highly correlated (.76 and .68, respectively).

The main results of this section can be summarized as follows. First, available measures of market participants' expectations of economic variables are not by themselves sufficient for developing innovations to those variables. That is, the expectations measures are sometimes biased and inefficient estimators. Still, they provide significant additional information relative to standard VAR techniques. In all cases examined, including the expectations measures reduced the innovation variance by at least

[5] All of the results presented in Table 4 were calculated using the unemployment rate as the measure of economic activity and the term federal funds rate as the expectations measure for the funds rate. Similar results were obtained with other measures.

one-half. Finally, innovations to the federal funds rate derived using the alternative approach are only somewhat correlated with standard VAR innovations. Innovations to other macroeconomic variables are essentially uncorrelated with their standard VAR counterparts, primarily because the former are innovations to lagged values of these variables rather than contemporaneous values.

On balance, these results could have serious implications for the identification of monetary policy shocks -- which rely on correctly estimated innovations -- as well as for any conclusions to be drawn about the effects of these shocks on other macroeconomic variables. These implications are the focus of the next section of the paper.

IV. Monetary Policy Shocks

The previous section calculated and examined the time-series properties of innovations to the federal funds rate, the CPI, and various indicators of economic activity. These innovations were calculated using a standard VAR approach and using an alternative approach which incorporated market expectations. This section uses these innovations to derive structural shocks that will be interpreted as monetary policy shocks. The effects of these shocks on various macroeconomic variables is also examined.

Policy Shocks

As discussed earlier, innovations to the federal funds rate can be decomposed using the relationship shown in equation (10). That is, the residuals from a regression of federal funds rate innovations on innovations to economic activity, the CPI, and PCOM can be interpreted as monetary policy shocks -- the exogenous component of monetary policy. An important question that is addressed is whether monetary policy shocks derived with a standard VAR approach have similar time-series properties to those derived with the alternative approach.

Table 5 presents the decomposition results, using the innovations computed in the previous section. Along with the parameter estimates (the γs), the table lists the R^2 for each regression. The first three rows of the table correspond to a regressions using standard VAR innovations, where economic activity is measured by, respectively, the unemployment rate, retail sales, and industrial production. The next three rows correspond to regressions using the modified VAR approach, and the last three to regressions that use innovations derived using market expectations.

The important results in the table can be summarized as follows. First, as indicated in the first line of each set of regressions, the federal funds rate responds contemporaneously to new information about the unemployment rate. This is true regardless of how the innovations are calculated, although the effects are less strong for the alternative approach than for the other two methods. (This result is also robust to other expectations measures for the federal funds rate other than the term federal funds rate.)

By contrast, the federal funds rate does not respond to new information about retail sales or the CPI and only weakly to innovations in industrial production. This could be attributable to the fact that retail sales and the CPI are more volatile series than the unemployment rate, and they are also subject to many more revisions than the unemployment rate. The Fed also appears to respond contemporaneously to PCOM, although the estimated response is not robust to how innovations are calculated. On balance, these results are consistent with Brunner (1994), who found that the unemployment rate is one of the few economic indicators that the Fed has responded to consistently in the post-war era, whereas the Fed has not responded very strongly to price developments and to other indicators of economic activity in recent years.

It is also interesting to observe that when additional information is used to calculate economic innovations (the third set of regressions), many of the regressors become less significant or even insignificant. This suggests that part of their role in the first two sets of regressions is not causal. Rather, they are serving as covariates with information that has been omitted in the standard and modified VAR approaches.

Finally, it is important to note that the R^2 for all of the regressions in Table 5 are quite low. In other words, although the response of the federal funds rate to some of these economic indicators is statistically significant, these innovations account for only a small fraction of the variance of federal funds rate innovations. This result is also consistent with Brunner (1994), who concluded that between 85 and 100 percent of the variance of innovations to the federal funds rate can be attributed to monetary policy shocks. As a consequence, the time-series properties of the monetary policy shocks that are implied by the regressions in Table 5 are nearly the same as the properties of the innovations to the federal funds rate that are shown in Table 4.

Impulse Responses

The final task of this paper is to examine the effects of monetary policy shocks on the macroeconomy. For the VAR model, these effects can be calculated by inverting the VAR model, as shown in equation (4). For the alternative approach, impulse response functions can be calculated by regressing W_t, a variable of interest, on several lags of the estimated monetary policy shocks:

$$W_t = \rho_0 + \sum_{i=1}^{q} \rho_{1i} W_{t-i} + \sum_{i=0}^{r} \rho_{2i} \epsilon_{t-i} + u_t \tag{14}$$

Note that a few lags of W_t are included in the regression. It was found that these lags were necessary to stabilize the estimates of ρ_{2i}, especially when W_t is a non-stationary variable.[6] It is also important to point out that this approach for computing impulse response functions is reminiscent of Barro's (1977, 1978) approach for examining the effects of unanticipated money, although the identification of the regressors (the εs) is quite different.

[6] This was the case for most variables examined in this paper.

Figure 4 presents impulse response functions for several macroeconomic variables, using monetary policy shocks calculated using both methodologies. The impulse responses to a VAR shock (the solid lines) were calculated using shocks derived from a VAR model that included the unemployment rate as the indicator of economic activity. That is, these impulse responses are based on the monetary policy shocks calculated in the first row of Table 5. Confidence bounds for the VAR impulse response functions are also plotted (the long-dashed lines).

Similarly, impulse response functions for the market expectations model (the short-dashed lines) were calculated using the unemployment rate as the indicator of economic activity and using expectations measures as discussed earlier. The regressions in equation (14) included three lags of the dependent variable (q=3) and 24 lags of the monetary policy shocks (r=24). In addition, consistent with the previous analysis, the regressions for UR, CPI, and PCOM did not include the contemporaneous value of the monetary policy shock (ε^{MP}_t). In other words, the assumption is that these particular variables do not respond within the period to monetary policy shocks.

The results are quite surprising. Although the two sets of monetary policy shocks -- derived using a VAR model and using market expectations -- are only somewhat correlated, they have remarkably similar effects on macroeconomic variables. As shown in panel (a), both shocks have a persistent, positive effect on the unemployment rate. Panel (b) illustrates the well-known "price puzzle," the counter-intuitive result that consumer prices increase for a few months following a contractionary monetary policy shock. Evidently, the market expectations measure of the policy shock suffers from the same defect as the VAR measure. That is, as discussed by Christiano, Eichenbaum, and Evans (1994), there is some variable -- likely some measure of raw material or labor costs -- that affects contemporaneously both the federal funds rate and the CPI. As shown in panel (c), however, both sets of shocks have a small negative (but insignificant) effect on commodity price inflation.

As shown in panel (e), both sets of shocks have a strong liquidity effect on NBR, consistent with the effects documented by Leeper and Gordon (1992), Christiano, Eichenbaum, and Evans (1994), and Brunner (1994). The effects of a monetary policy shock are also seen (eventually) in TOTR and M1, shown in panels (f) and (g), respectively.

V. Conclusion

This paper has considered an alternative econometric approach to the VAR methodology for identifying and estimating the effects of monetary policy shocks. The alternative approach incorporates available measures of market participants' expectations of economic variables in order to calculate economic innovations to those variables. In general, measures of expectations should provide important additional information relative to a standard VAR analysis, since market participants use a much richer information set to make their forecasts than the information set that is assumed in a typical VAR model. The resulting innovations are easily incorporated in a VAR-like framework, similar to the approach taken by Barro (1977, 1978) to examine the effects of unanticipated money on economic variables.

The empirical results are quite surprising. First, when expectations are incorporated, the variance of all innovations is reduced substantially. In all cases examined, the variances were reduced by at least one-half. Second, innovations to the federal funds rate using the two methodologies -- using a VAR model and using market expectations -- are only somewhat correlated. Innovations to other economic variables are essentially uncorrelated. Still, monetary policy *shocks* derived using the two approaches are also somewhat correlated, since innovations to prices and economic activity explain only a small fraction of innovations to the federal funds rate. As a consequence, the impulse responses of economic variables to the two sets of monetary policy shocks have remarkably similar properties.

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Table 1. Available Monthly Measures of Market Participants' Expectations of Selected Economic Variables

Economic Variable	Source(s) of Expectations
FFR_t	$TFFR_{t-1}$
	TBR_{t-1}
	CDR_{t-1}
	EDR_{t-1}
	FFR_{t-1}
UR_{t-1}	Money Market Services Survey
$RSLS_{t-1}$	Money Market Services Survey
IP_{t-1}	Money Market Services Survey
CPI_{t-1}	Money Market Services Survey

Table 2. Are "Forward-Looking" Interest Rates
Efficient and Unbiased Estimators of the Future Federal Funds Rate?
(based on 179 monthly observations from 1980 to 1994)

$$FFR_t - E[FFR_t \mid \hat{I}_{t-1}] = \alpha + \beta(L)[X'_{1,t-1} X'_{2,t-2}] + (\delta - 1) E[FFR_t \mid \hat{I}_{t-1}] + u_t^{FFR} \quad (12)$$

Market Interest Rate	Significance Levels				R^2
	$\alpha = 0$	$\beta s = 0$	$\delta = 1$	$\beta s = 0, \delta = 1$	
$TFFR_{t-1}$	.85	<.01	.36	<.01	.41
TBR_{t-1}	.07	<.01	<.01	<.01	.78
CDR_{t-1}	.36	<.01	.84	<.01	.41
EDR_{t-1}	.74	<.01	.31	<.01	.43
FFR_{t-1}	.58	<.01	<.01	<.01	.45

Table 3. Are MMS Forecasts Efficient and Unbiased Estimators of Future Economic Activity?
(based on 179 monthly observations from 1980 to 1994)

$$Z_t - E[Z_t \mid \hat{I}_{t-1}] = \alpha + \beta(L)[X'_{1,t-1} X'_{2,t-2}]' + (\delta - 1) E[Z_t \mid \hat{I}_{t-1}] + u_t^Z \qquad (13)$$

Economic Variable (Z_t)	Significance Levels				R^2
	$\alpha = 0$	$\beta s = 0$	$\delta = 1$	$\beta s = 0, \delta = 1$	
UR_{t-1}	.43	.05	.01	.05	.14
$\%\Delta\ RSLS_{t-1}$	.90	<.01	.01	<.01	.26
$\%\Delta\ IP_{t-1}$	.24	.13	.06	.13	.18
$\%\Delta\ CPI_{t-1}$	.82	.61	.89	.62	.00

Table 4. Are VAR Innovations Correlated with Innovations Derived Using Market Expectations? (based on 179 monthly observations from 1980 to 1994)

i) Federal Funds Rate

Source of Innovation	Variance	Correlation with: (1)	(2)	(3)
1) Standard VAR [a]	.411	1.00		
2) Modified VAR [b]	.503	.95	1.00	
3) Modified VAR plus $TFFR_{t-1}$ [c]	.155	.56	.55	1.00

[a] Derived using 12 lags of {UR_t CPI_t $PCOM_t$ FFR_t NBR_t $TOTR_t$ $M1_t$}.
[b] Derived as above, excluding UR_{t-1} and CPI_{t-1}.
[c] Derived as above, including expectations measure.

ii) Unemployment Rate

Source of Innovation	Variance	Correlation with: (1)	(2)	(3)
1) Standard VAR [a]	.024	1.00		
2) Modified VAR [b]	.023	.05	1.00	
3) Modified VAR plus MMS Forecast [c]	.013	-.04	.76	1.00

[a] Derived for UR_t using 12 lags of {UR_t CPI_t $PCOM_t$ FFR_t NBR_t $TOTR_t$ $M1_t$}.
[b] Derived for UR_{t-1} using 12 lags of {UR_{t-1} CPI_{t-1} $PCOM_t$ FFR_t NBR_t $TOTR_t$ $M1_t$}.
[c] Derived as above, including expectations measure.

Table 4. (cont.) Are VAR Innovations Correlated with Innovations Derived Using Market Expectations?
(based on 179 monthly observations from 1980 to 1994)

iii) Consumer Price Index

Source of Innovation	Variance	Correlation with: (1)	(2)	(3)
1) Standard VAR [a]	.033	1.00		
2) Modified VAR [b]	.034	.14	1.00	
3) Modified VAR plus MMS Forecast [c]	.016	-.04	.68	1.00

[a] Derived for CPI_t using 12 lags of $\{UR_t\ CPI_t\ PCOM_t\ FFR_t\ NBR_t\ TOTR_t\ M1_t\}$.
[b] Derived for CPI_{t-1} using 12 lags of $\{UR_{t-1}\ CPI_{t-1}\ PCOM_t\ FFR_t\ NBR_t\ TOTR_t\ M1_t\}$.
[c] Derived as above, including expectations measure.

Table 5. Decomposition of FFR Innovations
(based on 179 monthly observations from 1980 to 1994)

$$u_t^{FFR} = \gamma_1 u_t^{Y} + \gamma_2 u_t^{CPI} + \gamma_3 u_t^{PCOM} + \eta_t^{MP} \qquad (10)$$

Source of Innovation	Parameter Estimates γ_1	γ_2	γ_3	R^2
1) Standard VAR [a]				
Y=UR	-.51***	-.18	.91**	.06
Y=RSLS	.00	-.14	.72**	.02
Y=IP	.12*	-.11	.64**	.04
2) Modified VAR [b]				
Y=UR	-.84***	.02	1.07**	.10
Y=RSLS	.01	.12	.80**	.02
Y=IP	.10*	.12	.84**	.04
3) Modified VAR plus Expectations [c]				
Y=UR	-.43*	-.03	.10	.01
Y=RSLS	.05	-.03	-.05	.00
Y=IP	.00	-.10	.02	.00

[a] Derived using 12 lags of $X_t = \{Y_t\ CPI_t\ PCOM_t\ FFR_t\ NBR_t\ TOTR_t\ M1_t\}$.
[b] See "b" table notes in Figure 4.
[c] Derived as above, including $TFFR_{t-1}$ or MMS expectations measure.
*** Significant at the 1% level.
** Significant at the 5% level.
* Significant at the 10% level.

Figure 1. The Federal Funds Rate and Forward-Looking Interest Rates

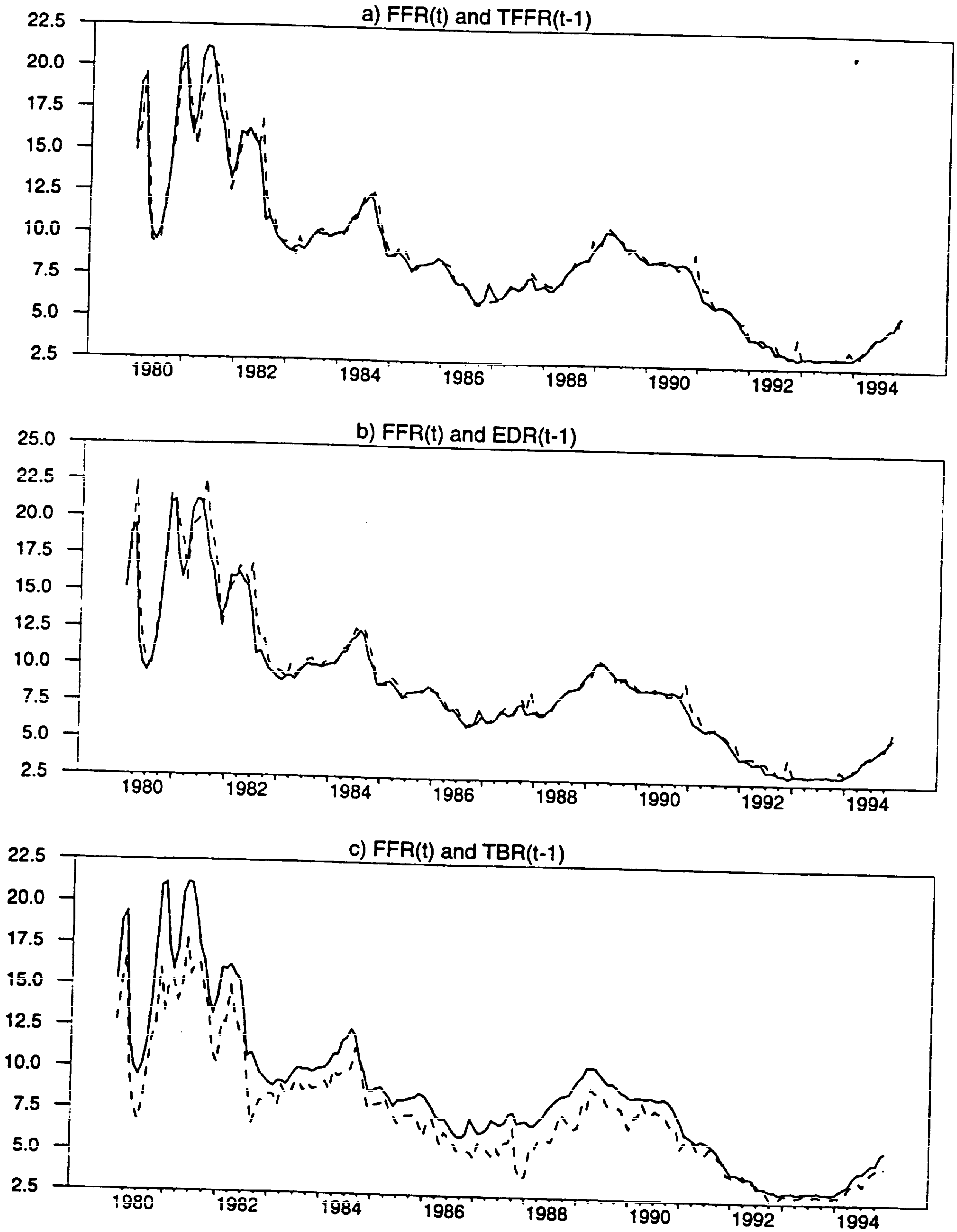


Figure 1 (cont). The Federal Funds Rate and Forward-Looking Interest Rates

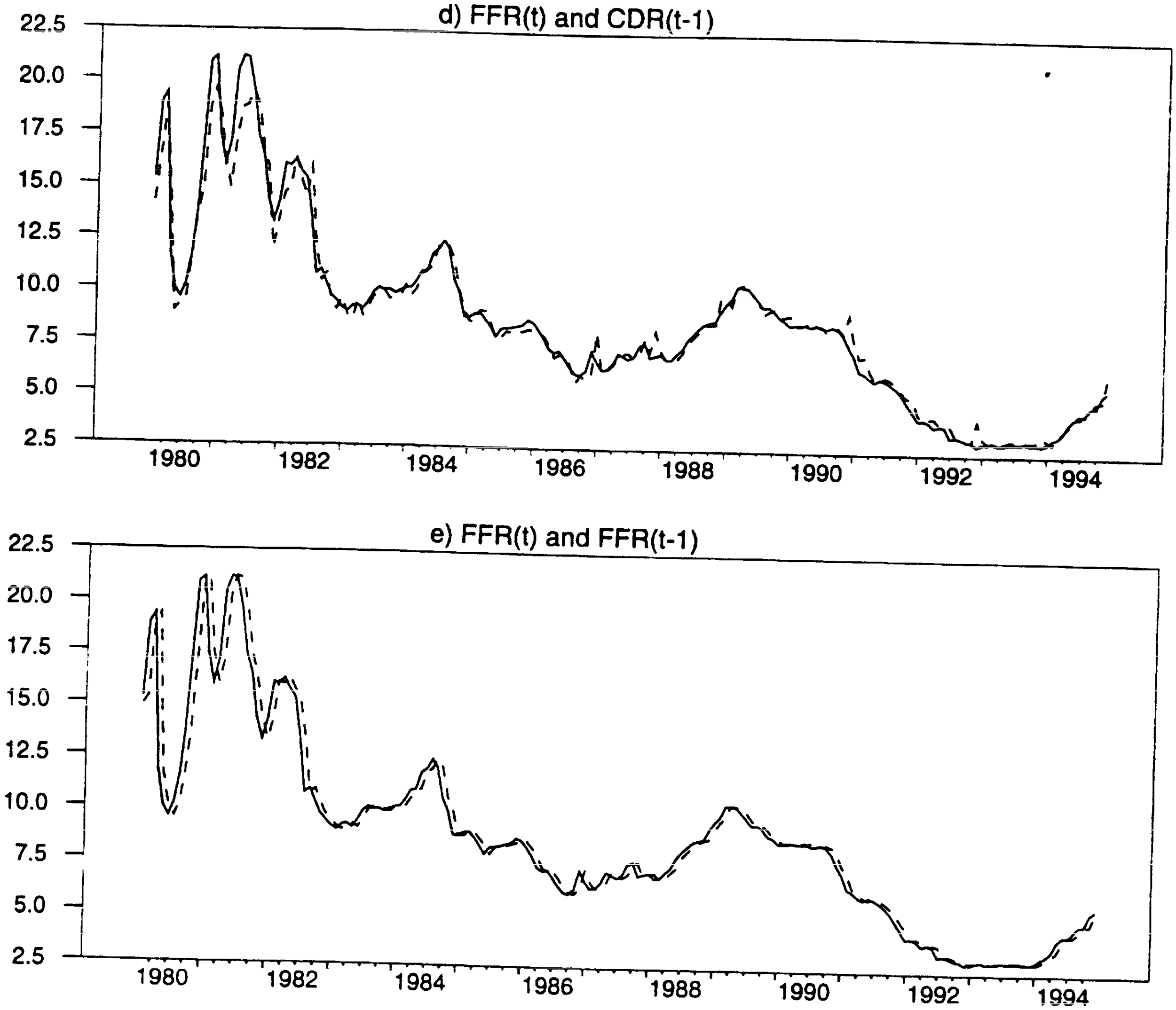


Figure 2. Actual and MMS Forecasts of Economic Growth

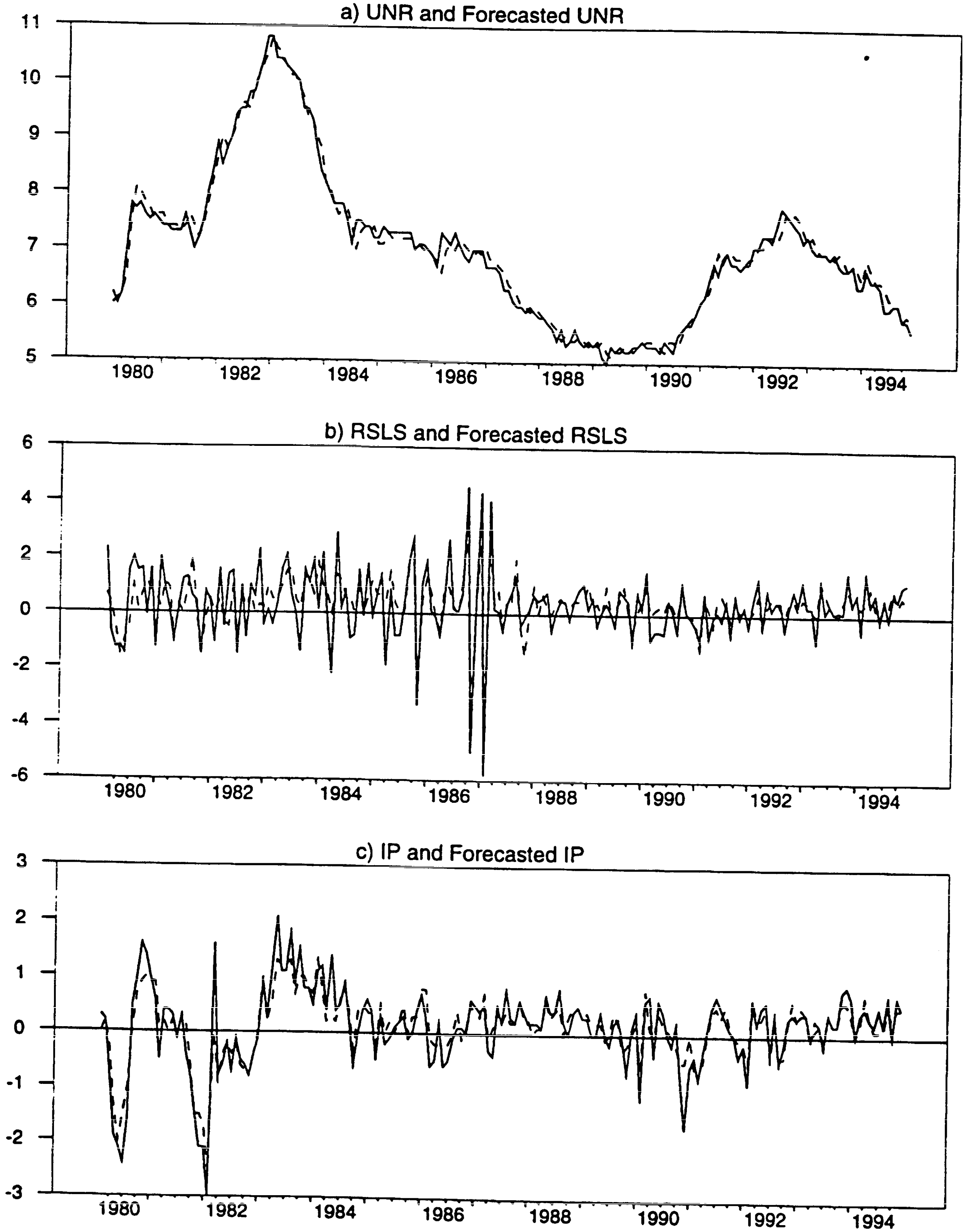


Figure 3. Actual and MMS Forecasts of CPI Inflation

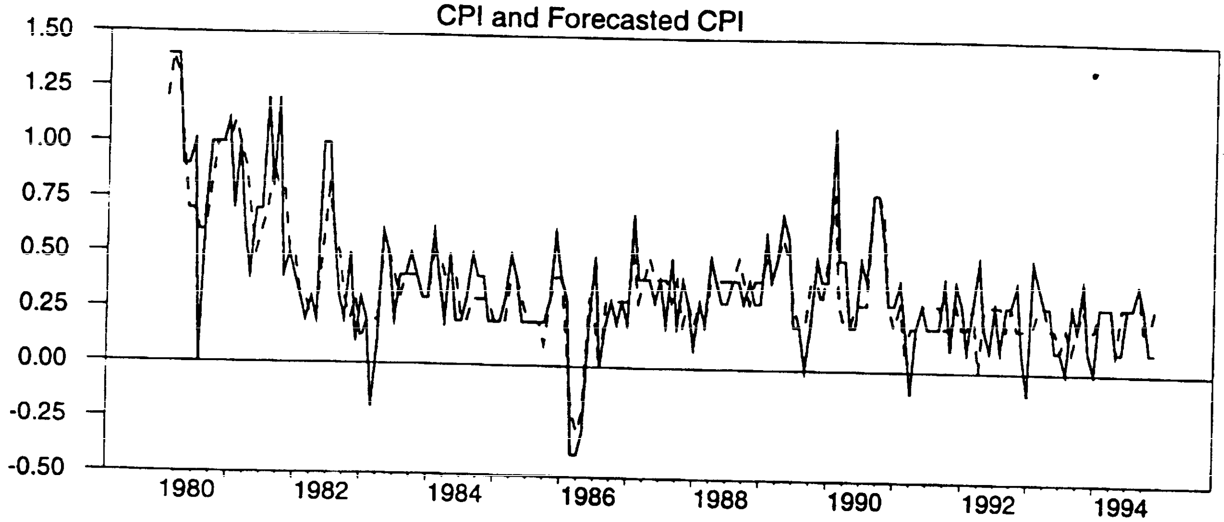


Figure 4. Responses to a Monetary Policy Shock

(VAR=____ EXP=_ _ _)

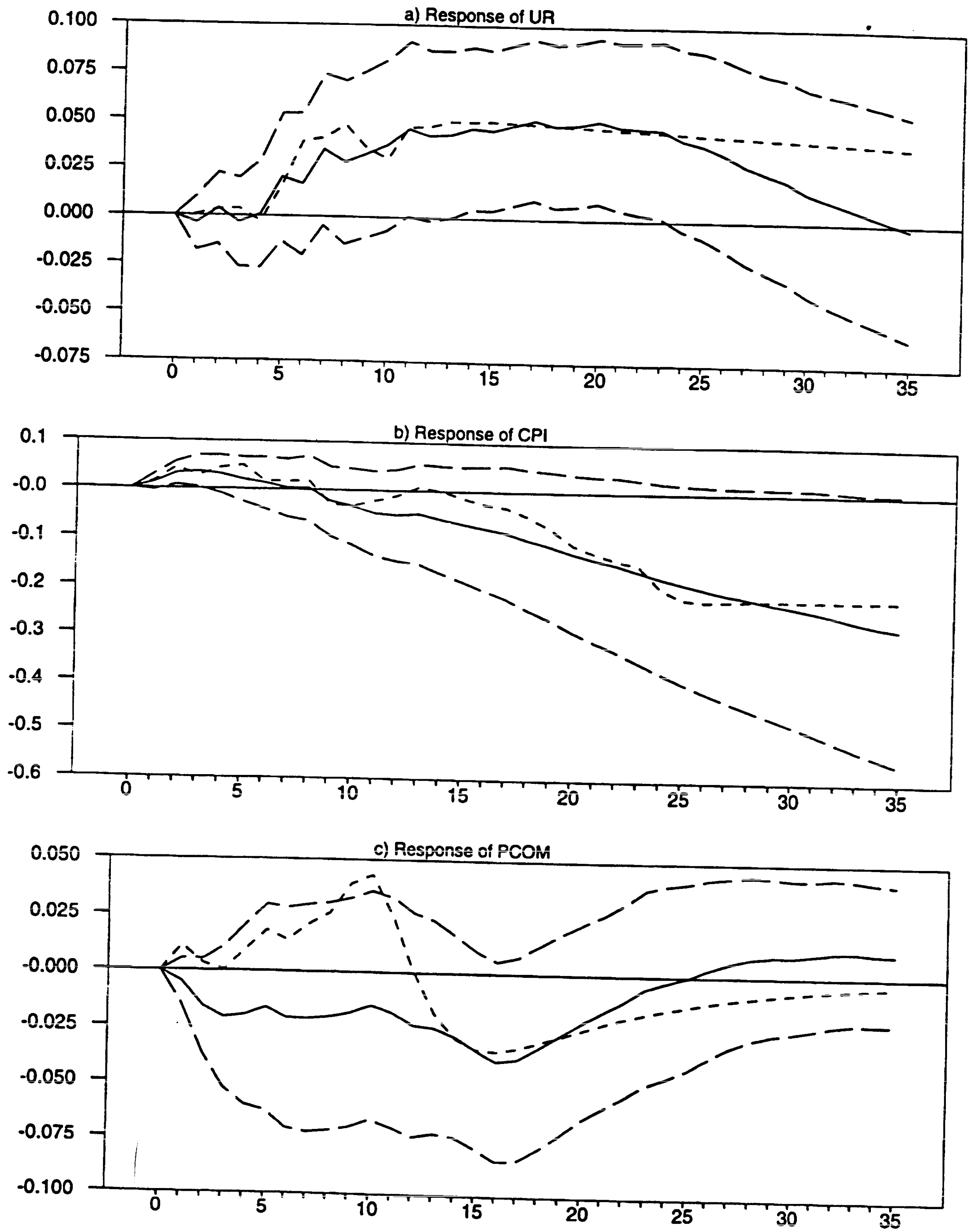


Figure 4 (cont). Responses to a Monetary Policy Shock

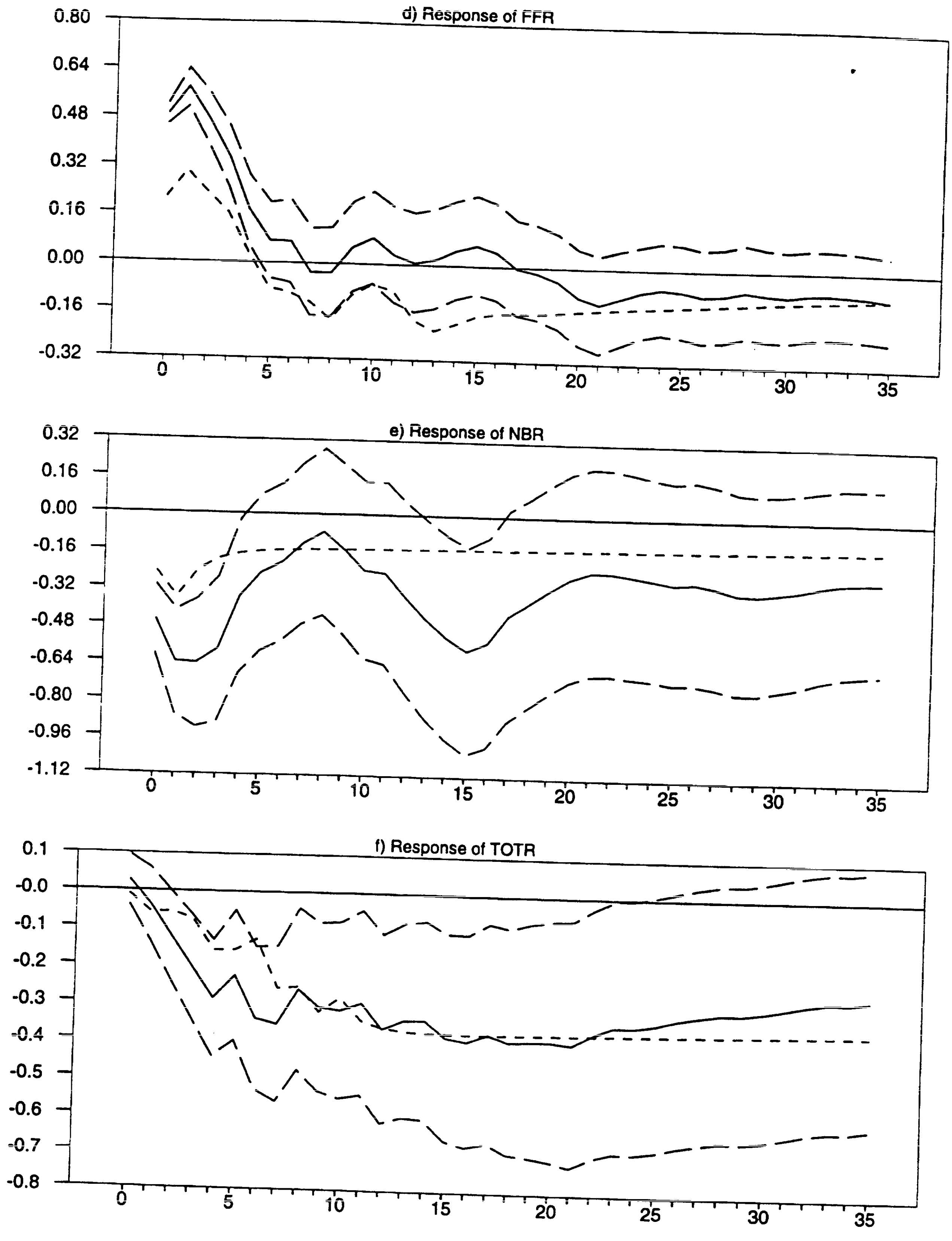
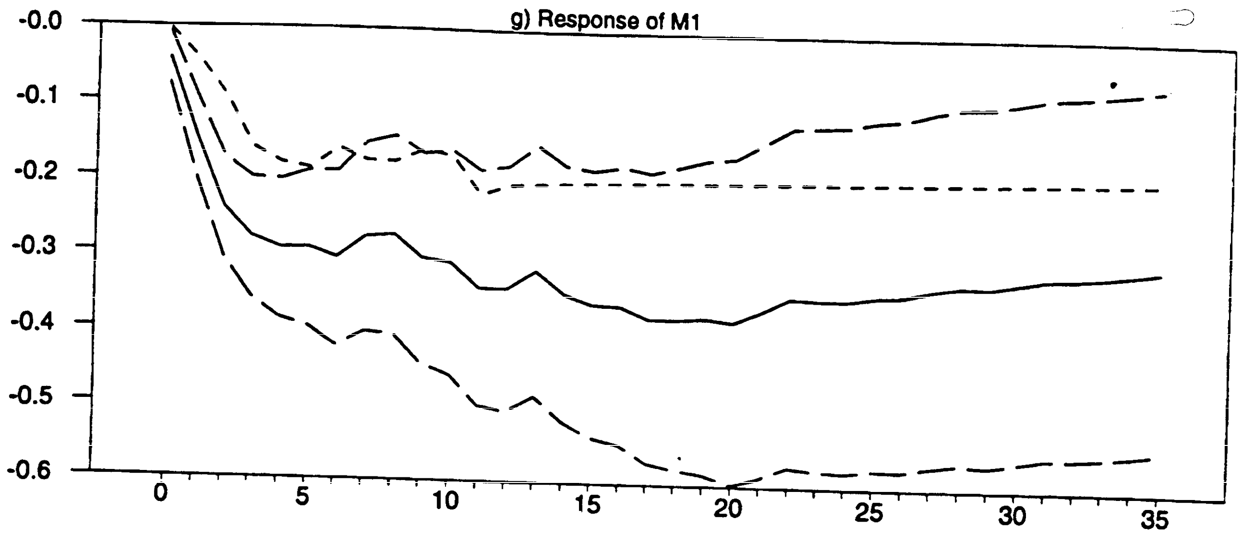


Figure 4 (cont). Responses to a Monetary Policy Shock



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