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Modest Policy Interventions

Eric M. Leeper and Tao Zha

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Abstract: This paper brings together identification and forecasting in a positive econometric analysis of policy. We contend that a broad range of important policy questions is consistent with the existing policy process and is not subject to Lucas's critique. We analyze the economics of "business as usual" and show that modest policy interventions, whose effects can be projected even if expectations are modeled as depending solely on past policy, can address routine questions like those raised at regular policy meetings. And modest interventions matter: they can shift the projected paths and probability distributions of macro variables in economically meaningful ways.

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Key words: monetary policy, identification, forecasting, policy analysis, VAR, Lucas critique

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Modest Policy Interventions

Eric M. Leeper and Tao Zha

1. Introduction

Lucas's (1976) criticism of econometric policy evaluation has paralyzed policy analysis. Fearful of committing crimes against rationality or studying trivial policies, macroeconomists have largely avoided probing the range of questions that can be addressed without changing the existing policy process. This is an unfortunate outcome for it leaves unstudied a class of monetary policies that central banks routinely implement.

We contend that a broad range of important questions are consistent with the underlying policy process and, hence, are not subject to Lucas's critique. The questions involve policy interventions that do not create an incentive for either private agents or the policy advisor to change their models of the economy. Policymakers, in considering these interventions, and private agents, in responding to them, are conducting "business as usual."¹

This paper brings together identification and forecasting in a positive econometric analysis of policy.² In analyzing the economics of "business as usual" the paper offers a single framework for evaluating and implementing policy. To analyze questions motivated by routine policy choices the paper projects the impacts of modest policy interventions of the kind considered by

¹ We thank Torsten Persson for suggesting this phrase.

² Heckman (1999, pp. 4-5) ties this point to the Cowles Commission: "The tension between the goal of producing accurate descriptions of the data and the goal of producing counterfactual causal analyses for interpretation and policy prediction is a lasting legacy of the research of the Cowles Commission...."

central banks before policy meetings. Although modest interventions are the stuff of actual policymaking, they receive scant attention in the modern literature.

The rational expectations branch of the literature inspired by Lucas and Sargent (1981) regards modest changes in policy as “trivial” interventions. Those interventions are not the policies that have dominated the research efforts of macroeconomists. Rational expectations analyses instead focus on once-for-all permanent changes in policy and impose expectations that are consistent with the contemplated policy behavior. Although this work explicitly identifies expectations of policy, it rarely specifies how policy is formed. It is also true that models in this line have not yet developed to the point where their fit and forecasts are adequate.³

The vector autoregression branch of the literature initiated by Sims (1980) uses policy history to model expectations formation and seems like a natural way to frame the issue. Vector autoregressions have been put to several uses. One use infers the role of monetary policy in producing comovements in time series and asks whether policy shocks have contributed to business cycles.⁴ Another use tests dynamic, stochastic general equilibrium models by checking if the theoretical responses to policy shocks match those that VARs produce.⁵ Both uses concentrate on the marginal impacts of one-time transitory shifts in policy and downplay the more important endogenous part of policy. A third use forecasts with VAR models conditional on relatively long sequences of variables.⁶ The sustained deviations from usual policy behavior

³ Leeper and Sims (1994), Altig, Carlstrom and Lansing (1995), Ireland (1997), and Leeper (1997) document the poor fit of some dynamic, stochastic general equilibrium models of policy.

⁴ Leeper, Sims and Zha (1996) survey the identified VAR literature with this use in mind.

⁵ Christiano, Eichenbaum and Evans (1998) emphasize this use and argue it answers Lucas’s (1980) call for testing if theoretical models are “...useful imitations of reality...”

⁶ See, for example, Doan, Litterman and Sims (1984) or Fackler and McMillin (1999).

that the forecasts typically entail can make it difficult to maintain the VARs' assumption that expectations depend only on past policy.

Because neither once-for-all permanent changes nor one-time transitory shifts inform routine policy choices, there is a great gulf between how policy is analyzed and how policy is practiced. This paper begins to bridge that gulf by embedding the analysis in a realistic model of policy choice. The first step is to acknowledge a tension between the true policy process and any econometric model of the process. Our analysis keeps that tension in the foreground to arrive at a description of policy behavior that is closer to reality in key respects. We model how policy choices respond to the regular arrival of new information. That information, coupled with the sequential nature of policy choice, generates modest, incremental changes in policy. Modest changes are part of the actual policy process, are regarded as such by private decisionmakers, and therefore do not induce shifts in private decision rules. The changes nevertheless have nontrivial impacts on the macro economy and constitute important policy interventions.

We model the true policy process as composed of a part that depends on the economic state that private agents observe, and an unpredictable part that is independent of that state. The model identifies past responses of policy to the state with private agents' expectations of policy. The unpredictable part of policy is exogenous to the econometric model. Because most variation in policy arises from responses to changes in the state, econometrically exogenous changes account for only a modest amount of policy variation. To be consistent with the modest exogenous variation in policy, we consider a limited class of policy questions. We show that modest interventions, whose effects can be projected even if expectations are modeled as depending solely on past policy behavior, can address routine questions like those raised at

regular policy meetings. And modest interventions matter: they can shift the projected paths and probability distributions of macro variables in economically meaningful ways.

We offer a metric for assessing whether a given policy intervention is large or small relative to past policy behavior. A priori, larger interventions are more likely to induce private agents to believe the policy process has changed, requiring agents to re-solve their decision problems. By that metric we find that many interventions the Federal Reserve actually considers and implements are modest and unlikely to be subject to the Lucas critique.

We establish the results in a small illustrative model of the U.S. economy in which we identify monetary policy behavior. We assess the estimated model's in-sample and out-of-sample fits and its suitability for the policy questions we put to it. The questions concentrate on two recent episodes. The first episode is the 1990-1991 recession, which was a time of aggressive easing of policy and one in which the Fed perceived itself as facing difficult tradeoffs between inflation and real activity. The analysis offers a probabilistic ex-ante assessment of the tradeoffs, conditional on alternative policy actions. The second episode is the Fed's 1994 "pre-emptive strike" against inflation, during which the federal funds rate increased 300 basis points in a year. Sequential forecasts from the model suggest that the incremental increases in the funds rate that occurred through the year are a natural outcome when policy choices are reappraised in light of new information arriving in early 1994. The analysis shows how uncertainty about future exogenous disturbances leads to conservative policymaking, as Brainard (1967) advocates, and it formalizes Blinder's (1997) description of how central banks reappraise their policy decisions.

2. An Econometric Framework for Policy Analysis

This section describes the econometric structure and the procedure for estimating it.

2.1 Policy Specification

Actual policy behavior is a complicated function of a high-dimensional vector of variables. Policymakers choose $R(t)$, the vector of policy choices at date t , as a function of their information set, $\Omega(t)$. True (or actual) policy behavior is a function g such that

$$R(t) = g(\Omega(t)). \quad (1)$$

Policies consistent with (1) are “business as usual.”

To private agents, policy is not perfectly predictable. This fact is crucial in three ways. First, it provides a means to identify policy behavior by distinguishing between the effects of policy on the economy and the response of policy to the economic state. Second, it implies that private agents place probability mass on more than one policy action, given their understanding of the state. This leaves room for policy analysis while still respecting the Lucas critique. Finally, it creates a basis for computing projections conditional on alternative policies.

We assume that private agents are not privy to the details of the policymakers’ decision problems, including the policymakers’ incentives and constraints. That is, they observe $S(t) \subset \Omega(t)$. Agents perceive that policy is composed of a regular response to the state of the economy that they observe at time t , $S(t)$, and a random part, $\varepsilon_p(t)$, that is independent of the state. The econometric model of policy is:

$$R(t) = f(S(t)) + \varepsilon_p(t). \quad (2)$$

The function f summarizes the average behavior of policy when the observed state is $S(t)$ and $\varepsilon_p(t)$ is a disturbance that is exogenous to the econometric model.

The specifications in (1) and (2) reflect the tension between the true policy process, described by g , and our model of policy, described by f . The difference between the two descriptions is ε_p , the part of policy that cannot be predicted from the state vector that agents observe. Modest policy interventions are modeled as small and brief deviations of ε_p from its expected value of zero. To be modest, variations in ε_p must lie within the range that has occurred historically. Consistency with “business as usual” for the policy authority restricts the deviations from the model’s characterization of policy behavior to those that are unlikely to lead private agents to believe policy behavior is anything other than (1).

Because actual policy behavior depends on more information than the model contains, there will always be aspects of policy choice that any model cannot explain. One interpretation of the information discrepancy stems from the fact that most actual policy authorities are not monolithic entities maximizing a single objective function. In the United States the Federal Open Market Committee consists of 12 individuals and, given the nonspecific mandate of the Federal Reserve, arguably 12 different objective functions. Even in countries where the central bank has a clear objective like inflation targeting, the resulting policy rule is not an exact function of publicly available information. Each voting member of the monetary policy committee may weigh differently the risks that forecasted inflation would exceed its target level. The weights members apply cannot be observed and may evolve randomly. The eventual committee decision emerges as a nondeterministic aggregate of all the members’ choices. The process of making policy decisions, therefore, introduces a part of policy that is random to private agents. So long as the model projections are independent of the process that evaluates

conditional projections and culls the final policy action, forecasts from the model can be used to inform policy decisions without undermining the probabilistic structure of the model.

2.2 *The Model*

The policy behavior described in (2) is embedded in a system of structural equations. If $y(t)$ is an $(m \times 1)$ vector of time series, the structural form is written as⁷

$$\sum_{s=0}^p A_s y(t-s) = \varepsilon(t), \quad (3)$$

where $\varepsilon(t)$ is a vector of i.i.d. structural disturbances that are exogenous to the model. Those disturbances hit both nonpolicy and policy sectors of the economy, so

$$\varepsilon(t) = \begin{bmatrix} \varepsilon_N(t) \\ \varepsilon_p(t) \end{bmatrix}, \quad (4)$$

where $\varepsilon_N(t)$ is the vector of nonpolicy disturbances.

Structural prediction as developed by Marschak (1953) and the Cowles Commission projects endogenous variables conditional on assumed paths for exogenous variables. To address policy questions, we use the structure in (3) to project y conditional on hypothesized paths for ε_p . Counterfactual questions require varying $\varepsilon_p(t)$ independently of $S(t)$. Thus we assume $\varepsilon_p(t)$ is a vector of exogenous random variables, uncorrelated with all the nonpolicy exogenous disturbances in the economy and, therefore, with $S(t)$. The errors are Gaussian with

$$E(\varepsilon(t)\varepsilon(t)'|y(t-s), s > 0) = I, \quad E(\varepsilon(t)|y(t-s), s > 0) = 0, \quad \text{all } t. \quad (5)$$

The A_s matrices and the probability distribution of ε define the model's structure.

⁷ We suppress constants and other deterministic terms.

Because we assume the matrix of contemporaneous coefficients, A_0 , is non-singular, there is a representation of y in terms of the impulse responses functions:

$$y(t) = \sum_{s=0}^{t-1} C_s \varepsilon(t-s) + E_0 y(t). \quad (6)$$

The elements of C_s report how each variable in y responds over time to the behavioral disturbances in ε . The responses are the model's equilibrium. $E_0 y(t)$ is the projection of $y(t)$ conditional on initial conditions. The reduced form of (3) is

$$\sum_{s=0}^p B_s y(t-s) = u(t), \quad (7)$$

with $B_0 = I$ and the covariance of the reduced-form errors, u , is $\Sigma = A_0^{-1} A_0^{-1'}$.

Expressions (3) and (7) imply a linear mapping from the reduced-form errors to the behavioral disturbances:

$$u(t) = A_0^{-1} \varepsilon(t). \quad (8)$$

Identification of the structural form follows from imposing sufficient restrictions on A_0 so that there are no more than $m(m-1)/2$ free parameters in A_0 .

2.3 *Measuring Policy Interventions*

Policy interventions that change expectations may create incentives for private agents to resolve their optimization problems and implement new decision rules. When decision rules shift, a model that embeds rules estimated using past data is likely to produce unreliable predictions of policy effects. The unreliable predictions generate patterns of forecast errors that are at odds with the historical probability structure. We seek a measure of policy interventions that sheds light on how likely a given intervention is from the perspective of private agents.

The expectational effects of changes in policy can vary across variables and horizons. To capture this variety, one natural measure of the size of an intervention is how much it shifts forecasts of variables relative to the (no-intervention) unconditional forecasts. This leads us to evaluate whether an intervention generates forecast errors that differ significantly from zero. The calculation assesses how far wrong private agents would go if they were to continue to base their expectations of policy on $f(S(t))$, when in fact policy is governed by $g(\Omega(t))$. The larger and the more persistent are the deviations of hypothesized policy from agents' expectations about policy, the more the forecast errors will differ from zero, and the stronger is the incentive for agents to re-optimize.

From (6), forecasts over an K -period horizon given information at time T are

$$y(T+K) = \sum_{s=0}^{K-1} C_s \varepsilon(T+K-s) + E_T y(T+K). \quad (9)$$

When conditioning on exogenous monetary policy actions, the sum over the K -period horizon of the forecast errors implied by (9) is

$$\eta_p(T, K) = \sum_{s=0}^{K-1} C_s(:, i) \varepsilon_p(T+K-s), \quad (10)$$

where the monetary policy equation is the i^{th} equation in the system. The vector $\eta_p(T, K)$ of forecast errors arising from policy actions is normally distributed with mean zero and variance vector $\sum_{s=0}^{K-1} C_s^2(:, i)$, and can be transformed to a vector of standard normal variables, $\eta_p^*(T, K)$.

With the maximum likelihood estimates of the parameters and a hypothetical path of ε_p , it is straightforward to compute the vector $\eta_p^*(T, K)$. If the absolute values of all elements in $\eta_p^*(T, K)$ are less than 2 (corresponding to within two standard deviations or a 95 percent

confidence level), we shall refer to the underlying intervention as *modest*. In those cases, we are comfortable assuming private decision rules do not shift.

2.4 Estimation

Litterman (1986) shows that reduced-form Bayesian VARs forecast out-of-sample better than other time series methods or commercial models do. We adopt the Bayesian procedures for identified VARs that Sims and Zha (1998a) develop.

There are two layers to the prior information. The first layer is a base prior that reduces the sampling error that produces erratic results in large models under a diffuse prior [Leeper, Sims and Zha (1996)]. For the base prior we postulate a joint normal prior, with a diagonal covariance matrix on the elements of A_0 that the identification does not constrain to equal zero. We then specify a joint normal prior on all the coefficients in A_s , for $s > 0$, conditional on A_0 . To implement Litterman's random walk specification, we assume the conditional mean of $A_1|A_0$ is A_0 , while the conditional mean of $A_s|A_0$, for $s > 1$, is zero. The prior standard deviations of the elements of the A_s matrices shrink as s increases, dampening unreasonably large lagged coefficients.

The second layer of the prior corrects the overfitting problem endemic to VARs. Because the number of parameters in A_s grows with the square of the number of variables, model (3) tends to fit the data unrealistically well in sample but can fail badly when projecting post-sample. This manifests as deterministic components of the model explaining implausibly large fractions of the observed variation in the data. To express our belief that such outcomes are implausible, we add to the base prior parameters that control beliefs about the number of unit roots and the number of

cointegrating relationships in the m -variable system. The data determine the exact number of unit roots and cointegrating vectors.⁸

The prior can also accommodate an idea Hall (1996) proposed to relax the dogmatic zero restrictions typical in simultaneous equations models. Instead of restricting a coefficient to be exactly zero or freely estimating it, we can specify a “soft zero” restriction. The restriction shrinks a coefficient’s prior standard deviation around a zero mean without forcing the coefficient to be zero.

Estimation and inference explore the overall shape of the likelihood surface for A_0 and A_3 . Maximum likelihood estimates occur at the peak of the posterior density.

3. Illustrative Model

Here we present a small structural model of American monetary policy behavior. We discuss the identification scheme, present estimates and inferences, display the model’s implications for the dynamic impact of an exogenous change in policy, and evaluate the model’s in-sample and out-of-sample fits. The section contains a discussion of parameter stability.

⁸ In Sims and Zha’s (1998a) notation, the tightness of the prior is set as $\lambda_0 = 0.6$, $\lambda_1 = 0.1$, $\lambda_2 = \lambda_3 = 1$, $\lambda_4 = 0.1$, $\mu_5 = 5$, and $\mu_6 = 5$. See Robertson and Tallman (1999) for discussion.

3.1 Identification

We estimate a version of the model in (3) that contains six variables and three sectors. The identification scheme follows the general approach in Gordon and Leeper (1994) and Sims and Zha (1998b). Table 1 shows the restrictions placed on the contemporaneous coefficient matrix A_0 . There are no restrictions on lagged variables.

Three goods market variables – real GDP (y), consumer prices (P), and the unemployment rate (U) – compose the production sector. The variables are the ultimate objectives of monetary policy. We do not model the markets for reserves and a broad monetary aggregate, opting for compactness to treat the $M2$ money stock as the aggregate and the federal funds rate (R) – the monetary policy instrument – as the price that clears the money market. The third sector describes an “information variable” – commodity prices (CP) – that is available at high frequencies and reacts instantaneously to shocks from all sectors of the economy. The data, which an appendix describes, are monthly from January 1959 to September 1998. Monthly GDP is interpolated from quarterly GDP using the procedure that Leeper, Sims and Zha (1996) describe. All data are logarithmic except for the federal funds rate and the unemployment rate. We estimate the model with 13 lags.⁹

The identification treats the production sector as predetermined for the rest of the system, reflecting the view that production, pricing, and employment decisions do not respond immediately to shocks from outside the sector. Production sector variables interact only with each other within the period. Money market variables and information variables do not enter this sector, reflecting sluggishness in the goods market due to contracts and advance planning of

production. Distinct behavioral equations within the production sector are not identified; instead, the coefficients are arranged in lower triangular form in the order y , P , and U .¹⁰

The monetary and information sectors interact simultaneously, with the strongest simultaneity determining the money stock and the federal funds rate. The demand for nominal money balances is as many theories posit: it depends on the short-term nominal interest rate, real income (proxied by real GDP), and the price level. We do not impose short-run homogeneity in prices. Changes in ε_{MD} reflect exogenous shifts in money demand.

We base the specification of monetary policy behavior in (2) on the information available to the Federal Reserve within the month. During the month, the Federal Reserve sets its interest rate instrument based on current observations on the money stock and commodity prices.¹¹ We set to zero the coefficients on y , P , and U in the policy function because within the month the Federal Reserve does not observe data on output, the general price level, and the unemployment rate.¹² The error term in the monetary policy equation, ε_p , represents exogenous policy actions.

An efficient markets assumption guides the specification of the information sector, so commodity prices may respond to all variables immediately. The error term ε_l is the exogenous information disturbance.

⁹ Because the prior downweights the influence of distant lags, a longer lag length will not affect the results [see Miller and Roberds (1991) and Sims and Zha (1998a)].

¹⁰ The responses of y , P , and U to exogenous monetary policy actions are invariant to the triangular order of these variables [Theorem 4 of Zha (1999)].

¹¹ We accommodate the idea that the Federal Reserve may choose not to react strongly to commodity prices by shrinking the prior standard deviation on the coefficient of CP toward the zero prior mean by a factor of .05.

¹² The Fed has some contemporaneous information about these variables. We experimented with soft zeroes on P and U and found that the more we relaxed the zero restrictions the more likely the identification was to produce nonsensical responses to exogenous monetary policy actions.

3.2 *Parameter Estimates and In-Sample Fit*

Table 2 reports the estimated contemporaneous coefficients along with 68 percent equal-tailed probability intervals for the behavioral coefficients, estimated over the full sample period. The estimated money demand and monetary policy equations have reasonable economic interpretations. The interest elasticity of demand is negative and the output elasticity is positive. The price elasticity is small and imprecisely estimated. Monetary policy responds strongly to the money stock: disturbances that raise the money stock induce the Fed to increase the federal funds rate. Although the estimates seem to suggest the Fed does not react much to information contained in commodity prices, this interpretation may be misleading. In the policy equation the coefficients on R and CP are highly correlated (.97), as are the coefficients on $M2$ and CP (.72); these correlations muddy inferences about individual coefficients.

In the information sector all but two coefficients are tightly estimated. The coefficients on output and $M2$ are highly correlated with the coefficients on the price level and unemployment, so the separate influences cannot be discerned. The estimates imply a quick reaction of commodity prices to exogenous disturbances from elsewhere in the economy.

We seek a probabilistic assessment of the model's overall fit. That assessment is based on exploring the shape of the likelihood surface, rather than on tests of whether individual coefficients are different from zero [Sims and Zha (1999)]. We nonetheless display the marginal distributions of individual parameters to show that they are extremely skewed, with most of the probability mass concentrated around the maximum likelihood estimates. Nothing we intend to do with the model rests on an individual parameter in A_0 . We care about the equilibrium effects of exogenous policy actions. Those effects depend on the joint distribution of all the parameters, not the marginal distribution of an individual parameter.

The model is overidentified so we must evaluate its fit. To evaluate whether the data favor the overidentified model relative to the reduced-form model, we conduct an exact small-sample comparison using a Bayes factor. Given the data, Y , we compare the probability densities of Y under these two models, denoted by $p(Y|M_R)$ and $p(Y|M_U)$ where M_R represents the restricted model and M_U the unrestricted model. When it is infeasible to compute the probability density of the data given a model, researchers often use the Schwarz criterion or the method of Laplace to approximate the Bayes factor from knowledge of the posterior peaks within the two parameter spaces [Sims (1999c)]. With recent developments in Bayesian analysis and computer technology we are now able to calculate the Bayes factor accurately [Geweke (1999)]. In particular, we use the procedure that Chib (1995) developed to compute that

$$\log p(Y|M_R) - \log p(Y|M_U) = 0.9.$$

This result implies that the data weakly favor the restricted model.¹³ The data can favor a restricted model because the Bayes factor integrates the likelihood over the parameter space, effectively compensating for over-parameterization.

To use the model to compute projections conditional on alternative policies, the policy disturbances must be uncorrelated with the current state. In equation (2), we require that $\varepsilon_p(t)$ be uncorrelated with $S(t)$. By construction, $\varepsilon_p(t)$ is uncorrelated with all information at dates $t-1$ and earlier. We use a small-sample procedure to check the restriction in (5) that $\varepsilon_p(t)$ and $\varepsilon_N(t)$ are uncorrelated. For each simulated draw from the posterior distribution of the model's

¹³ The Schwarz criterion computes the chi-square statistic with degrees of freedom multiplied by the log of the sample size. The chi-square statistic, which is twice the difference in log likelihood values of the unrestricted and the restricted models at their peaks, is 18.56. The critical value is 18.11, so the Schwarz criterion weakly rejects the restricted model.

parameters, we compute the sequence of exogenous disturbances consistent with the data. We then calculate the correlation matrix for this sequence. Table 3 reports the .68 probability intervals for the correlations among the exogenous shocks, along with the correlations calculated at the maximum likelihood estimates of the parameters.

The correlations between the policy disturbance and nonpolicy disturbances are not different from zero. With the disturbances uncorrelated is reasonable to condition on a path of exogenous policy actions, while drawing nonpolicy disturbances independently.¹⁴

3.3 *Dynamic Impacts of an Exogenous Monetary Policy Action*

The model's dynamic responses to monetary policy disturbances, the C_s 's in (6), are equilibrium outcomes. Figure 1 displays responses over 48 months of the six variables in the model to a unit (one standard deviation) exogenous monetary policy contraction. The solid lines are the maximum likelihood estimates of responses and the dashed lines, following Sims and Zha (1999), are equal-tailed error bands containing .68 probability. To examine the shape of the likelihood surface near the peak, 68 percent bands are more informative than the wide 95 percent intervals often adopted for hypothesis testing. Figure 2 translates the paths in Figure 1 into the annual average growth rates that typically inform policy debates, reporting the paths 1 to 4 years after the exogenous policy action.

The contraction raises the funds rate initially and immediately decreases the money stock and commodity prices, both of which continue to decline smoothly over the four-year horizon. After

¹⁴ The table suggests, however, that the model does not fit the correlation between the money demand shock and the unemployment shock well. Although reduced-form forecasts are unaffected, this will affect some behavioral inferences. The nonzero correlation between the two structural disturbances, for example, implies one should not forecast the dynamic effects of exogenous money demand shifts without further identifying assumptions. We do not attempt such analyses.

a brief delay, output falls and stays lower, while unemployment rises. Six months after the exogenous action, both output and unemployment are likely to differ from their initial levels. Consumer prices adjust more slowly and are unlikely to be appreciably lower for about a year. After a year prices decline smoothly and remain well below their initial level.

The annualized results in Figure 2 resemble the evidence put forth to argue that inflation, π , follows money growth with a lag: money growth falls rapidly after the policy contraction, while the biggest effects of policy on inflation occur after several years. These are not simple correlations between money and inflation: they are joint endogenous responses to an exogenous change in monetary policy. In addition, after four years the maximum likelihood estimate of money growth is .15 percent lower, while that of inflation is .22 percent lower. With output leveling off, monetary contraction must reduce the growth rate of velocity.

The response of the interest rate to an exogenous policy contraction stands out. In Figure 1 the initial liquidity effect lasts about eight months, but by 18 months the funds rate lies well below its initial level. The decline in the funds rate then persists. This is the classic shape of the path of the short-term nominal interest rate following a monetary contraction. Friedman (1968) and Cagan (1972) describe the path as a short-lived liquidity effect followed by income and expected inflation effects.¹⁵ Most striking is that after four years, the declines in inflation and the federal funds rate are the same size, as one might anticipate if expected inflation is the dominant source of fluctuations in nominal rates over long periods.

¹⁵ The expected inflation effect may be related to the simultaneous determination of money and the interest rate. It appears in Gordon and Leeper (1994) and in some models in Leeper, Sims and Zha (1996). It disappears in models where the demand for money is interest inelastic.

Most of the longer run responses are precisely estimated. This is not typically true in VARs that do not incorporate Bayesian prior information. We attribute the improved precision to the aspects of the prior that allow for the possibility of unit roots and cointegration.

The patterns of responses in the figures carry implications both for interpretations of past monetary policy and for policymakers' behavior. Goodfriend (1987, 1991) argues that the Fed smooths interest rates by minimizing surprise changes in the federal funds rate and that it avoids "whipsawing the market" by rapidly changing the direction of its federal funds target. The results formalize Goodfriend's argument as referring to endogenous adjustments of the policy instrument to nonpolicy disturbances. Exogenous changes in policy, according to the figure, generate relatively rapid changes in the direction of the funds rate. Because this model attributes less than 20 percent of the variation in the funds rate over two-to-three year horizons to exogenous policy actions, there is no inconsistency here.

Conventional wisdom says that if the Fed wishes to lower the inflation rate, it should raise the federal funds rate. The responses in the figures suggest that to lower inflation persistently the Fed should raise the funds rate only briefly. Because lower inflation is ultimately associated with a lower funds rate, the Fed must begin to reduce the rate within about a year, and then keep it lower.

3.4 Out-of-Sample Fit

To have confidence in the model's projections conditional on alternative future policies, it is important to evaluate the model's out-of-sample forecast performance. This subsection compares the annual forecast performance of our model under the Sims and Zha (1998a) prior to forecasts with a VAR with a diffuse prior and a VAR with Litterman's (1986) prior.

Table 4 lists the root-mean-square errors (RMSEs) for unconditional forecasts over horizons of one to four years using the three estimation methods. The models are estimated recursively using data from January 1959 up to the beginning of each forecast period. The RMSEs are computed from forecasts over four years beginning in December 1979 and running through September 1994.

The table shows that, except in the case of *M2*, the structural model outperforms the diffuse-prior VAR and the Litterman-prior VAR. The biggest improvement occurs in the inflation rate and the federal funds rate. This is encouraging for our purposes: inflation is the Fed's primary concern and the funds rate is the policy instrument.¹⁶

The forecasts compare favorably to the ones that Cecchetti (1995) computes and to the DRI forecasts of inflation that Cecchetti reproduces. Kohn (1995) reports that the Federal Reserve's one-year forecasts of inflation have RMSEs of from 1 to 1¼ percentage points. Our structural model's RMSE for one-year inflation forecasts is .95 percentage points. The model's compactness relative to the Fed's models makes its performance especially remarkable.

3.5 *Parameter Stability*

Because many analyses work from the premise that U.S. monetary policy has shifted substantially over the post-World War II period, some readers may object to our assumption that the parameters of the VAR model are constant. We think the issue is unsettled. Bernanke and Mihov (1998a, 1998b) carefully test the stability of the reduced-form coefficients and the residual covariance matrices in VARs containing many of the same time series in our model.

¹⁶ Robertson and Tallman (1999) study the forecast performance of this model relative to others.

Surprisingly, perhaps, they conclude that the reduced-form parameters are stable.¹⁷ In contrast, tests of the covariance matrices of VAR innovations – from which the structural model’s A_0 parameters are obtained in (8) – find evidence of breaks in late 1979 or early 1980 and between early 1982 and early 1988.¹⁸ The results conform to Sims’s (1999a) reaction function estimates. Using a hidden Markov chain approach, he finds strong evidence that the Fed’s responsiveness to commodity price inflation deviates from a linear, Gaussian reaction function. But in terms of model fit, he reports that variations in the size of the errors to the policy rule are more important than variation in the coefficients of the rule.

These patterns of results suggest that much work remains to understand the nature and the import of instability in U.S. monetary policy behavior. Changes in the covariance matrix of innovations that leave correlations among innovations unchanged pose no difficulty for the methods in this paper. One needs simply to scale the size of exogenous monetary policy actions appropriately. Changes in correlations among innovations, however, alter the estimates of A_0 and present new econometric challenges. More generally, non-normality of VAR residuals appears to be an important feature of the data, but the technology for handling this problem in identified VARs does not yet exist.

Much recent attention focuses on the finding that coefficients in simple specifications of the Fed’s policy rule shift over time [e.g., Clarida, Gali and Gertler (1998) and Taylor (1999)]. The simple rules emerge from restrictions on the policy behavior embedded in VARs. For our

¹⁷ They use a Lagrange multiplier variant of Andrews’s (1993) test, which checks every possible break point and tests the significance of the associated LM statistics. Using quarterly data, Sims and Zha (1998b) corroborate Bernanke and Mihov’s results by comparing a model fit from 1964:1 to 1994:1 to one fit separately to 1964:1-1979:3 and 1983:1-1994:1. Both the Akaike and Schwartz criteria favor the restricted model.

¹⁸ Bernanke and Mihov use switching-regression techniques as well as LM tests of the elements of the covariance matrices.

purposes, what matters is whether the dynamic responses to exogenous policy actions are stable. The responses depend on the system of equations, not just the policy rule. To explore the system properties, we compute the responses to exogenous policy actions using models estimated over a variety of sub-periods.

Figure 3 reports responses to all six exogenous disturbances for models estimated over four sub-periods. The periods covered are 1959:1-1998:9 (entire sample); 1959:1-1979:9 (pre-Volcker); 1959:1-1982:12 (including non-borrowed reserves targeting); 1959:1-1998:9 with 1979:10-1982:12 eliminated (excluding non-borrowed reserves targeting). The reserves targeting period from 1979:10 to 1982:12 is too brief to obtain reliable estimates from just those years, so we treat the three years as potentially anomalous relative to the entire sample. Although it is popular to treat the Greenspan era (late 1987 to the present) as a distinct policy regime, we do not. The past 12 years contain only one mild recession and few interesting exogenous disturbances, except possibly from the stock market. But it is unclear whether those market gyrations have influenced monetary policy behavior in any systematic manner.

The qualitative responses to exogenous policy actions are robust across sub-periods.¹⁹ There is some tendency for the responses estimated by eliminating the reserves targeting episode to be slightly weaker and for those estimated only through the end of 1982 to be somewhat stronger. Otherwise, the responses to policy are even quantitatively very similar.²⁰

¹⁹ Qualitative differences do appear in responses to some non-policy disturbances, especially money demand and goods market shocks.

²⁰ We also examined the stability of the impulse response functions over the periods we study in detail in sections 3, 4, and 6 (estimation periods ending in September 1990, January 1994, April 1994, and September 1998). The appendix (Figure 9) reports that dynamic responses to \mathcal{E}_p disturbances are nearly indistinguishable across the sub-periods.

Overall, the model's in-sample and out-of-sample fits are very good. The overidentifying restrictions do not invalidate the uses to which we wish to put the model. The uses rely on whether exogenous policy actions are uncorrelated with nonpolicy disturbances. Tests confirm that this assumption holds well. An exact small-sample comparison of the restricted and unrestricted models using a Bayes factor somewhat favors the restricted model. The model forecasts well relative to competing models. Finally, the dynamic responses of the economy to exogenous monetary policy actions are quite stable over time. Taken together, these indicators of fit and robustness lend credibility to the model's projections conditional on policy.

4. The Dangers of “Exogenizing” Policy

Econometric answers to counterfactual questions require *some* identification of exogenous variation in policy. Indeed, the separation of policy into “endogenous” and “exogenous” components defines the set of policy questions one can sensibly consider with an econometric model. All empirical efforts to address counterfactuals make this separation, explicitly or implicitly. Here we argue that because actual policy has been endogenous, conducting counterfactual policy experiments without regard to past policy behavior entails many pitfalls.

4.1 Aggressive Endogenous Policy

From late 1990 through 1993 the Federal Reserve reduced the federal funds rate over 500 basis points. Our analysis confirms that even during this period of aggressive easing of policy, most of the change in the funds rate was an endogenous response to economic conditions. The analysis implies that only modest counterfactuals, modeled as nonzero ε_p 's in equation (2), are likely to be consistent with the true policy process, equation (1), over this period.

Based on model estimates over the full sample, we use an in-sample analysis to draw ex-post inferences. Figure 4 graphs the actual time paths of the model's variables (solid lines). The figure also shows the paths the variables would have followed had exogenous policy actions been identically zero while all nonpolicy disturbances equaled their realized values (dashed lines).²¹ Endogenous responses of policy to nonpolicy disturbances account for most of the funds rate path; exogenous monetary policy actions explain very little of the dramatic decline.

In spite of the strong endogenous response of the funds rate in 1990, exogenous monetary policy actions were important for macro developments. Exogenous policy contributed to substantially lower inflation in 1992 and 1993, as well as to lower output growth and higher unemployment in those years (Figure 4). Despite the rapid drop in R , monetary policy was actually *tighter* in late 1990 and early 1991 than it was on average in similar economic states.

4.2 *Limitations of Existing Methods for Policy Analysis*

Two diametric approaches to econometric policy analysis appear in the literature. The rational expectations econometric program that Lucas and Sargent (1981) and Sargent (1984) lay out identifies the mapping from policy behavior to private expectations and decision rules and evaluates the impacts of alternative processes for policy. Doan, Litterman and Sims (1984) propose a contrasting approach that uses forecasting models to project the effects of alternative sequences of policy variables, taking private expectations and decision rules as given by history. Neither approach explicitly connects actual policy behavior to the class of policy interventions it contemplates. In terms of the description in section 2.1, neither approach distinguishes between

²¹ In Figure 4 accounting for uncertainty in parameters does not alter the inferences we draw.

the g and f specifications of policy. Without that distinction it is impossible to judge if a policy intervention is small or large, consistent with the on-going policy process or a departure from it.

Sargent (1984) explicitly describes the canonical rational expectations policy experiment. The experiment embodies an extreme dichotomy: in the sample period policy was “arbitrary” (or “exogenous”) and in the projection period policy is “purposeful” (or “endogenous”). If past policy was “arbitrary,” then all observed changes in policy are independent of the economic state. Sargent’s method decouples expectations from the existing policy process and allows him to consider a broad class of policy interventions that includes changes in the process governing policy. Papers throughout the policy literature make analogously strong assumptions, though rarely are the authors as explicit about their assumptions as Sargent is.

Doan, Litterman and Sims (1984) describe a method to compute conditional forecasts from a reduced-form model like (7) that makes no explicit separation of policy into exogenous and endogenous parts. If the model is estimated using data through time T , conventional K -step-ahead unconditional forecasts set the future errors to zero $u(T + j) = 0$, $j = 1, 2, \dots, K$, and use the dynamics embodied in the VAR coefficients to project $y(T + j)$. Doan, Litterman and Sims propose to condition on future paths of some subset of the endogenous variables in $y(T + j)$. As (7) implies, whenever there is nonzero correlation across the errors this is equivalent to conditioning on paths of all the reduced-form errors, $u(T + j)$. The procedure amounts to computing projections subject to the set of linear constraints

$$\Gamma(\theta)' \begin{matrix} u \\ K \times 1 \end{matrix} = \begin{matrix} \gamma(\theta) \\ q \times 1 \end{matrix}, \quad q < K, \quad (11)$$

where θ is a stacked vector of all the reduced-form VAR parameters, q is the number of conditions or constraints, u is a $K \times 1$ vector of future errors needed to meet all the constraints, and elements of Γ and γ are functions of θ . $\Gamma(\theta)$ is obtained from the impulse responses of the

reduced-form VAR and $\gamma(\theta)$ reflects the deviations of the conditioned variables from their unconditionally forecasted paths. The conditional projection finds a set of future reduced-form errors that minimizes the error sum of squares subject to constraint (11).

Because the Doan-Litterman-Sims procedure does not identify monetary policy behavior, it is of limited value in addressing counterfactual policy questions. Many analysts nonetheless follow a forecasting procedure similar to their approach when they compute projections conditional on an assumed future path of policy. First, analysts “exogenize” the policy instrument: they vary it independently of the current state. Then they specify a path for the instrument over the forecast horizon and use an econometric model to trace out the resulting paths for aggregate time series. The exercise has a clear behavioral interpretation if actual policy was independent of the economy.

That condition on policy behavior typically fails to hold. More realistically, if most past variation in policy is from responses to nonpolicy disturbances striking the economy, then the “exogenizing” procedure has a muddled behavioral meaning. The meaning is muddled because the exercise assumes that a particular linear combination of policy and nonpolicy disturbances will be realized over the forecast period. The forecasted paths of macro variables then do not report the impacts of policy alone; they also reflect the impacts of endogenous policy responses to realizations of nonpolicy disturbances. Because policymakers do not know what nonpolicy shocks will occur in the future, these forecasts cannot address the counterfactual questions policymakers often pose.

Both the Doan-Litterman-Sims and the Lucas-Sargent approaches are at odds with the sequential nature of policymaking. In the Lucas-Sargent framework, policy choices are couched as once-for-all, which necessarily precludes sequential decisionmaking. Less extreme is Doan,

Litterman and Sims's suggestion to condition forecasts on long sequences (on the order of four years) of nonzero policy errors, ε_p 's. Even this suggestion may make the resulting predictions misleading for policy purposes. To see this, consider Blinder's (1997, p. 9) characterization of on-going policy evaluation:

“First, you must plan an entire hypothetical path for your policy instrument....

Second, when next period actually comes, you must appraise the new information that has arrived and make an entirely new multi-period plan. If the surprises were trivial...step one of your plan will mimic the hypothetical step two of your old plan.

But if significant new information has arrived, the new plan will differ notably from the old one. Third, you must repeat this reappraisal process each and every period.”

Kohn (1995, p. 235) echoes the perspective: “[Policymakers] need to be flexible in revising forecasts and the policy stance in response to new information contradicting their previous predictions.”

The perspective raises several difficulties with conditioning projections on long sequences of counterfactual policy actions. To be concrete, suppose that monetary policy targets the inflation rate within some range. The Doan-Litterman-Sims procedure sets all future nonpolicy disturbances to zero and solves for a sequence of ε_p 's that produces a desirable inflation path. If exogenous monetary policy actions were the main source of fluctuations in inflation, little difficulty arises. But the identified VAR literature finds that nonpolicy disturbances play a substantial role in determining inflation. That fact makes the procedure problematic. “Exogenizing” policy forces paths of ε_p to account for all the variation in inflation. Because that is inconsistent with historical patterns, it can distort policy decisions. The potential distortions increase the stronger is the endogeneity of policy.

As Blinder and Kohn suggest, when the assumed path for policy is long, it is more likely that significant news will arrive over the forecast horizon. Realizations of nonpolicy disturbances that reduce inflation will make the initial policy choices appear too aggressive, while shocks that raise inflation will render the original policy too conservative. In either case the original choice of a path for policy will probably be quite far from the reappraised policy choices. To top it off, future policymakers are not bound to execute the hypothesized actions, so the predictions are of uncertain utility to policymakers.

Large counterfactual policy assumptions cause problems for methods that rely on past policy behavior to estimate private expectations. The Doan-Litterman-Sims procedure amounts to systematically deviating from the estimated policy equation while holding the remaining equations in the model fixed. A limiting case of conditioning on a long sequence of disturbances replaces the estimated monetary policy process by a different process and traces the dynamic effects of the policy change through the model, maintaining *ceteris paribus* assumptions.²²

4.3 “Exogenizing” Policy Can Produce Incredible Results

The pure forecasting exercise that Doan, Litterman and Sims (1984) propose, and which is implemented in many practical applications, can generate implausible results. We illustrate the point with the dramatic period beginning in September 1990. The period clarifies a problem that applies generally. We mimic conventional out-of-sample forecasting by “exogenizing” the federal funds rate, forcing the actual path of R over the next 48 months to be produced solely by exogenous policy actions. For each month of the forecast period we calculate the $\varepsilon_p(t)$ that produces a forecast that equals the actual funds rate, $R(t)$, given the calculate value of ε_p .

Instead of conditioning on reduced-form errors, this interpretation of Doan, Litterman and Sims derives the sequence of exogenous policy actions consistent with the R path.

Table 5 reports the central tendencies for the paths of the funds rate, output growth, inflation, and unemployment over the four-year forecast horizon. The actual funds rate fell dramatically over the period, from an annual average of almost 8 percent in 1990 to an average of less than 3 percent in 1993. It takes a sequence of same-signed exogenous impulses to generate that decline solely from exogenous policy actions. The impulses drive output growth and inflation into double digits and the unemployment rate down to 3.5 percent. Given the actual path for the policy instrument, the implausible paths for macro variables suggest that much of the movement in R over the period was an endogenous response of policy to nonpolicy disturbances.²³ This confirms the ex-post findings in section 4.1.

The results in Table 5 come from hypothesizing policy behavior that deviates substantially from any behavior observed over the sample. By the measure of the size of interventions described in section 2.3, this is a large, immodest intervention. The forecast errors for each variable are extremely unlikely, as shown by the t-statistics below:

²² Bernanke, Gertler and Watson (1997), Dungey and Pagan (1997), Sims (1999b), and Sims and Zha (1998b) are examples of this exercise. Lucas and Sargent (1978) criticize the exercise.

²³ Altig, Carlstrom and Lansing (1995) assume a path of exogenous monetary policy disturbances to use their general equilibrium model to simulate the effects of reducing inflation by a percentage point over a two-year period and holding it at the lower value for three more years. The model predicts implausible paths for the nominal interest rate and output growth.

Variable	η_p^*
<i>R</i>	-2.93
<i>y</i>	18.95
<i>P</i>	9.64
<i>U</i>	-18.96
<i>CP</i>	17.57
<i>M2</i>	19.15

Because private expectations continue to be based on past policy and the counterfactual behavior lies outside of historical experience, there is no a priori reason to believe that the nonpolicy parameters in the model should remain fixed.

4.4 *Is an Unchanged Instrument an Unchanged Stance of Policy?*

Routine policy analysis often holds the instrument constant in establishing a baseline forecast. Although there is no conceptual difficulty with this, it is a short step from treating a constant instrument path as the baseline to interpreting it as reflecting an unchanged stance of policy.²⁴ Because the stance of policy depends on the state of the economy, there are times when a constant instrument requires large deviations from “business as usual” policy behavior. In those times, holding the instrument fixed amounts to “exogenizing” it and may confound behavioral interpretations of results.

The stance of policy depends on how the policy instrument is set relative to the state of the economy. The Policy Directive of the Federal Reserve Board makes the state dependence

²⁴ Many central banks refer to an unchanged instrument as an unchanged stance of policy. See Board of Governors of the Federal Reserve System (1999b) or Sveriges Riksbank (1999).

explicit. To keep the federal funds rate unchanged the Directive states that the Federal Open Market Committee “seeks conditions in reserve markets consistent with maintaining the federal funds rate” at its current level.²⁵ Because conditions in reserves markets depend on all current and past disturbances to the economy, the actions necessary to implement the policy rule depend on the current state of the economy. A priori one cannot presume that a constant funds rate implies policy generates no exogenous expansionary or contractionary impulse.

Table 6 reports forecasts conditional on the exogenous monetary policy actions necessary to hold the funds rate constant. To illustrate how the policy stance depends on the states, we compute conditional forecasts at two different dates – October 1990 and February 1994 – when the funds rate is held fixed at two different levels – 8.20 percent (the level in September 1990) and 3.00 percent (the level in January 1994). Section 4.1 showed the problems with large policy interventions; now we consider the more modest intervention that holds the funds rate constant for four consecutive months.²⁶ Table 6 also records the marginal impacts of the exogenous policy actions associated with holding the rate fixed in the two periods. The marginal impacts are the difference between the conditional forecasts and the unconditional forecasts, for which the exogenous part of policy is identically zero.

²⁵ Board of Governors of the Federal Reserve System (1999a).

²⁶ By our intervention measure, these are modest. The t-statistics for the forecast errors from holding the funds rate fixed on the two dates are

Variable	$\eta_p^*(90:9)$	$\eta_p^*(94:1)$
<i>R</i>	-0.48	0.15
<i>y</i>	-0.37	0.12
<i>P</i>	-0.80	0.23
<i>U</i>	0.03	-0.02
<i>CP</i>	-0.51	0.15
<i>M2</i>	-0.58	0.17

On the two dates the implied stances of policy are different. In 1990 a constant funds rate is contractions. The constant-rate counterfactual produces exogenous contractions that make the rate 14 basis points higher in 1990 and 34 basis points higher in 1991 than it would otherwise have been (panel A). Exogenous contraction reduces inflation by .7 to .8 percentage points in 1992 and 1993, reduces output growth by half a percent in each of the years 1991 and 1992, and raises unemployment in each of the years 1991 to 1993. Contrasting these marginal impacts to the conditional forecasts underscores that the endogenous aspects of the forecasts can often outweigh the exogenous impacts of policy actions.

In 1994 a constant rate is mildly expansionary. The funds rate is 14 basis points lower in 1994 than it would have been with no exogenous policy impulse (panel B). Inflation rises by .23 percentage points in 1996 and 1997, while output growth is .24 percentage points higher in 1995. In this period the endogenous and exogenous components of the forecast are reinforcing, so the conditional forecasts and the marginal impacts move in the same direction.

5. Addressing Counterfactuals with Conditional Forecasts

Table 5 underscores the dangers of exogenizing policy to address counterfactual questions. This section describes a procedure for computing conditional projections of policy effects that avoids the dangers. It explains why using the procedure to formulate policy will not destabilize the econometric model.

5.1 The Procedure

We want behaviorally unambiguous answers to counterfactual questions. To produce answers we condition on ε_p , a controllable part of policy that is identified to be exogenous and independent of the current state of the economy.

We limit the analysis to modest counterfactual questions for two reasons. First, we do not want to run afoul of the Lucas critique. Second, we seek to define policy interventions that are consistent with some key aspects of actual policymaking. To avoid Lucas’s criticisms, we choose hypothetical paths of ε_p that are consistent with its historically estimated probability distribution. In terms of the policy specification in (1) and (2), if the ε_p deviations from f are small enough to be consistent with the range of outcomes agents expect from the true policy process g , then there is no incentive for agents to revise their views of policy behavior. Agents believe policy continues to obey f . With unchanged beliefs about policy, agents stick to their initial decision rules, and the policy interventions are not subject to Lucas’s critique. The sequences constitute modest interventions, which are necessary for “predicting under unchanged structure,” in Marschak’s (1947, 1953) terminology.

The restricted class of policy interventions also conforms to key aspects of actual policymaking. Limiting the range of exogenous policy actions to be relatively small and short-lived is consistent with the sequential nature of policymaking. It implements Blinder’s (1997) description of reappraising policy choices and maintains the flexibility that Kohn (1995) describes as an important feature of policymaking.

We quantify the two types of uncertainty that Brainard (1967) emphasizes. One important source of uncertainty comes from nonpolicy shocks yet to be realized. We quantify that uncertainty by drawing nonpolicy disturbances over the projection period from their historically estimated probability distributions. We also compute error bands for the projected path of the policy instrument to reflect the fact that its target level also depends on the probability distribution of future exogenous disturbances. A second source stems from the sampling

distribution of the estimated parameters. To quantify that uncertainty, the projections also draw from the posterior distribution of the model's parameters.

Suppose that a structure has been estimated using data up to time T . The econometrician provides the policymaker with a menu of future paths of the economy over the next K periods. Each path is associated with a different policy assumption. In keeping with conventional terminology, we call the paths that set to zero all future exogenous disturbances “unconditional forecasts” and those that set $\varepsilon_p(T + q) \neq 0$ for $q \leq K$ periods “conditional forecasts.” This leads to the following forecasting procedure.

Procedure to Forecast Effects of Alternative Counterfactual Policies.

1. Specify the sequence $(\{\varepsilon_p(T + j)\}, j = 1, 2, \dots, q)$ that addresses the counterfactual question being posed; tighter policy implies $\varepsilon_p > 0$ and looser policy implies $\varepsilon_p < 0$. q is the number of periods the policy intervention lasts; we take this to be on the order of a few months.
2. Set $\varepsilon_p(T + j) = 0, j = q + 1, q + 2, \dots, K$ to fill out the sequence of assumed policy actions.
3. Draw K values of ε_N from the standard Gaussian distribution to obtain the complete sequence of exogenous disturbances, $(\{\varepsilon(T + j)\}, j = 1, 2, \dots, K)$.
4. To account for parameter uncertainty, draw structural parameters from the estimated posterior distribution. The parameter draws are independent of the ε draws.
5. Use the structural impulse response functions, (6), together with the simulated paths of structural disturbances, $(\{\varepsilon(T + j)\}, j = 1, 2, \dots, K)$, and actual data for dates T and earlier, to compute the conditional distribution of $y(T + j), j = 1, 2, \dots, K$.

5.2 *Using the Model for Policy Choice Will Not Destabilize It*

The forecasting procedure maps a sequence of exogenous policy actions into a distribution of macro variables. Given those forecasts, if the analyst minimized a deterministic policy loss function, policy choices would be exactly determined at each date. This seems to lead to a paradox. Using the model's forecasts to derive an optimal rule for policy alters the stochastic structure of the model: given the model's forecasts and the policy loss function, private agents can glean exactly what the choice of policy will be at each date. Then policy "disturbances" are neither stochastic nor exogenous to the model. The paradox derives from too simple a view of policymaking that fails to acknowledge the intrinsic randomness of policy choice from the perspective of private agents.

Sims (1987) develops this argument generally, but a simple example derived from his paper may be helpful. Let Y denote a vector of macro outcomes and X denote a vector of policy actions. The econometrician computes and reports to the policymakers a menu of conditional distributions $Y|X = (Y_1|X_1, \dots, Y_n|X_n)$. In addition to the menu of $Y|X$, the policymakers observe a variable Z , which may enter their objective functions or constraint sets. Policymakers choose among the X 's assuming that $Y|X$ is independent of Z . As in Sims (1987), Z may be a noisy signal about the state of the economy, which policymakers observe in advance of the private sector. Alternatively, Z may be interpreted as random variation in policy preferences or randomness in the technology of policy choice.

We prefer to think of Z as reflecting the mechanism that selects a particular X_i from the menu of projections. If the VAR excludes Z , then the selection process is not modeled and the choice of X each period will appear to be random. There will then always be a random part to the policy rule in the VAR. The presence of Z generates the discrepancy between the

policymakers' true behavior, summarized in (1), and the econometric model of policy behavior, described by (2). It also ensures there is no deterministic mapping from $Y|X$ to policy choices.

5.3 *Modest Interventions and Practical Policy*

We arrive at a somewhat prosaic view of the role VARs can play in policy choice. In Sims's (1980, p. 13) words, projections from identified VARs help "...to implement effectively the existing rule."²⁷ The projections translate the rule into a menu of future paths from which policymakers choose at each date. The menus of projections help individual policymakers execute their own rules.

By some interpretations of the rational expectations critique of econometric policy evaluation, it is a waste of time to "implement the existing rule." Lucas's (1976) critique has persuaded many macroeconomists that interesting (and important) policy analysis requires identifying expectations and estimating parameters of preferences and technologies. As Lucas and Sargent (1981) put it, identified VARs are not useful for policy analysis because the models will not remain stable under "nontrivial" policy changes.²⁸ But this view *defines* "nontrivial" interventions to be once-for-all permanent changes in the policy process. And it shifts research attention away from understanding policies that leave the underlying process unchanged.

Sims (1986) applies Hurwicz's (1962, p. 238) reasoning that "the concept of structure is relative to the domain of modifications anticipated" and argues that in practice the policy changes that concern Lucas and Sargent are rare. The point is especially relevant for routine monetary policy decisions, where implementing the existing rule is the *modus operandi*. We

²⁷ That is, the VAR uses f , sequences of \mathcal{E}_p 's, and the rest of the model to help implement g .

articulate the argument by showing that the class of modest policy interventions describing routine monetary policy can address practical policy questions.²⁹ Conditioning on short sequences of exogenous policy actions can produce important shifts in the probability distributions of macro variables. There is nothing “trivial” about the policies that can be usefully evaluated in identified VARs.

6. Some Practical Analysis of U.S. Monetary Policy

This section addresses some questions that Federal Reserve officials may have asked during the 1990s. We focus on the two periods of aggressive policy moves: the 500 basis point drop in the funds rate from late 1990 through 1993 and the 300 basis point increase in the rate between January 1994 and early 1995. We show how to answer questions in terms of joint probability statements regarding the tradeoffs policymakers face. The section also illustrates the appraisal/reappraisal process in which the Fed engaged in the first half of 1994.

²⁸ Sargent (1984, p. 413) elaborates on this perspective: “In dynamic decision and game theory, the relevant choices are among different stochastic processes. In these terms, an analysis that maintains the assumption of a fixed probabilistic structure permits no policy advice to be given, or choices to be delineated.”

²⁹ Of course, if policymakers are learning about the true structure of the economy from the VAR projections, as in Sargent (1999), or if policymakers were to change how they conduct “business as usual,” then the linear projections will be unreliable.

6.1 *Modest Policy Interventions Can Matter*

The efficacy of our forecasting procedure rests on whether conditioning on short sequences of exogenous policy actions is relevant for routine policy decisions. We now show that this class of interventions can generate economically meaningful shifts in the distributions of forecasted macro variables and clarify for policymakers the tradeoffs among alternative policies. The analysis also demonstrates that a complete probability model, which quantifies the uncertainties that Brainard (1967) emphasizes, can answer complex joint probability questions about the tradeoffs policymakers face.

We conduct the analysis through the eyes of a policymaker who has information about the economy through September 1990. Minutes of the October 2, 1990 FOMC meeting reveal that the Fed predicted a mild downturn in economic activity followed by a rapid resumption of moderate growth. The minutes report that “insofar as could be judged on the basis of traditional indicators, the available data did not point to cumulating weakness and the onset of a recession (p. 135).”³⁰ Political developments in the Middle East, however, generated concerns about future oil prices and created uncertainty about the outlook for inflation. While the domestic policy directive that emerged from the meeting sought “to maintain the existing degree of pressure on reserve position,” several FOMC members dissented. One member favored immediate easing and three members opposed the FOMC’s perceived leaning in favor of easing.

In light of the dissension among FOMC members, we consider two scenarios for the menu of conditional projections to present to policymakers. The first scenario conditions forecasts on the

³⁰ Board of Governors of the Federal Reserve System (1990).

actual path of the federal funds rate from October 1990 to January 1991. An alternative scenario considers tighter policy over those four months.³¹

Figure 5 reports the actual time series, the out-of-sample forecasts conditional on the actual path of the funds rate, and 68 percent probability bands for the forecasts. The actual funds rate was 8.11 percent in October, 7.81 percent in November, 7.31 percent in December, and 6.91 percent in January. With that path of the funds rate, there is substantial probability that inflation will rise above 5½ or 6 percent through 1993, real growth will fall below 1 percent in 1991, and unemployment will rise to near 7 percent through 1993. Based on the path of the funds rate, it may appear that the Fed was concerned primarily about recession. As it happened, inflation fell to 3 percent by 1992, a recession occurred from July 1990 to March 1991 (according to the NBER dating), and unemployment hit 7½ percent in 1992. Of course, as the model’s forecasts confirm, policymakers were unaware in October that the recession began three months earlier.

The FOMC minutes report that some policymakers were concerned about higher inflation. For those members an analyst might prepare forecasts conditional on tighter policy. The forecasts assume exogenous policy actions that raise the funds rate by 50 basis points in October (to 8.70 percent) and an additional 25 basis points over the period from November 1990 to January 1991. Ex-ante it appears that tighter policy would reduce the likelihood of higher inflation, but at the cost of raising the probability of negative real growth in 1991 (Figure 6). The

³¹ The t-statistics for the forecast errors associated with these interventions are

Variable	η_p^* (Actual <i>R</i>)	η_p^* (Tighter Policy)
<i>R</i>	0.12	-0.88
<i>y</i>	0.10	-0.69
<i>P</i>	0.19	-1.49
<i>U</i>	-0.02	0.04
<i>CP</i>	0.13	-0.94
<i>M2</i>	0.14	-1.07

point forecasts of output growth and unemployment, conditional on tighter monetary policy, come very close to the actual paths of the variables in 1991 and 1992. In spite of the sharp decline in the funds rate, exogenous monetary policy exerted a contractionary influence.

Most analyses of alternative policies do not place error bands on the policy instrument. The reasoning is that if the instrument can be controlled by the central bank, then from the policymakers' perspective there is no randomness to policy choice. That reasoning is flawed. The bands on R that Figure 5 and Figure 6 report are integral parts of coherent forecasts. Forecasts use the entire estimated model, including the policy rule. That rule maps current and past realizations of macro variables into choices of the funds rate. If the figures reported the same past for R for every realized path of macro variables, they would imply a different endogenous response of policy for each realized path. This amounts to "exogenizing" policy. The forecasts would have implicitly employed a policy process different from the estimated one, muddling the interpretation of the forecasts.

Debate during the October 1990 FOMC meeting centered on the tradeoffs associated with alternative policy choices. The tradeoffs can be framed as joint probability statements. To answer the concerns over economic slowdown and higher inflation, Table 7 reports a variety of joint probabilities involving real GDP growth in 1991 or 1992 or 1993 and inflation in 1992 and 1993, conditional on two alternative policies. "Tighter" policy assumes the same counterfactual policy behavior as in Figure 6, while "Actual R " adjusts exogenous policy to be consistent with Figure 5.

The probabilities put a sharp point on the tradeoffs Federal Reserve officials perceived they faced. In terms of the marginal probabilities, tighter policy makes it very likely that inflation

will remain low in 1992 and 1993 (below 5½ percent), but it also produces a better than 50 percent chance of a recession in 1991 (negative real GDP growth for the year). More relevant to policymakers is the apparent tradeoff: tighter policy creates a one-third chance of a recession in 1991 or 1992 or 1993 and low inflation in 1992 and 1993.

For exogenous policy to generate the actual path of the funds rate, the Fed would have to ease slightly in December and January. The column in the table labeled “Actual R ” reports these results. Easing reduces by half the marginal probability of a recession in 1991 while lowering the marginal likelihoods of low inflation in 1992 and 1993. Modest loosening also greatly reduces the joint probability of a recession in 1991 or 1992 or 1993 and low inflation in 1992 and 1993. Again the tradeoff is clear: the probability of no recession coupled with inflation over 5½ percent now exceeds 40 percent, compared to 18 percent when policy is tighter.

6.2 *Appraising and Reappraising Policy*

The appraisal/reappraisal process inherent in routine policymaking helps to understand the Federal Reserve’s “preemptive strike” against inflation in 1994. Our analysis shows that in February the tighter policy looked to be sufficient to offset higher inflation in 1996 and 1997; it was not sufficient by April, once three months of new information arrived. When we reappraise policy in April, a further tightening appears necessary to preempt inflation. The analysis puts empirical flesh on Brainard’s (1967) argument for conservatism.

Figure 7 displays actual data and out-of-sample forecasts made in January under two alternative policy scenarios for February through May.³² Given that the federal funds rate had been nearly constant at 3 percent over the previous year, a natural baseline maintains this

³² The figures do not report error bands. Accounting for uncertainty does not alter the inferences.

constancy through May. That policy portends rising inflation over the next several years, exceeding 3½ percent in 1996 and 1997, but policymakers do not seem to face an unpleasant tradeoff between inflation and real activity. Real GDP is expected to grow at least 3 percent annually from 1995 to 1997, while the unemployment rate is projected to continue to decline.

Key policy questions were when to raise the rate and how much to raise it. To address the questions we consider a conservative alternative policy of modest exogenous tightening that raises the funds rate along its actual path.³³ In January even modest exogenous tightening shifts the projected inflation path down without severely affecting real activity.

The Fed reappraises policy in April, using three additional months of news about the economy. Now the baseline of a constant funds rate at 3.75 percent leads policymakers to expect inflation will once again drift toward the 3½ to 4 percent range in 1996 and 1997 (Figure 8). The outlooks for output and unemployment remain promising, so the Fed still does not face a difficult tradeoff. A somewhat stronger tightening move to match the actual path of the funds rate from

³³ Although the actual funds rate rose a full percentage point from January to May, that path is realized by a sequence of relatively small exogenous actions, $\varepsilon_p = (.5, 0, .5, 1.1)$. Maintaining a constant funds rate requires slight easing, $\varepsilon_p = (-.3, -.2, -.2, -.2)$. The t-statistics for the forecast errors associated with these interventions are

Variable	η_p^* (Constant R)	η_p^* (Actual R)
<i>R</i>	0.15	-0.34
<i>y</i>	0.12	-0.28
<i>P</i>	0.23	-0.53
<i>U</i>	-0.02	0.07
<i>CP</i>	0.15	-0.34
<i>M2</i>	0.17	-0.40

May through August, pushes the funds rate to 4.47 percent in August and shifts the mean forecast of inflation down below 3 percent through 1997 without risking recession.³⁴

By reappraising their decisions in light of updated forecasts, policymakers move conservatively against inflation. So long as they project far enough into the future, so that it is reasonable to expect monetary policy to affect sluggish variables like inflation over the forecast horizon, the conservative approach can be successful. This analysis formalizes Blinder's (1997) description of policymaking. It also illustrates why uncertainty about future exogenous disturbances may lead policymakers to move cautiously, as Brainard (1967) instructs.

³⁴ A constant rate implies $\varepsilon_p = (.1, -.3, 0, 0)$ and the tightening implies $\varepsilon_p = (.8, .4, .1, .8)$. Error bands on output place little probability on a recession. The t-statistics for the forecast errors associated with these interventions are

Variable	$\eta_p^*(\text{Constant } R)$	$\eta_p^*(\text{Actual } R)$
<i>R</i>	0.03	-0.34
<i>y</i>	0.03	-0.28
<i>P</i>	0.05	-0.54
<i>U</i>	-0.01	0.05
<i>CP</i>	0.03	-0.34
<i>M2</i>	0.04	-0.41

7. Concluding Remarks

This paper offers an approach to policy evaluation that complements existing econometric models of policy. By probing the range of policy questions that do not involve changing the existing policy process, we can address a rich class of practical policy questions in a manner that is consistent with rational expectations. The framework integrates the identification of exogenous variation in policy with a complete probability model for observed time series, bringing together identification and forecasting. Answers to policy counterfactuals take the form of joint probability distributions for the time paths of forecasted variables. The joint distributions deliver probabilistic assessments of the risks and tradeoffs associated with alternative policy scenarios.

It is currently fashionable to study simple monetary policy rules in single- or few-equation models. The popularity of this style of analysis stems in part from the perception that the remarkable performance of the world economy over the past 15 years is largely due to good monetary policy. If a simple rule can describe that policy behavior, then future generations of policymakers may be able to reproduce the success. A related effort to reproduce that success is through the adoption of inflation targeting by central banks around the world. Narrowing the objectives of policy may increase the likelihood policy will be successful.

The desire to reproduce past policy success does not rationalize current modeling fashions. Identified VARs consistently conclude that monetary policy does *not* obey simple rules. Instead, policy choices depend systematically on a large set of current and past information. Simple rules such as Taylor's (1993), for example, are degenerate special cases of the complicated dynamic rules that emerge from VARs. A single, well-specified objective for policy – like an inflation

target – does not imply the rule is simple [see Bernanke, Laubach, Mishkin and Posen (1999) for more discussion]. Rather, it prescribes how policy should respond to the myriad disturbances affecting the economy.

If one aim of research is to describe past policy behavior so it can be reproduced in the future, our approach helps achieve that goal. Reproducibility amounts to implementing the existing rule. Our approach is a tractable way to reproduce the success of past policy behavior in all its realistic complexity.

Appendix: Data

The data, from 1959:1 to 1998:9, are collected from the Bureau of Economic Analysis, the Department of Commerce unless otherwise stated.

Federal Funds Rate: effective rate, monthly average. Source: Board of Governors of the Federal Reserve System (BOG).

M2: M2 money stock, seasonally adjusted, billions of dollars. Source: BOG.

CPI: consumer price index for urban consumers (CPI-U), seasonally adjusted.

GDP: Real GDP, seasonally adjusted, billions of chain 1992 dollars. Monthly real GDP is interpolated using the procedure described in Leeper, Sims and Zha (1996).

Unemployment: civilian unemployment rate (16 and over), seasonally adjusted. Source: Bureau of Labor Statistics.

Commodity Prices: International Monetary Fund's index of world commodity prices. Source: *International Financial Statistics*.

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Table 1. Structure of Contemporaneous Variables

Money demand

$$a_1 M2 + a_2 R + a_3 y + a_4 P = \varepsilon_{MD}$$

Monetary policy

$$a_5 R + a_6 M2 + a_7 CP = \varepsilon_P$$

Information sector

$$a_8 CP + a_9 M2 + a_{10} R + a_{11} y + a_{12} P + a_{13} U = \varepsilon_I$$

Production sector

This subsystem is arranged in the lower-triangular order y , P , and U .

Table 2. Maximum Likelihood Estimates of Contemporaneous Coefficients

Money demand

$$310.33 M2 + 161.89 R - 28.47 y + 6.84 P = \varepsilon_{MD}$$

(49.65, 434.46) (45.33, 184.55) (-36.44, -9.11) (-23.95, 36.95)

Monetary policy

$$100.66 R - 336.84 M2 - 3.10 CP = \varepsilon_P$$

(-12.08, 169.12) (-444.63, -40.42) (-11.29, 4.90)

Information

$$49.84 CP - 35.84 M2 + 20.63 R - 7.09 y - 41.64 P + 48.43 U = \varepsilon_I$$

(45.85, 50.83) (-65.95, 36.56) (6.60, 51.59) (-19.57, 3.40) (-65.79, -15.82) (21.31, 85.24)

68 percent probability intervals for the maximum likelihood estimates are reported in parentheses. Those intervals are based on exact finite-sample results computed by a Gibbs sampler algorithm with 360,000 Monte Carlo draws. See Waggoner and Zha (1998) for details.

Table 3. Correlations Among Exogenous Disturbances

Maximum likelihood estimates and 68% probability intervals, in parentheses, based on 360,000 draws from the posterior distribution of the model coefficients

	ε_P	ε_{MD}	ε_I	ε_y	ε_{CPI}	ε_U
ε_P	1.0 (1,1)					
ε_{MD}	.013 (-.048,.052)	1.0 (1,1)				
ε_I	-.016 (-.064,.032)	-.015 (-.060,.032)	1.0 (1,1)			
ε_y	.020 (-.056,.084)	-.001 (-.052,.044)	.003 (-.048,.044)	1.0 (1,1)		
ε_{CPI}	.042 (-.004,.052)	-.0023 (-.056,.044)	-.009 (-.060,.036)	-.002 (-.052,.040)	1.0 (1,1)	
ε_U	-.041 (-.140,.068)	-.192 (-.192,-.088)	.001 (-.048,-.044)	.001 (-.052,.044)	.002 (-.048,.044)	1.0 (1,1)

(grouped into bins of size .002 to keep storage demands manageable)

Table 4. Summary of Out-of-Sample Forecast Performance

The following root-mean-square errors are computed using forecast horizons from 1 to 4 years. Forecasts begin in December 1979 and run through September 1994, 4 years before the end of the sample.

Years ahead		1	2	3	4
<i>Federal Funds Rate</i> (<i>R</i>)	Diffuse Prior	2.534	6.478	9.443	12.074
	Litterman	1.945	4.212	5.310	5.747
	Sims-Zha	1.572	2.531	2.784	3.287
<i>Real GDP Growth</i> (<i>y</i>)	Diffuse Prior	2.142	3.038	2.831	4.067
	Litterman	1.613	2.022	2.283	2.561
	Sims-Zha	1.384	2.324	2.013	1.706
<i>Inflation</i> (π)	Diffuse Prior	1.199	3.397	4.987	4.571
	Litterman	1.138	2.959	4.201	4.532
	Sims-Zha	0.951	2.066	2.825	3.238
<i>Unemployment</i> (<i>U</i>)	Diffuse Prior	0.760	1.794	2.070	2.961
	Litterman	0.535	1.109	1.338	2.116
	Sims-Zha	0.537	1.241	1.525	1.832
<i>Commodity Prices</i> (<i>CP</i>)	Diffuse Prior	10.599	21.103	18.504	16.481
	Litterman	8.593	16.829	15.633	13.063
	Sims-Zha	7.316	11.279	10.461	10.969
<i>Money Stock</i> (<i>M2</i>)	Diffuse Prior	1.792	3.455	3.352	3.187
	Litterman	1.553	2.643	2.369	2.638
	Sims-Zha	1.534	3.103	3.885	4.359

Table 5. Out-of-Sample Forecasts Conditional on Actual Path of R

Forecasts assume the path R is produced by exogenous policy actions only
Forecasts from October 1990 to September 1994

Maximum likelihood estimates; annual average growth rates or percentage points.

	R	y forecast (actual)	π forecast (actual)	U forecast (actual)
1990	8.1	1.4 (1.2)	5.4 (5.4)	5.6 (5.6)
1991	5.7	1.4 (-0.9)	6.0 (4.2)	6.7 (6.9)
1992	3.5	7.8 (2.7)	7.2 (3.0)	6.0 (7.5)
1993	3.0	15.0 (2.3)	12.7 (3.0)	3.5 (6.9)

Table 6. Forecasts Conditional on Constant Funds Rate

Out-of-sample forecasts conditional on holding R constant for 4 months, unconditional thereafter. Unconditional forecasts assume exogenous monetary policy actions are identically zero. Marginal policy impact is computed as the difference between the conditional forecast and the unconditional forecast. This is equivalent to the impulse response function generated by the specified ε_p impulses.

(annual averages in percentage points or percent growth rates)

A. R held constant at 8.20% from October 1990 to January 1991

Forecast year	R		π		y		U	
	conditional forecast	marginal policy impact	conditional forecast	marginal policy impact	conditional forecast	marginal policy impact	conditional forecast	marginal policy impact
1990	8.22	0.14	5.41	0.00	1.44	0.00	5.62	0.00
1991	7.51	0.34	5.81	-0.15	0.19	-0.57	6.86	0.11
1992	6.77	-0.33	4.83	-0.67	2.74	-0.55	7.27	0.29
1993	6.97	-0.55	4.77	-0.83	4.02	0.15	7.09	0.19

Based on VAR estimated from January 1959-September 1990; conditional on $\varepsilon_p = (.8, 1.0, .8, .6)$ from 90:10-91:1 and $\varepsilon_p = 0$ thereafter.

B. R held constant at 3.00% from February 1994 to May 1994

Forecast year	R		π		y		U	
	conditional forecast	marginal policy impact	conditional forecast	marginal policy impact	conditional forecast	marginal policy impact	conditional forecast	marginal policy impact
1994	3.05	-0.14	2.47	0.00	2.73	0.08	6.49	-0.01
1995	3.27	0.05	2.91	0.13	3.06	0.24	6.30	-0.08
1996	3.64	0.17	3.35	0.23	3.31	0.03	6.09	-0.08
1997	4.14	0.19	3.84	0.23	3.35	-0.05	5.93	-0.03

Based on VAR estimated from January 1959-January 1994; conditional on $\varepsilon_p = (-0.3, -0.2, -0.2, -0.2)$ from 94:2-94:5 and $\varepsilon_p = 0$ thereafter.

Table 7. Joint and Marginal Probabilities Conditional on Alternative Policies

Outcomes Based on Out-of-Sample Forecasts from September 1990.

“Tighter” policy raises R to 8.70% in October and to 8.95% in November 1990-January 1991 and is produced by the sequence of exogenous actions $\varepsilon_p = (2.3, 1.7, 1.0, 0.9)$.

“Actual R ” sets R at 8.11% in October, 7.81% in November, 7.31% in December, 6.91% in January 1991 and is produced by the sequence of exogenous actions $\varepsilon_p = (0.5, 0.1, -0.7, -0.7)$.

	Tighter	Actual R
$P(\text{low } \pi \text{ in } 1992)$	.67	.47
$P(\text{low } \pi \text{ in } 1993)$	.66	.46
$P(\text{low } \pi \text{ in } 1992 \text{ and } 1993)$	.57	.36
$P(\text{recession in } 1991)$	.53	.27
$P(\text{recession in } 1992)$	.12	.05
$P(\text{recession in } 1993)$	.05	.06
$P(\text{recession and low } \pi)$	.33	.11
$P(\text{recession and high } \pi)$	.25	.22
$P(\text{no recession and low } \pi)$	.24	.25
$P(\text{no recession and high } \pi)$	.18	.42

$P(\text{recession})$ is the probability of negative real GDP growth in 1991 or 1992 or 1993.

$P(\text{low } \pi)$ is the probability of inflation below 5½ percent in 1992 and 1993.

Figure 1. Responses to an Exogenous Monetary Policy Contraction: Monthly

Maximum likelihood estimates (solid) and 68% probability bands (dashed). Log levels or percentage points.

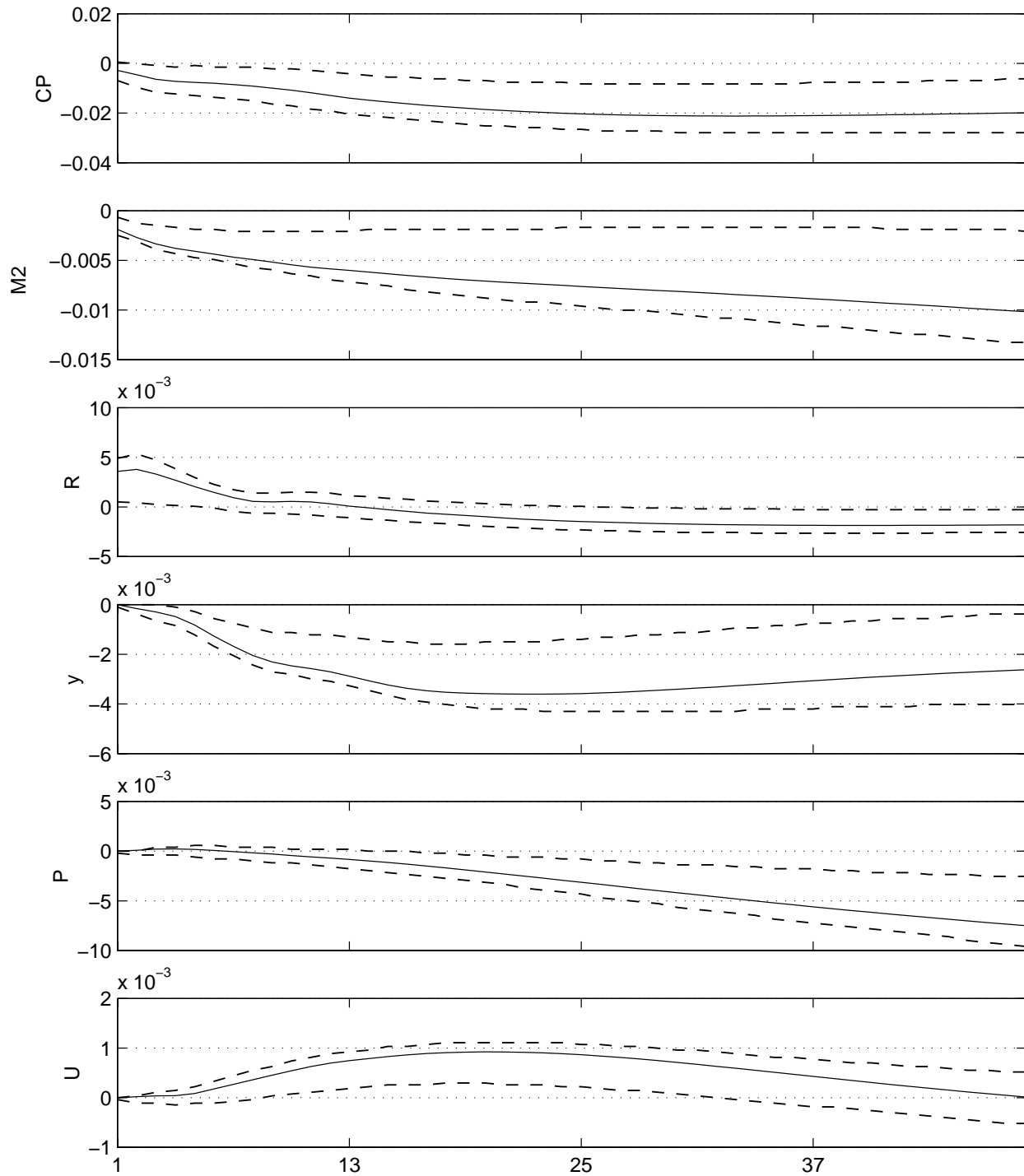


Figure 2. Responses to an Exogenous Monetary Policy Contraction: Annual

Maximum likelihood estimates (solid) and 68% probability bands (dashed). Annual average growth rates or percentage points.

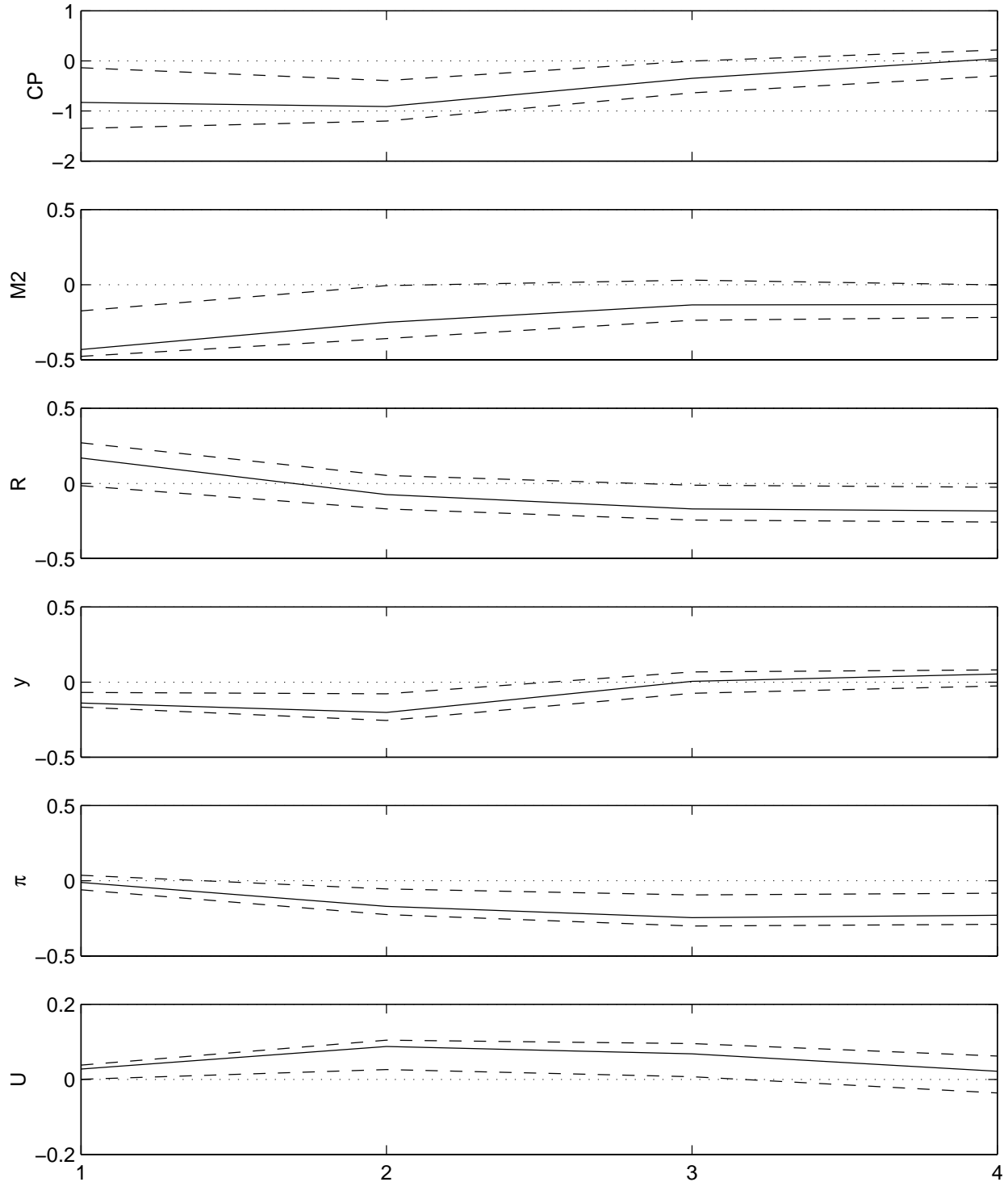


Figure 3. Full Model Responses Estimated Over Various Sub-Periods

Impulse response functions estimated over various sub-periods. Solid line is entire sample period, 1959:1-1998:9; dashed line is 1959:1-1979:9; dashed/dotted line is 1959:1-1982:12; dotted line is 1959:1-1998:9 with 1979:10-1982:12 eliminated.

ε_x denotes exogenous disturbance; $x = I$ (commodity prices – information sector), = P (monetary policy), = MD (money demand), = y (GDP – goods sector), = CPI (price level – goods sector), U = (unemployment – goods sector)

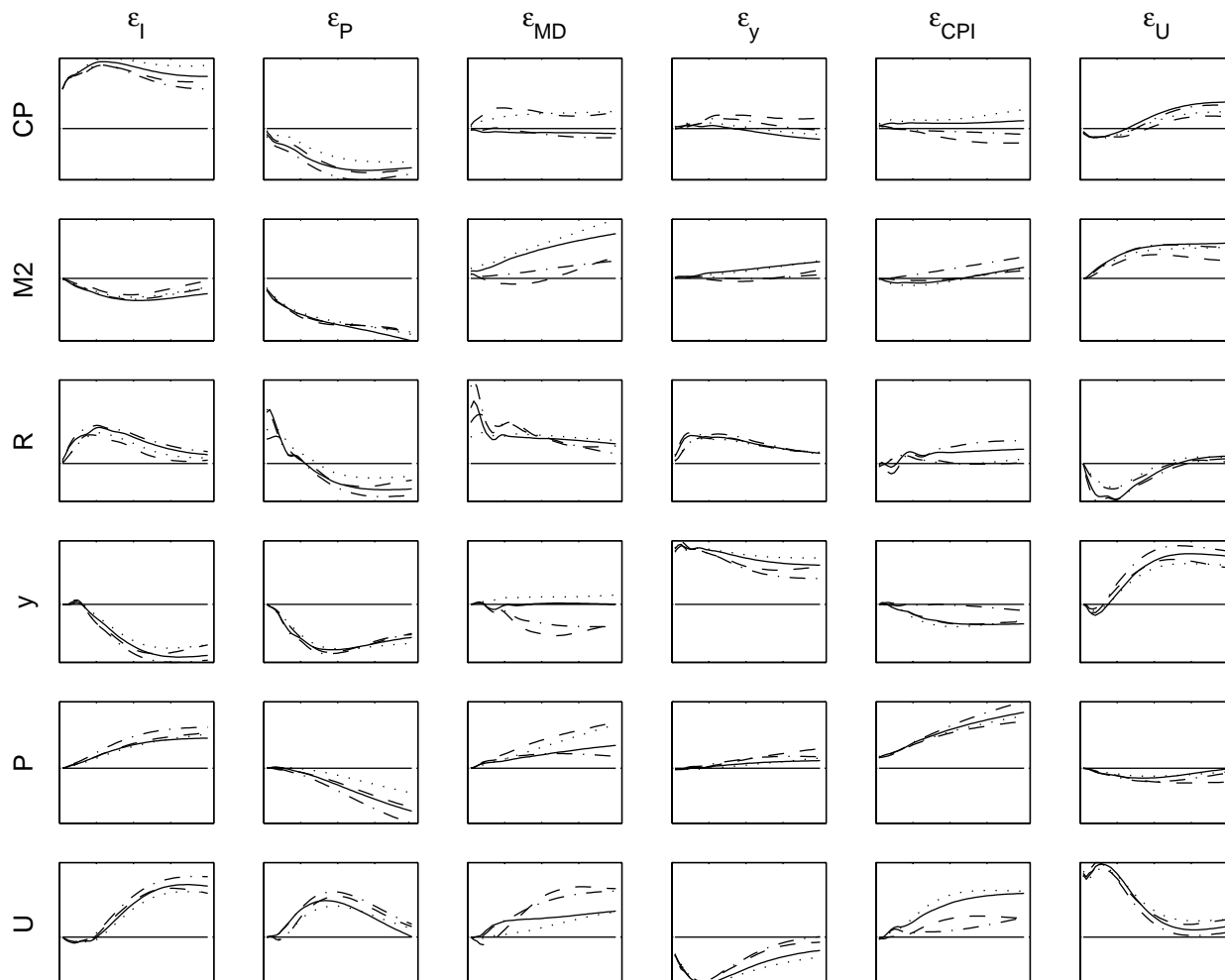


Figure 4. In-Sample Forecasts Incorporating All Nonpolicy Disturbances

Actual (solid) and in-sample forecast (dashed). In-sample forecasts composed of unconditional forecast plus forecast conditional on actual values of all nonpolicy exogenous disturbances. Annual average growth rates or percentage points.

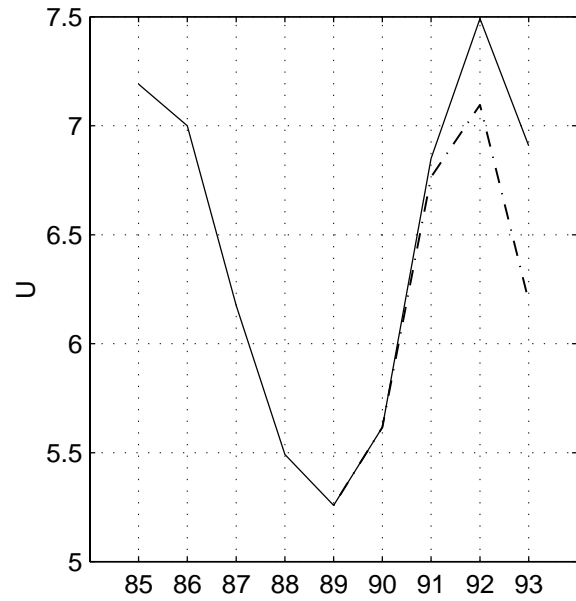
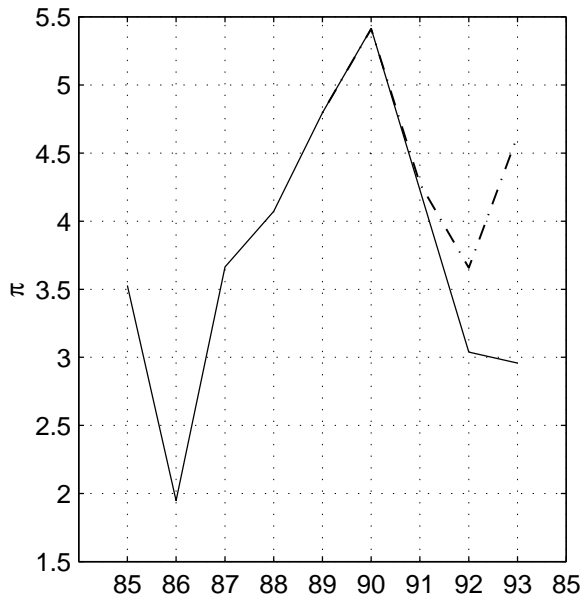
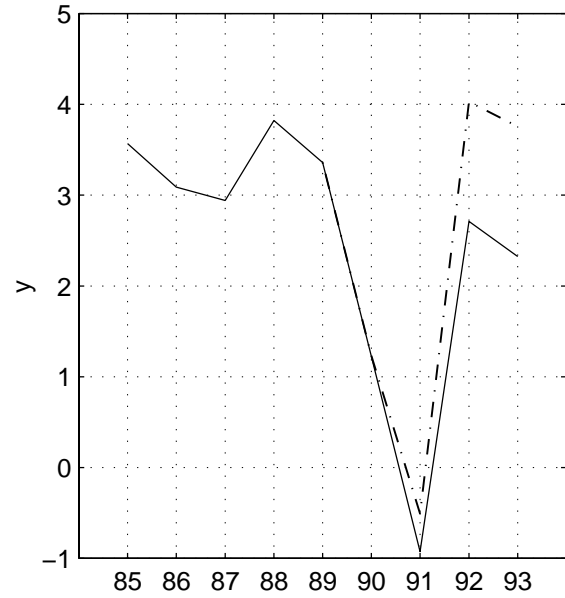
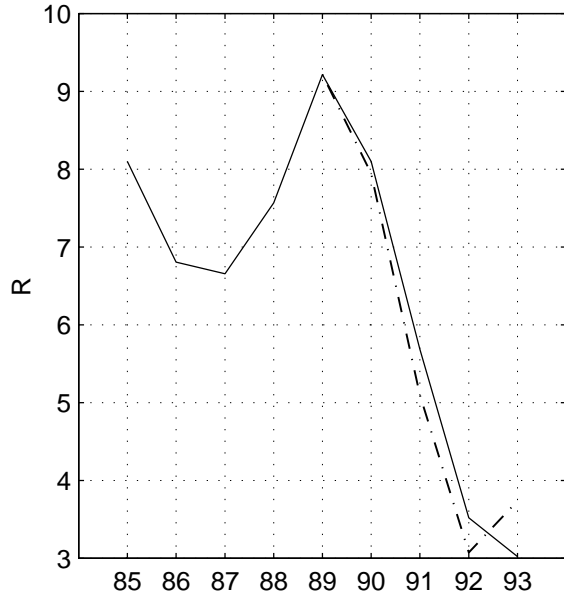


Figure 5. Forecasts Conditional on Actual Path of Funds Rate

Actual (solid) and out-of-sample forecast (dashed). Out-of-sample forecasts conditional on actual path of the federal funds rate from October 1990 to January 1991. Forecasts include maximum likelihood estimates (dashed-dot) and 68% probability bands (dashed). Annual average growth rates or percentage points.

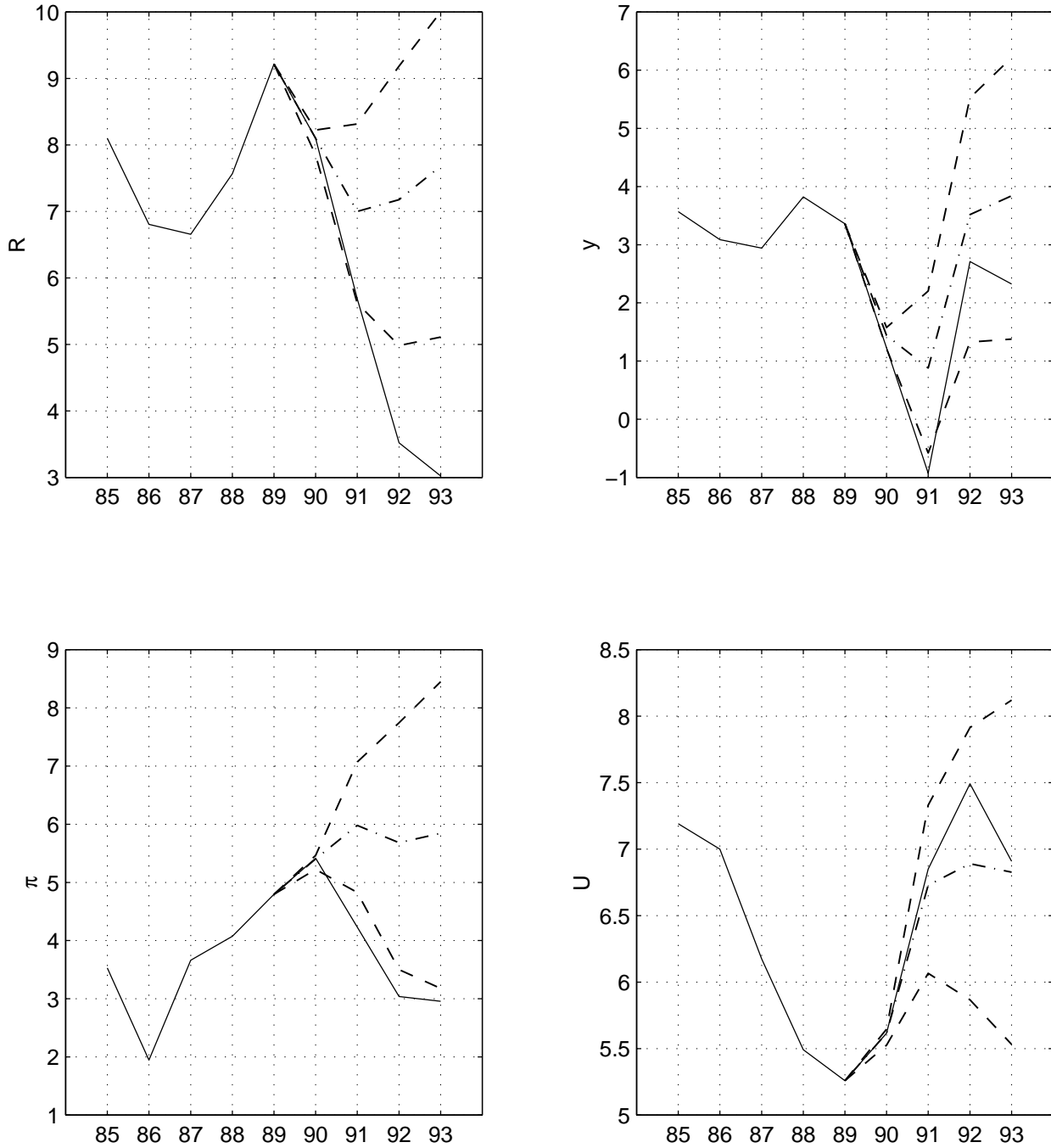


Figure 6. Forecasts Conditional on Tighter Exogenous Policy Actions

Actual (solid) and out-of-sample forecast (dashed). Out-of-sample forecasts conditional on tighter policy, raising the federal funds rate 50 basis points in October 1990 (to 8.70%) and another 25 basis points over November 1990 to January 1991 (to 8.95%). Forecasts include maximum likelihood estimates (dashed-dot) and 68% probability bands (dashed). Annual average growth rates or percentage points.

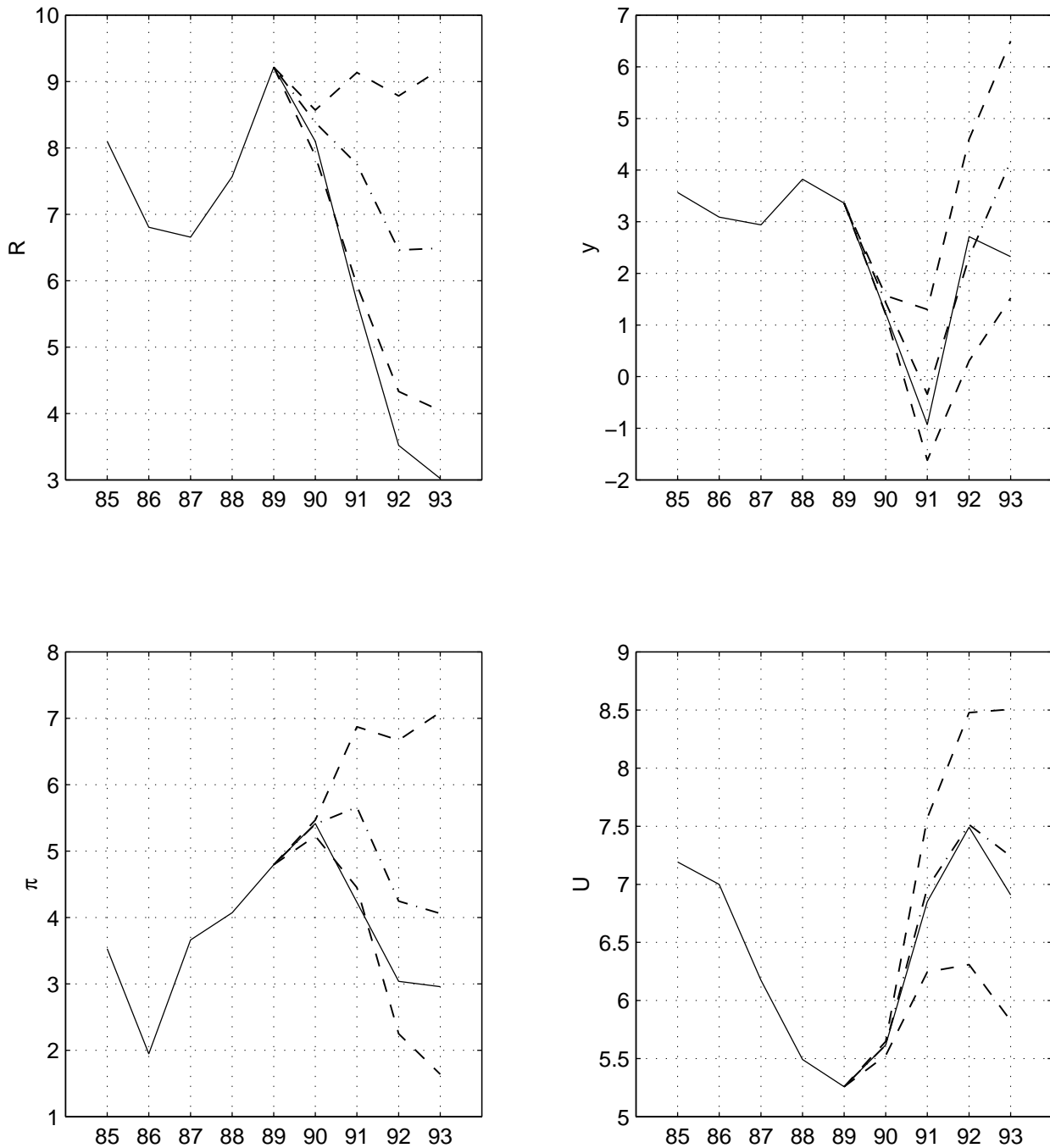


Figure 7. Forecasts Conditional on Constant and Actual Funds Rate: 94:2

Actual (solid) and out-of-sample forecasts conditional on a constant funds rate (+) and on the actual path of the funds rate (*) from February to May 1994. Constant rate is 3.00%; actual path is 3.25%, 3.34%, 3.56%, 4.01%. Annual average growth rates or percentage points.

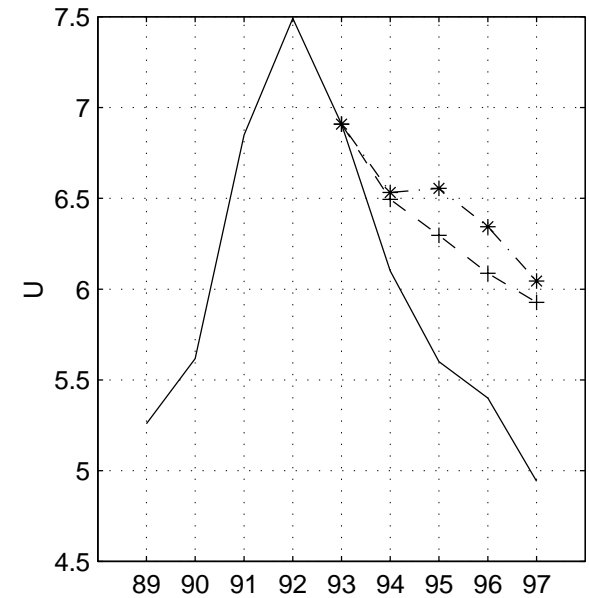
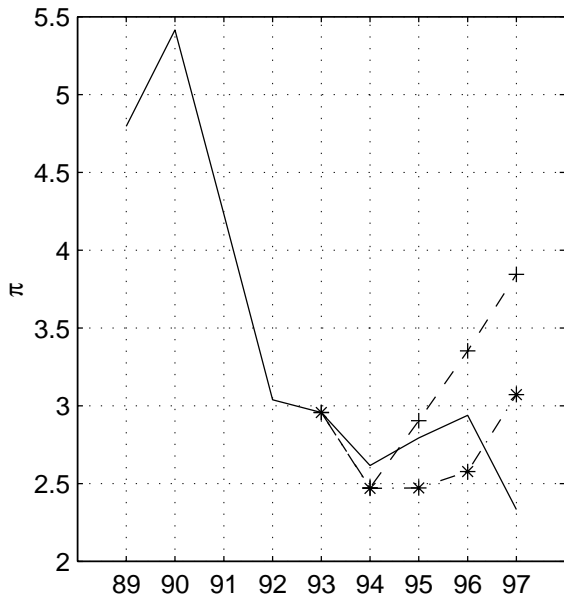
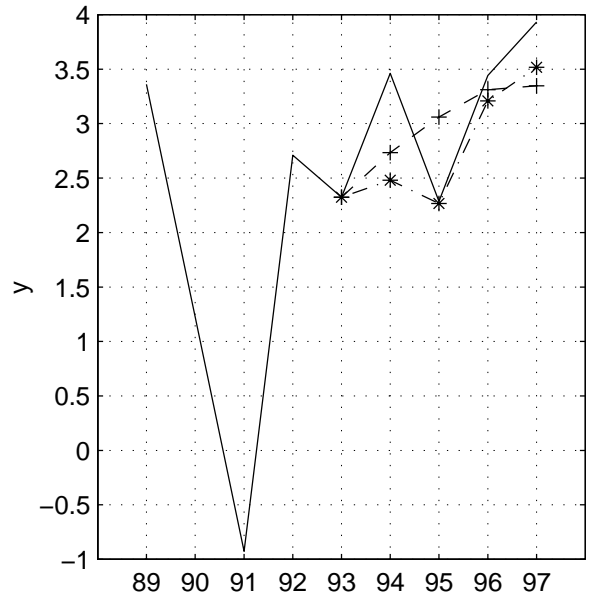
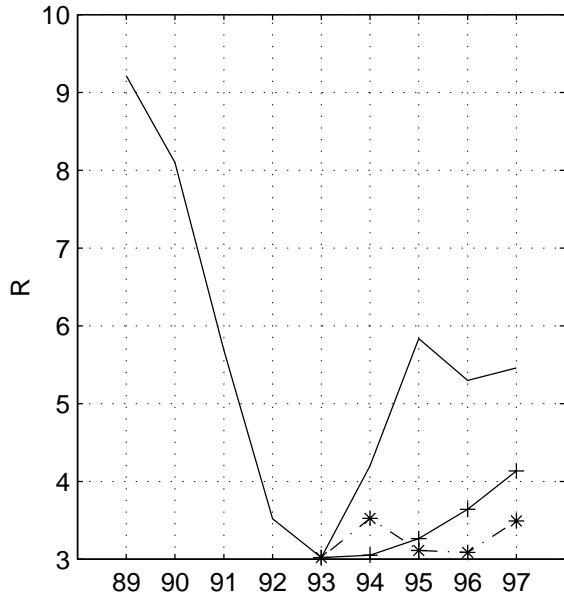


Figure 8. Forecasts Conditional on Constant and Actual Funds Rate: 94:5

Actual (solid line) and out-of-sample forecasts conditional on a constant funds rate (+) and on the actual path of the funds rate (*) from May to August 1994. Constant rate is 3.75%; actual path is 4.01%, 4.25%, 4.26%, 4.47%. Annual average growth rates or percentage points.

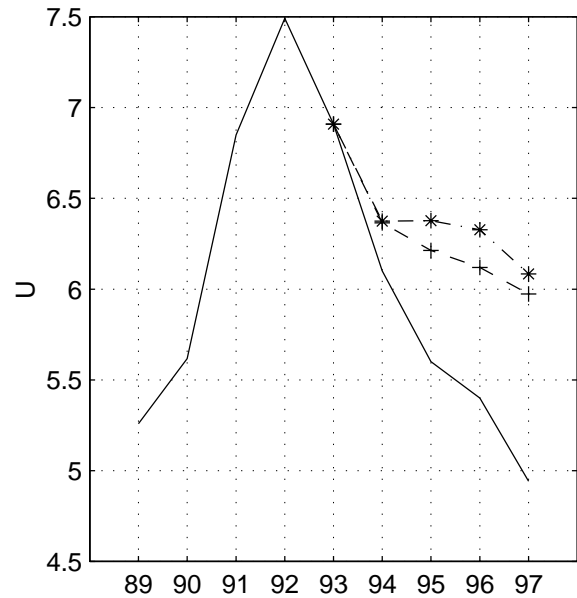
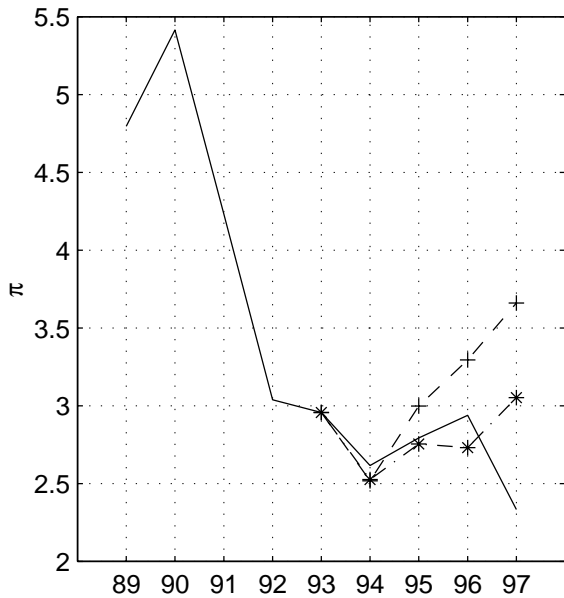
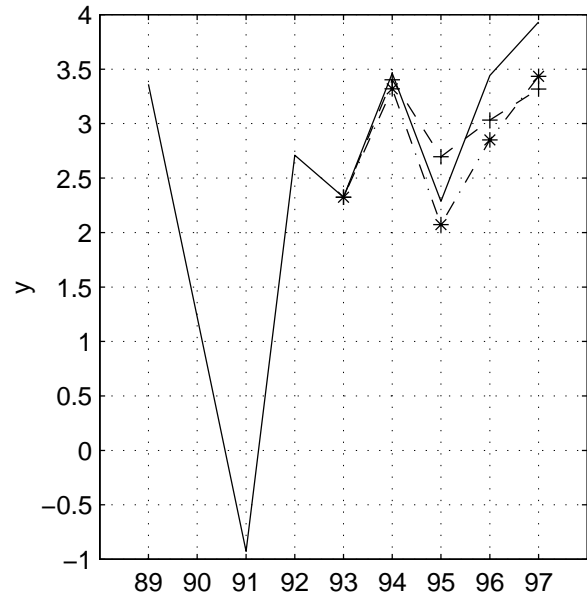
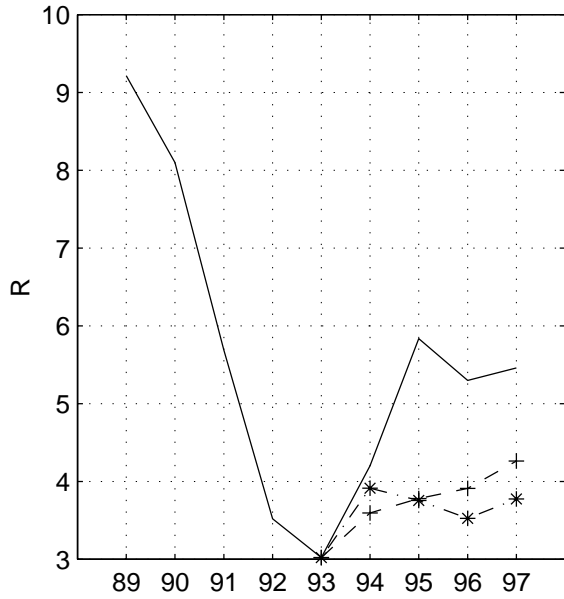


Figure 9: Appendix

Impulse response functions estimated over various sub-periods. Solid line is entire sample period, 1959:1-1998:9; dashed line is 1959:1-1990:9; dashed/dotted line is 1959:1-1994:1; dotted line is 1959:1-1994:4.

ε_x denotes exogenous disturbance; $X = I$ (commodity prices – information sector), = P (monetary policy), = MD (money demand), = y (GDP – goods sector), = CPI (price level – goods sector), $U =$ (unemployment – goods sector)

