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Evidence Uncovered: Long-Term Interest Rates, Monetary Policy, and the Expectations Theory

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Abstract

A large body of literature has failed to find conclusive evidence that the expectations theory of the term structure holds in U.S. data. This paper asks more narrowly whether the theory holds conditional on an exogenous change in monetary policy. We argue that previous work on the expectation theory has failed to sufficiently account for interactions between monetary policy and bond markets in the determination of long and short interest rates. Using methods that directly account for this interaction, we find strong evidence supporting a term structure channel for policy that is consistent with the expectations theory. We show that the marginal effect of our consideration for this source of simultaneity bias is significant in uncovering evidence for the theory. We also discuss previous claims that policy regime changes and short-term interest rate smoothing by the Fed accounts for the theory's unconditional failure in light of our findings.

Keywords: term structure, vector autoregression, interest rate smoothing, policy regimes, Bayesian VAR

JEL Classification: C11, C32, E43, E44, E52

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1. Introduction

Conclusive evidence in support of the expectations theory of the term structure continues to elude economists. Numerous studies have shown the arbitrage condition implied by efficient market conditions relating a long-term interest rate to a product of expected future short rates to be unsubstantiated in US data.[1] The theory's persistence in academic and policy circles despite its spotty empirical record is none-the-less remarkable.[2]

This persistence in policy circles, in particular, suggests that there may be special circumstances in which the theory holds irrespective of its failure under more general conditions. Specifically, it may be that changes in short rates that are *induced by an exogenous shift in monetary policy* lead to changes in long rates that are well predicted by the expectations theory. Since policy makers are necessarily concerned with the transmission of policy actions to the macro economy, this type of conditional evidence for the theory would naturally hold special importance.[3]

This paper examines evidence for a conditional form of the expectations theory of the term structure. Focusing on the variation in long rates that is associated with an exogenous change in monetary policy, we ask whether bond market outcomes —at least in this case— are well predicted by theory. Evidence affirming the theory in these narrower circumstances would provide valuable support for a term structure channel for monetary policy. It would also demonstrate that the theory's empirical failure is not a generic result, motivating a re-evaluation of previous explanations for the theory's unconditional failure in light of new findings. Looking forward, future research on the source of the unconditional failure would likely benefit from the knowledge that a structural decomposition of interest rate variations into policy and non-policy sources provides information relevant to the empirical success of the theory.

Isolating the variance in long rates that is conditional on exogenous monetary policy is a non-trivial task. Although a recent literature has managed to isolate the qualitative effects of exogenous monetary policy using structural vector auto-regressive techniques, there exist many specifications of policy behavior (also referred to as policy rules) that are equally well supported by the data.

[1] Some of the works in this literature yielding conflicting evidence on the theory include Campbell and Shiller(1991 and 1987), Hansen and Sargent(1980), Sargent(1979) and more recently, Roberds, Runkle, and Whiteman (1996), and Dejong and Whiteman(1996).

[2] Shiller, Campbell, and Schoenholtz (1983) made the following tongue-in-cheek remark:"...the theory seems to reappear perennially in policy discussions as if nothing happened to it...We are reminded of the Tom and Jerry cartoons that precede feature films at movie theatres. The villain, Tom the cat, may be buried under a ton of boulders, blasted through a brick wall (leaving a cat shaped hole), or flattened by a steamroller. Yet seconds later he is up again plotting his evil deeds." pg. 175

[3] Goodfriend (1998) discusses the usefulness of the term structure to policy makers. Akhtar(1995) motivates the need for structural models of the relationship between policy and long term interest rates from a policy perspective.

Different specifications of policy typically yield different quantitative predictions for the dynamic paths of macro and policy variables following a policy shock,[4] yet quantitative accuracy in the estimation of long and short rate dynamics is likely important to uncovering evidence on the expectations theory. In this case, failure to recognize the sensitivity of estimated interest rate responses to the specification of policy behavior could conceivably lead to false negative conclusions about the theory's validity. [5]

This paper uses methods that avoid such false negative conclusions by searching across a broad subset of qualitatively reasonable models of monetary policy to see if any model closely matches the predictions of the expectations theory. By conducting a more comprehensive search for evidence than conventional structural VAR approaches which typically rely on a single or small finite set of specifications, we are more likely to find evidence in support of the theory, if it exists. If, on the other hand, deviations from the theory are found to be large across the entire subset of policy specifications we consider, the breadth of our search provides convincing evidence against the theory.

In the end, we find that a number of reasonable specifications of policy exist that predict long rate responses to an exogenous change in policy that are consistent with the theory. In the absence of a widely accepted theory of Federal Reserve behavior that would allow us to better identify actual policy behavior, the policy specifications uncovered in this paper in support of the expectations theory are as reasonable as the many specifications in the policy literature with similar qualitative predictions and equivalent fits to the data.[6]

An important hypothesis in this paper is that, while support for the unconditional expectations theory in the literature is in general lacking, many of the previously recorded failures derive from inappropriate econometrics. Whereas the expectations theory predicts that policy affects long rates by influencing expectations of future short rates, it is also true that policy makers monitor bond markets for information on, among other things, inflation expectations. Policy responses to developments in bond markets create simultaneities in the determination of short- and long-term

[4] See Leeper, Sims, Zha(1996) and Christiano, Eichenbaum, Evans(1998) for examples of alternative VAR models of monetary policy behavior and their predictions for variable responses to an exogenous change in policy.

[5] Many aspects of the VAR specification not related to policy behavior can also affect the strength and of the predicted variable responses to policy, including, for example, assumptions about price and output rigidities following a policy shock. For this reason we will often refer more generally to "policy specification" and "models of monetary policy" to incorporate these other non-robust aspects of VAR specification which have quantitative implications for estimation of the effects of monetary policy.

[6] Because the methods in this paper obtain underidentified systems –making full model, goodness of fit measures inappropriate– we will gauge goodness of fit by the qualitative consistency of our impulse responses with those in the literature.

interest rates. As we will discuss in the next subsection, the literature tends to neglect this potential source of simultaneity bias. In contrast, this paper uses methods which disentangle the interactions between policy and the bond market and uncovers evidence for the expectations theory conditional on policy.[7]

In section 4.3 of this paper we examine whether recognition of the potential simultaneities between policy and bond markets is important to uncovering evidence for the expectations theory. We compare results from specifications of monetary policy that allow for varying degrees of simultaneity between policy and the bond market and find that the more simultaneous model specifications predict consistently smaller deviations from the expectations theory. This finding supports reasoning by McCallum(1994) that many of the previous failures of the theory derive from econometric error rather than financial market inefficiency.[8]

Lastly, the results in this paper provide a new framework to evaluate arguments that Federal Reserve behavior accounts for past failures of the expectations theory. Mankiw and Miron(1986) were the first to argue that interest rate smoothing by the Fed reduces agents' unconditional expectations of future short rate variation, and thereby the proportion of ex-post long rate variation resulting from arbitrage activity under the theory relative to (albeit small) variation in the term premium.[9] The result, they argue, is that single equation regression tests of the expectations theory yield false negative conclusions. Hamilton(1988) and Fuhrer(1996) also protest the single equation regression approach common in the literature, arguing that historical policy regime changes imply non-linearities which can not be captured in full sample, linear models.

Neither Mankiw and Miron's or Hamilton's explanation for the previous failures allows the expectations theory to hold conditional on a policy shock however. Either argument, if true, should lead to the empirical failure of the theory conditional on any type of shock hitting the economy as long as the model of future short rate expectations incorporates the (respective) proposed source of the theory's failure. Our models of expected future short rates both: 1) incorporate expected future short rate smoothing based on historically estimated Fed behavior; and 2) are based on linear projections estimated from an unbroken data set covering multiple policy regime periods discussed in the monetary policy literature. Yet we are able to find evidence that the theory holds conditional on exogenous policy. Thus by implication, neither interest rate smoothing or policy

[7] Specifically, it employs VAR methods that isolate an exogenous component of policy and then simulates the effects of a change in this component on interest rates, money, and other macro variables such as prices and output.

[8] McCallum's arguments will be discussed in section 2 below.

[9] Other literature deriving from Mankiw and Miron's hypothesis include: Roberds, Runkle and Whiteman(1996), Rudebusch(1995), and Dotsey and Otrok(1995)

regime changes are likely alone responsible for the past recorded failures of the theory.

1.0.1. Literature

While previous authors have looked at the effects of policy on long-term interest rates, we believe that much of this work has failed to sufficiently account for simultaneity between policy and the bond market. Most notably, Cook and Hahn(1989) measured the effect of policy on long rates by tracking their response to a change in the FOMC funds rate target. Because this data selection method fails to distinguish between rate changes that are endogenous responses by policy and those that are truly exogenous however, their results likely confuse the effects of policy with changes in the state of the economy to which policy was responding.[10]

Ellingsen and Soederstroem(2000) also base their analysis on FOMC target changes, introducing measures of endogenous and exogenous policy by interpreting media commentary at the time of the target changes. When they interpret contemporary media reports as indicating a perceived change in Fed preferences they classify the target change as an exogenous policy innovation, while other changes are judged to be endogenous, reflecting new information about the state of the economy available asymmetrically to the Fed. This classification scheme is necessarily subjective however. The sensitivity of their results to changes in the classification of only a few data points suggests that investigation of alternative approaches to exogenous policy identification like the one pursued in this paper are warranted.

Other authors including Marshall and Evans(1998) and Edelberg and Marshall(1996) use structural VAR methods to look at the effects of an exogenous policy shock on long-term interest rates. While these papers find mixed evidence in favor of the conditional expectations theory, they make strong assumptions about the interaction between policy and the bond market by specifying policy behavior that does not respond directly to long-term bond rates. As a result, their estimates of long rate responses to a policy shock are potentially confused with policy responses to the bond market.[11] As already mentioned, this paper uses methods that fully account for simultaneities

[10] Cook and Hahn also do not distinguish between anticipated and unanticipated changes in the funds target by the FOMC. Because anticipated changes in the short rate would likely be priced into long rates well before the two to three day time period surrounding the target change that they examine, the correlation between long and short rates within this period is an inaccurate measure of the effects of monetary policy.

[11] Edelberg and Marshall(1996) address the simultaneity problem indirectly by conditioning the policy shock on policy responses to commodity prices – which they posit contain the same information about inflation expectations as long bond rates. Their use of commodity prices in this manner has no theoretical justification however. In order to accurately isolate the correlation between long and short rates that is due to policy, the policy shock needs to be conditioned directly on policy responses to long rates. Evans and Marshall(1998) use the Christiano, Evans and Eichenbaum(1996) , Gali(1992), and Sims and Zha(1998a) identifications which do not allow for full simultaneity between long and short rates.

between policy and bond markets and finds consistent evidence in support of the theory.

The rest of this paper is structured as follows. The next section will briefly review the expectations theory and discuss the implications of simultaneity between policy and bond markets for tests of the theory that are common in the literature. Section 3 will then describe the methodology used in this paper to identify monetary policy and section 4 will present our results. Section 5 will conclude.

2. The Expectations Theory of the Term Structure

The expectations theory of the term structure asserts that the return to holding a long-term bond should equal the product of the current and future short rates expected to hold up to the maturity of the longer term instrument plus a term-to-maturity risk premium. This theory is expressed in an arbitrage condition derived from the fact that, in efficient markets, there should not exist a profit opportunity from holding a zero coupon bond with maturity n over holding a zero coupon bond with the same risk structure but of shorter maturity m (with $\frac{n}{m}$ equal to an integer) and rolling it over for $\frac{n}{m}$ periods. The following representation[12] of this relation holds for pure discount bonds:

$$R_t^n = \frac{1}{k}\sum_{i=0}^{k-1} E_t R_{t+i}^m + c \tag{2.1}$$

where $k = \frac{n}{m}$, R_t^n is the interest rate on the longer maturity bond at time t, $E_t R_{t+i}^m$ is the expected rate on the shorter maturity bond i periods ahead conditional on time t information, and the parameter c represents a time invariant term premium.

Subtracting the current short rate from both sides, rearranging terms, and imposing rational expectations yields the following regression equation:

$$\frac{1}{k}\sum_{i=0}^{k-1} R_{t+i}^m - R_t^m = \alpha + \beta(R_t^n - R_t^m) + \varepsilon_t \tag{2.2}$$

where equation 2.1 suggests that we should obtain estimates for α and β equal to $-c$ and 1 respectively. Many empirical studies have failed to find consistent evidence that β is insignificantly different from one in regressions based on equation 2.2 - most notably Campbell and Shiller(1991) - or even that variation in the spread consistently explains a significant portion of the variation in the future path of interest rates as measured by the R-squared statistic from this type of regression.

[12] Campbell, Shiller, and Schoenholtz (1983)

A more general form of equation 2.1 allows for a covariance stationary term premia which may be serially correlated but is exogenous with respect to R_t^n, R_t^m, and $E_t(R_{t+j}^m)$:

$$R_t^n = \frac{1}{k}\sum_{i=0}^{k-1} E_t R_{t+i}^m + c_t \tag{2.3}$$

where

$$c_t = \rho c_{t-1} + \mu_t \tag{2.4}$$

Here μ_t is white noise and $|\rho| < 1$. As discussed by McCallum(1994), this specification may be more reasonable in that we should not expect term premia to have zero period-to period variation, but rather to exhibit some random fluctuation as a result of changes in financial market preferences or other disturbances that do not play an important role in the total variation of long-term rates.[13] While this form of the theory allows that there may be some variation in the term premium, it none-the-less maintains the nature of the original hypothesis by assuming that such variation is random.

The difficulties in past regression analyses based on equation 2.2 become understandable when we also consider policy behavior that responds to movements in $R_t^n - R_t^m$, as might be expected from a central bank that is concerned about future inflation or output growth. Even when long-term interest rates are governed by the process in equation 2.1, McCallum(1994) shows that policy responses to changes in c_t imply that $E_t(\varepsilon_t|(R_t^n - R_t^m)) \neq 0$ in equation 2.2 such that the probability limit of β is no longer equal to one. In this case simultaneity between policy and financial market behavior in the determination of long-term interest rates implies that regression tests based on equation 2.2 are inappropriate.

This paper takes the view that policy responses to information in the term structure necessitate estimation procedures that model the correlation between long and short interest rates as a product of the interactions between financial markets and policy behavior as well as other economic market activity. We use a structural VAR framework to model these interactions. We then simulate the equilibrium paths of interest rates (and other macro variables) following an exogenous change in policy and compare the long rate path predicted by this model with that predicted by the expectations theory. As we will see, our concern about simultaneity between long and short rates is warranted.

[13] Another possibility is that financial innovation affects the relative liquidity characteristics of different assets and thereby the term premia between them as a function of the demand for these assets conditional on the same preferences.

3. Identification of Monetary Policy

A common structural VAR method seeks to identify the effects of an exogenous one time change in policy by appropriately restricting the decomposition of the contemporaneous variance covariance matrix of one step ahead forecast errors from a reduced form VAR of the form:

$$B(L)y_t = \mu_t \tag{3.1}$$

where y_t is an $mx1$ vector of macro economic time series, $B(L) = \sum_{i=0}^{p} B_i L^i$, $B_0 = I$, and $\mathrm{E}(\mu_t \mu_t') = \sum_{\mu}$. The identifying restrictions on $\sum_{\mu}$ reflect assumptions about the contemporary behavioral relationships among the variables in y_t that are believed to hold in the structural model underlying the data which can be approximated as:

$$A(L)y_t = \nu_t \tag{3.2}$$

where $A(L)$ is a different matrix polynomial in L, and v_t are independently distributed structural shocks with $\mathrm{E}(\nu_t \nu_t') = I$. Equations 3.1 and 3.2 imply a mapping between the one step ahead forecast errors and the structural shocks:

$$\mu_t = A_0^{-1} \nu_t \tag{3.3}$$

which in turn yields a moving average representation of y_t as a function of current and past structural errors:

$$y_t = R(L)\nu_t \tag{3.4}$$

where $R(L) = B(L)^{-1} A_0^{-1}$. By including interest rate and money aggregate variables in the VAR, we can restrict the decomposition of $\hat{\sum}_{\mu}$ in such a way that equation 3.3 obtains a money demand and monetary policy shock associated with a money demand and monetary policy equation according to 3.2. The deterministic component of the policy equation in 3.2 in this way estimates systematic policy behavior while the policy shock captures a typical, idiosyncractic, exogenous change in policy. We can then simulate the responses of all the variables to an exogenous shift in the policy equation , $\nu_{MP} \in \nu_t$, using equation 3.4.

3.1. An Alternative Mode of Policy Identification

Estimation of the effects of monetary policy using conventional identified VAR methods is subject to the inherent weakness that it requires a minimum number of coefficient restrictions.[14] Because this minimum number is generally quite large for a reasonably sized system of equations, it is usually necessary to impose additional restrictions beyond the set that can be easily derived from economic theory. Specification of the policy equation itself, for example, typically incorporates such ad hoc restrictions since there is not yet a generally accepted theory on monetary policy behavior. While many sets of identifying restrictions obtain qualitatively robust predictions for the effect of monetary policy on macro variables, it is difficult to apply these methods to tests of the expectations theory because there remain significant quantitative differences between various specifications that obtain equivalent fits to the data.[15] Quantitative accuracy in the estimation of long and short rate dynamics is likely important to uncovering evidence on the expectations theory however. Reliance on a particular set of identifying restrictions could in this case lead to false negative conclusions about the conditional expectations theory.

Faust(1998) provides an alternative approach to policy identification which allows the researcher to learn what inferences are supported by the data without requiring prior assumptions about the behavioral relationships determining the observed series. Policy is instead identified through examination of the variable impulse responses for consistency with conventional monetary theory about the qualitative effects of monetary policy. This approach allows us to consider a broad subset of policy specifications with reasonable impulse responses across which we can perform a systematic search for evidence on the conditional expectations theory. Thus if support for the theory exists in the data, this approach is likely to find it. If we instead find only meager evidence for the theory, the comprehensive nature of our search will allow us to draw robust conclusions against the theory.

To understand how the Faust procedure works, it is useful to develop notation that allows us to describe the full set of possible specifications of the data. We begin with a generic moving average representation of an estimated VAR formed using a Cholesky decomposition of the one step ahead forecast errors, $\Sigma_\mu = HH'$:

[14] By symmetry of Σ_μ, the assumption that $\varepsilon_t \varepsilon_t' = I$ implies that there must be no more than $m(m-1)/2$ free parameters in A_0 such that

$$\sum \mu = A_0^{-1} A_0^{-1'}$$

[15] Again, see Leeper, Sims, and Zha(1996) and Christiano, Evans and Eichenbaum(1998) for a review of the literature.

$$y_t = B(L)^{-1}HH^{-1}\mu_t = C(L)\varepsilon_t \tag{3.5}$$

where $\mathrm{E}(\varepsilon_t\varepsilon_t') = I$, $B_0 = I$, $C(L) = B(L)^{-1}H$, and L is a polynomial lag operator. There exist many, observationally equivalent, behavioral interpretations of this reduced form which can be expressed as linear transformations of 3.5, each formed according to an orthonormal matrix D:

$$y_t = C(L)DD'\varepsilon_t \tag{3.6}$$

To see the dynamic response of all the variables in y_t to the jth shock we can read off the jth column of $C(L)D$ in 3.6 which can be written as $C(L)\alpha$, where α is the jth column of D. The jth shock is then $\alpha'\varepsilon_t \in D'\varepsilon_t$.[16]

Using this notation, monetary policy is in general identified when we can somehow rule out all but a single α, α^*,defining the policy shock $\alpha^{*\prime}\varepsilon_t$. In practice, many $\alpha's$ can often be eliminated by comparing their associated impulse response functions, $C(L)\alpha$, with our prior beliefs about how the variables in y_t respond to a policy shock. The set of prior information based on economic theory available for this purpose is generally insufficient for exact identification in this strict sense however. Researchers using conventional VAR identification methods proceed by, in effect, choosing a particular α from a subset of $\alpha's$ that obtain reasonable impulse responses based on a number of additional ad hoc restrictions. They then test the sensitivity of their results by performing the same analysis on a small set of alternative $\alpha's$ which also yield reasonable impulse responses.

The Faust procedure also seeks identification by limiting the space of possible $\alpha's$ to that in which variable responses to the shock $\alpha'\varepsilon_t$ are consistent with our priors about the effects of policy. In this case, however, our set of prior beliefs are more formally defined by imposing a set of linear shape and sign restrictions on the impulse response functions.

To illustrate, suppose we would like to restrict ourselves to the set of specifications which yield reasonable output, price, money, and interest rate responses to a contractionary monetary policy shock. For $C(L)$ obtained from a vector of data including (in order) output, Y, prices, P, an interest rate, R, and a money aggregate, M, we can describe the space of $\alpha's$ which yield negative initial Y, P, and M responses and a positive initial R response as that in which α satisfies the following set of linear restrictions:

[16] Note that the orthonormality of D implies $\mathrm{E}(D'\varepsilon_t\varepsilon_t'D) = I$.

$$C^R\alpha \geqq 0 \qquad ; C^R = \begin{bmatrix} -C_{y,0} \\ -C_{P,0} \\ -C_{M,0} \\ C_{R,0} \end{bmatrix} \tag{3.7}$$

where C^R contains elements of the generic MA parameter matrix, $C(L)$, with subscripts referring to the variable whose response is restricted in $C_0\alpha$. We could similarly restrict the space of specifications using linear restrictions across variables', or on the shapes of individual, impulse responses.

The Faust procedure differs most significantly from conventional identified VAR methods in how it proceeds toward identification within this space of reasonable impulse responses. Instead of choosing a particular α based on additional ad hoc, albeit necessary, identifying restrictions as conventional VAR methods do, the Faust procedure searches over the entire set of $\alpha's$ within the subspace defined by equation 3.7 to find the α that satisfies some criterion optimally.

In this way we can, for example, find the α that obtains impulse response functions that are consistent with a monetary policy shock and for which the long rate response is as closely predicted by the expectations theory as possible (in mean square error) by solving the following constrained minimization problem:

$$\begin{aligned} \min_\alpha \quad \alpha' M \alpha &= \alpha' \left[\frac{1}{h} \sum_{t=0}^{h-1} (\widehat{R_t^n} - \frac{1}{k} \sum_{j=0}^{k-1} \widehat{R_{t+j}^m})'(\widehat{R_t^n} - \frac{1}{k} \sum_{j=0}^{k-1} \widehat{R_{t+j}^m}) \right] \alpha \\ &= \frac{1}{h} \sum_{t=0}^{h-1} \left(\widehat{R_t^n}\alpha - \frac{1}{k} \sum_{j=0}^{k-1} \widehat{R_{t+j}^m}\alpha \right)^2 \end{aligned} \tag{3.8}$$

$$s.t. \qquad C^R\alpha \geq 0 \tag{3.9}$$

$$\alpha'\alpha = 1. \tag{3.10}$$

where $\widehat{R_t^n}$ is a row of C_t corresponding to R^n and h is a chosen mean horizon.[17] The matrix M in equation 3.8 contains elements that are quadratic in the elements of the generic form, $C(L)$, such

[17] The quadratic programming problem in equations 3.8 through 3.10 is solved by performing a series of minimum eigenvalue problems over the space defined by $C^R\alpha \geqq 0$. Because between zero and $n-1$ of the restrictions, where n is the number of linearly independent rows in C^R, can hold with equality at any one time, the procedure reduces to performing the minimization problem over each of the $\sum_{i=0}^{M} \frac{R!}{i!(R-i)!}$ policy subspaces,where M is the minimum of $n-1$ and R, the number of rows in C^R. After eliminating the cases that do not satisfy the remaining weak inequality restrictions, the result is a set of $\alpha's$ which satisfy both the monetary policy restrictions and the criterion function optimally within each policy subspace. The solution is then the α associated with the minimum eigenvalue in this set. For more information on the solution algorithm see the appendix in Faust (1998).

that $\alpha' M \alpha$ is the mean squared deviation in the term premium conditional on the shock $\alpha' \varepsilon_t$. The set of linear restrictions, $C^R \alpha \geq 0$, in equation 3.9 contain the sign and shape restrictions on the impulse response functions, $C(L)\alpha$, as already mentioned and the restriction that α has unit length maintains the normalization of error variance to unity.

The complete algorithm actually entails performing the optimization problem in 3.8 - 3.10 in a series of iterations to find a minimum set of restrictions sufficient to produce impulse responses consistent with our priors about the effects of a monetary policy shock.[18] By limiting the number of restrictions in $C^R \alpha \geqq 0$ to the set that is sufficient to obtain reasonable impulse responses, we obtain results that are consistent with a very broad class of policy specifications. By searching over the entire set of $\alpha' s$ within this class to find the closest fit with the expectations theory we can be reasonably certain that we will find evidence affirming the theory, if it exists. On the other hand, if it turns out that the resulting minimum mean squared premium deviations are none-the-less substantial, we will have robust evidence to the contrary based on a thorough search of alternative specifications.[19] Lastly, it bears repeating that, short of a widely accepted theory of Federal Reserve behavior, the policy specifications obtained with the Faust approach are as reasonable as those found in the standard VAR literature since the latter have been shown to robustly predict only the qualitative effects of policy.

3.2. Coverage Intervals

It will also be useful to generate coverage intervals that account for parameter uncertainty. We use Bayesian methods to obtain a sequence of 500 draws from the posterior of the reduced form VAR parameters in 3.1, formed with a flat prior. For each draw, we perform a Cholesky decomposition of the variance covariance matrix of one step ahead forecast errors and form the generic moving average representation, $C(L)\varepsilon_t$.[20] We then perform the minimization problem described in equations 3.8 to 3.10 using each of these generic moving average representations.

The intervals generated in this way require careful interpretation. Whereas conventional methods typically yield intervals for a single fully identified system, the intervals obtained using the

[18] Specifically, the process begins by defining $C^R \alpha$ with a small (or zero) number of restrictions, performing the optimization problem and then examining the impulse response functions for consistency with our priors. If the resulting impulse responses are in some way inconsistent with our prior beliefs about policy,(if prices increase following a contractionary shock for example) , then additional restrictions are added to $C^R \alpha$ to exclude such cases from the domain of the search , and the process is repeated until the resulting impulse responses are fully consistent with our priors about the effects of policy and the qualitative findings in the literature.

[19] In section 4.3 below we conduct a rough analysis of the procedure's power to reject the theory when false.

[20] The procedure for generating draws of the generic MA process is analogous to the RATS procedure generating error bands in just identified models.

Faust procedure are for the minimum premium deviations conditional on a policy shock within subset of underidentified models. In this case the intervals represent a *lower bound* for the mean squared premium deviation across *all specifications* satisfying $C^R\alpha \geqq 0$. As such, these intervals represent the range of the best cases in favor of the expectations theory conditional on a policy shock, rather than of possible outcomes for a particular fully specified model.

If this interval of minimum premium deviation cases contains only relatively high values this will lead us to question the robustness of a conclusion in favor of the theory based on point estimates. In this case we would expect that a random draw from the posterior of reduced form parameters could easily lead to higher minimum mean squared premium deviation than that based on the point estimates.

In calculating the posterior distributions, it will also be possible to calculate the ratio of the number of times that the Faust procedure performed an each draw of $C(L)$ yields an α satisfying the policy restrictions relative to the number of times it does not. This posterior odds ratio is a measure of how favorable the data are toward the restrictions in $C^R\alpha$.

3.3. The Empirical Model

We first model the monetary economy with the following seven variable system: monthly interpolated real GDP (Y)[21], consumer prices (P), commodity prices (CP), total reserves (TR)[22], the federal funds rate(RF) which is used for the short rate, R^m, M2 (M2), and a long-term interest rate - alternatively represented by annualized rates on zero coupon bonds with maturities of 2, 3, 4, 6, 9, 12, 24, 36 months for the long rate, R^n. The data are in monthly frequencies taken from 1959:1 to 1995:12 with the non-interest rate series in logs.[23] The long rate data up to 1991:2 is taken from the McCulloch and Kwon data set and remainder from Bliss(1996) data set.[24]. The long

[21] By using interpolated GDP we are inadvertently including some information about future GDP in the output series. While monthly industrial production data provides an alternative to this problem, we preferred to use the former as more complete measure of aggregate output.

[22] Some authors prefer to use non-borrowed reserves to identify policy. Our choice of total reserves is based on the belief that non-zero excess reserve holdings imply a reserve demand curve which is elastic with respect to the borrowing rate at a monthly frequency. Under these conditions, banks borrow from the discount window up to the point where the spread between the funds rate and the discount rate is equal to the non-precuniary costs of borrowing from the Fed. This arbitrage conditional makes non-borrowed reserves and borrowed reserves perfect substitutes, and therefore the composition of total reserves less informative about policy than the aggregate level.

[23] All data other than the data on long term interest rates was generously provided by Leeper and Zha(2000) who performed the monthly interpolation of GDP.

[24] The long rate data from both sets was generously provided by Charles Evans from Evans and Marshall(1998). In that paper they perform diagnostics to determine that the data split is insignificant. The McColloch and Kwon data can be downloaded from the world wide web at http://www.econ.ohio-state.edu/mccull.html. with documentation found in " U.S. Term Structure Data, 1947-1992," Ohio State University Working Paper #93-6.

rates are pure discount (zero coupon) bond yields for U.S. government securities that are adjusted for tax distortions and are continuously compounded.[25] The federal funds rate is continuously compounded and converted to a 365 day basis as described in Cook and Hahn (1991).[26] In this initial model the VAR's are estimated with two lags, in other models described later in the paper we increase the lag length to six..[27]

The set of restrictions, $C^R\alpha$, is chosen to yield impulse responses that are qualitatively consistent with those found in the identified VAR literature on monetary policy as well as conventional monetary theory about the macroeconomic effects of monetary policy. We require that the federal funds rate respond positively, and total reserves negatively, on impact to an unexpected contractionary shift in monetary policy. While debate exists about the degree of price and output inertia with respect to policy shocks, we require that these variables be unresponsive within the month of the shock's impact in order to be consistent with the greater part of the literature. We also restrict commodity prices and M2 to respond non-positively on impact of the policy shock.

Simulations based on this set of restrictions alone often obtained shocks that were incongruent with our priors about the effects of policy. In particular, we often obtained impulse responses in which output quickly increased and remained everywhere above its initial level and in which prices rose significantly through the first year in response to the supposed contractionary policy shock. To eliminate these cases from consideration we require that output be below its initial level at the sixtieth month following the shock and that the price response to be no greater than -.025 times the commodity price response in the second month. In order to obtain shocks that are quantitatively important it is also necessary to include restrictions that eliminate cases in which the shock accounts for only a small share of the funds rate forecast error variance.[28] Toward this end, we require that total reserve response in the tenth month following the shock exceed (be more negative than) a multiple of the response of M2 in the sixth month.[29] In one case, when $R^n = 9mo$, we also include

[25] A discussion of the need for continuous compounding and tax adjustment is found in the *Handbook of Monetary Economics*, 1990, Chapter 13. The Fama data was not tax adjusted. Marshall and Evans explain that tax adjustment was not an issue during the period sampled.

[26] See data appendix for more details on specific series used.

[27] Model tests for lags lengths based on the Akaike Information Criterion(AIC) and Schwarz Criterion(SC) consistently chose a lag length of two for all interest rate combinations. As one example, the values for AIC and SC in the case when $R^n = 3mo$ are given in Table 1 of the appendix.

[28] Although the above restrictions resulted in cases that were qualitatively reasonable, they all exhibited very small values (less than 2%) for the variance share of the funds rate due to policy. We performed Faust's procedure maximizing the variance share for the funds rate and compared the cases obtained to those from the minimum premium deviation cases. Observing that the primary difference was a delayed response in M2 in the former, we include a restriction on the initial M2 response to limit our search to cases with reasonable forecast error variance share for the funds rate.

[29] Because we found that the same restriction did not obtain a solution for all combinations of interest rate we used

the restriction that the initial total reserve response be greater (more negative) than four times the output response one year after the shock to avoid the case when total reserves do not respond on impact of the shock.

It is important to note that while these latter restrictions seem arbitrary in terms of magnitude and timing, subtle reasoning prevents the desirability of their exclusion. As described in the previous section, the process of policy identification proceeds interactively with the goal of finding a set of restrictions sufficient to obtain impulse response functions that are consistent with our priors about policy. Having achieved this, *relaxation of any of the non-necessary restrictions in* $C^R\alpha$ *can only improve the value of the objective function and thus obtain an even closer fit to the expectations theory conditional on monetary policy.* Although our results are achieved with a particular set of identifying restrictions, our conclusions are only sensitive to the accuracy of our prior beliefs about the effects of policy at which the restrictions aim.[30]

4. Results

Figure 4.1 below presents the variable and term premium impulse responses for the minimum mean squared premium deviation case that satisfies this set of policy identification restrictions when the long rate was equal to the three month rate. A similar graph with $R^n = 9$ is provided in the appendix (Figure 1, solid line). Both of these figures demonstrate that the procedure indeed resulted in reasonable representations of policy.

different factors, 6.67 and 10 across the simulations with different long rates as listed in Table 3 in the appendix.

[30] Put another way, there is not a one-to one relationship between $C^R\alpha$ and our set of priors. While the former are sufficient to obtain reasonable impulse responses, our conclusions with respect to policy only require that the latter be satisfied.

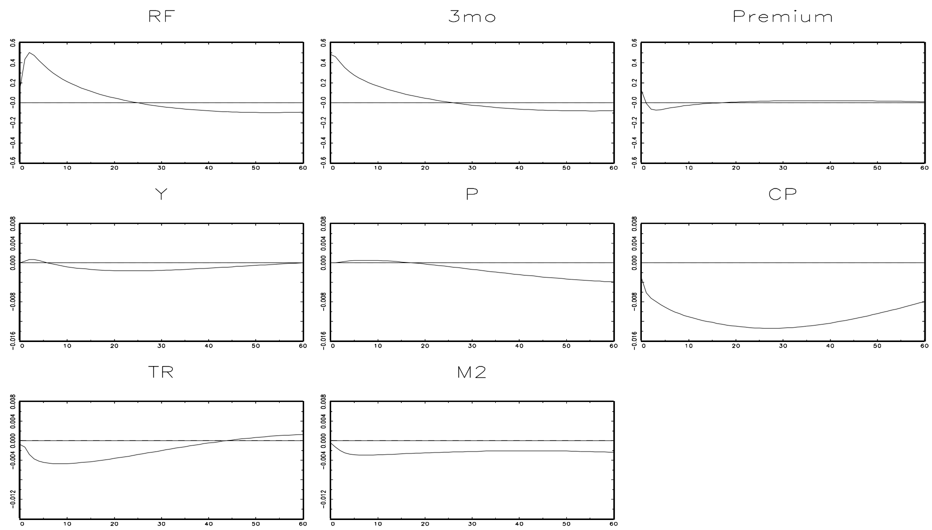

Figure 4.1: Impulse Responses to a Contractionary Policy Shock: percents or Δlog levels;
$y_t = (Y_t, P_t, PC_t, TR_t, Rf_t, M2_t, R_t^3)$;

Focusing on Figure 4.1, we see that the contractionary policy shock leads to a fifteen basis point increase in the funds rate (upper left) and small initial decrease (.07%) in total reserves (lower left). Following the initial shock, the funds rate increases for two more months to a maximum of fifty basis points, then falls slowly back to its initial level by the twenty-fourth month and continues below its initial level through the sixtieth month, reflecting the influence of fisher effects. Total reserves decrease further through the ninth month following the initial shock and then increase slowly back to their initial level by the forty-fourth month. Figure 4.1 also shows reasonable private market variable responses. Output and prices respond at a lag to the shock (as restricted), with output decreasing through the second year after an initial slight increase, then returning to its initial level in the case of output, and prices fall continuously through the sixtieth month after a similarly small initial increase.[31] Commodity prices also fall on impact of the shock, decrease further through the second year and then return slowly back to their initial level. M2 responds to the shock by falling initially with total reserves, decreasing further through the ninth month and then remaining below its initial level only increasing slightly through the sixtieth month.

Table 2 presents the shares of selected variable forecast error variances attributable to the identified shock in each of the R^n cases at the third and forty eighth month horizons. In the cases when $R^n < 12mo$, these numbers indicate that the shocks identified are reasonable in terms of

[31] These small initial increases in output and prices (the price puzzle) appear in other identifications of policy as documented by Leeper, Sims and Zha(1996) and Christiano, Eichenbaum, and Evans(1998). The anomalies are here are much less severe than usual and are likely statistically insignificant.

the magnitude of their impact on interest rates and output. The shares for RF and R^n at the 48th month horizon in these cases are between twenty and thirty percent and reflect a common finding in the literature that endogenous policy is more important than exogenous policy in the determination of the funds rate. The output shares for these cases are between six and ten percent, which is again consistent with (although somewhat smaller than) much of the literature that finds only modest real effects of policy.[32] Although Table 2 shows the variance shares for RF and Y in the cases with $R^n \geqq 12mo$ to be somewhat smaller, we will explain below that other reasons may justify our focus on the cases with $R^n < 12mo$.

4.1. The Conditional Expectations Theory

To determine how closely the long rate responses agree with the predictions of the expectations theory, we can first examine the term premium responses to the policy shock that appear in Figures 4.1 and Figure 1 in the appendix. We calculated the term premia responses in these graphs by taking the difference between the long rate response at each period and the average of the short rate responses at that and the next k periods following the initial shock. Figure 4.1 above and Figure 1 in the appendix show that the premium responses are indeed negligible when $R^n < 12mo$. In all of these cases the premium exhibits only a small amount of variation initially and then exhibits virtually no response through the fifth year following the shock. Perhaps more important, the magnitude of the conditional variation in the premia in these graphs appears to be insignificant relative to that of the long rate.

Table 3 presents statistics that more precisely measure the magnitude of the premium deviations in the optimal cases for all of long rate series, R^n, examined. The second column in Table 3 lists the restrictions for each case listed in column one. The third and fourth columns list point estimates for the minimum root mean squared premium deviations (RMPD) and for the total squared premium deviation relative to that for the long rate (in percentage terms conditional on the policy shock) - both calculated at the 48th month horizon - for each interest rate combination. While the former statistic describes a type of average deviation in the premium, the latter helps us understand how much of the variation in the long rate following the policy shock is attributable to deviations in the premium or alternatively how much of the complementary variation is attributable to arbitrage activity consistent with the expectations theory. Focusing on the cases where $R^n < 12mo$, we see that the average deviation in the premiums for these cases are all below four basis points and that

[32] Faust 1998 performs robustness tests on this apparent consistency in the identified VAR literature and finds that identifications exist in which policy explains a majority share of the variance of output.

the variation in the premium accounts for more than 5% of the variation in the long rate in only one case (it accounts for 6.1% when $R^n = 2mo.$). According to both measures the closest fit to the expectations theory occurs when $R^n = 6mo$, in which case the RMPD is only 2.1 basis points and the premium variation is only 1.8% of that of the long rate.

This evidence in support of the expectations theory is further demonstrated in the results in Table 4 which shows coverage intervals for the minimum RMPD and relative premia variances for the optimal cases for each long rate considered. These results show that for those interest rate combinations with $R^n < 12mo$, 75% of the alternative parameterizations yield RMPD's of less than 4 basis points with roughly 8% or less of the variation of the long rate explained by the premium variation.[33] Although the coverage interval for the relative premium variation when $R^n = 2mo$ is somewhat larger, it still holds that reasonable specifications can be found in which this statistic is less 5.5% for 50% of the possible parameterizations and in continues to hold that the 75% of these parameterizations yield RMPD of less than 4 basis points. These intervals thus demonstrate that the low point estimates in Table 3 are not unduly optimistic.

What about when $R^n \geqq 12mo$? Tables 3 and 4 show that the premium deviations are larger in these cases with RMPD now between five and ten basis points and over 10%, and as much as 70%, of the conditional variation in the long rate attributable to premium variation. Although further simulations, based on some alternative combination of policy restrictions, could potentially uncover specifications with smaller premium deviations for these cases, we decided it made more sense to take an alternative approach.

While many papers have demonstrated the usefulness of the funds rate to identify liquidity effects in the data, it is probably unrealistic to measure evidence for the expectations theory by comparing an overnight rate with the rate on a much longer term instrument. Another difficulty is the well known result that our ability to precisely estimate the responses of any variable to a shock decreases with the forecast horizon. Thus the greater the difference in maturity between the short and long rates examined, the greater the potential for in both statistics because the average of the expected future short rate must be calculated over a longer horizon. Either of these reasons may explain why much of the literature that focuses on the interaction between policy and the expectations theory constrains itself to the short end of the term structure.[34]

[33] Since the RMPD and premium variance are always positive, fit with respect to the theory should be evaluated on the basis of the intervals' proximity to zero rather than whether they contain zero. Note that it would not be helpful to construct intervals for the actual path of the premium because positive/negative values could result from differences in the non-policy aspects of specification across draws and not only from parameter uncertainty/sampling error as is usually the case when the model is fully identified.

[34] E.g. Roberds, Runkle and Whiteman(1996) do not use a long rate greater than 3 months, Mankiw and

With these considerations in mind, we consider several further sets of simulations that compare the various long rate responses to that of the one month rate instead of the funds rate. The first set of these are based on a monetary system constructed from the following vector of time series: $y_t = (Y_t, P_t, PC_t, M2_t, R_t^1, R_t^n)$. The identifying restrictions, $C^R\alpha \geqq 0$, for the simulations based on this system are: that the initial one month rate is positive; the initial M2 response negative; that prices and output do not respond on impact of the shock; and that commodity prices respond non-positively on impact of the shock. These restrictions were sufficient to obtain impulse responses that were consistent with our prior beliefs about the effects of a contractionary policy shock. Figure 2 shows the impulse responses to a policy shock when $\mathrm{R}^n = 60mo$, and Tables 5 and 6 the corresponding statistics and coverage intervals for the minimum RMPD cases for each interest rate combination with the short rate always equal to the one month rate.[35] The results in these cases are remarkable: the RMPD are now at or below one basis point; and the paths for the premia responses all show negligible deviation even when the long rate maturity is as long as ten years.

These latter results support the validity of our hypotheses about the potential difficulties involved in testing the expectations theory using the funds rate with relatively long, long-term interest rates, but they might raise concern about the appropriateness of identifying policy with a short interest rate that is not tightly controlled by policy. While it is not uncommon to find policy identifications in the literature that use longer terms rates to identify policy, much of the variation in longer term rates is due to private market behavior not controlled by the Fed which may lead to the association of spurious variation with the effects of a policy shock.

To account for this possibility, we conducted another set of simulations which again identify policy in the reserves market but also include the one month rate against whose path we can compare the paths of various long rates. The complete vector of variables in these cases was: $y_t = (Y_t, P_t, PC_t, TR_t, RF_t, M2_t, R_t^1, R_t^n)$. The identifying restrictions for these monetary systems are similar to those enumerated above and are listed below Table 7.[36] As an additional robustness

Miron(1986) look at the three month and sixth month spread, Rudebusch only looks at the spread between one and two period rates, Marshall and Evans(1998) , look only at long rates with a maturity of three years or less.

[35] Forecast error variance shares for the optimal cases based on this and all following model specifications are not included for space reasons but are available upon request.

[36] Specifically, we continued to require that the initial RF response be positive,that the initial M2, TR, and PC responses be weakly negative, and that prices and output not respond within the month of the shock. As was the case above, additional restrictions were needed to obtain impulse responses that were consistent with our prior beliefs about the effects of a contractionary policy shock. We found that the following additional constraints were sufficient in this regard: that the initial TR response have greater (negative) magnitude that the output response in the second month after the shock (to obtain a liquidity effect); that the TR response at six months after the shock was greater than the opposite of the initial M2 response (to obtain reasonable variance shares for the funds rate); that the funds

check we also increase the number of lags in the VAR to six. Figure 3 shows the impulse responses to a policy shock when $\mathrm{R}^n = 60mo.$,and Tables 7 and 8 the corresponding statistics and coverage intervals for the minimum RMPD cases for each interest rate combination under this policy modeling strategy. The results in these cases are again remarkable: the RMPD are now at or below three basis points; and the paths for the premia responses all show negligible deviation even when the long rate maturity is as long as five years.

While we believe that Figures 4.1 and 1 to 3 present a convincing argument in support of the conditional expectations theory based on impulse responses functions, we can also ask whether the policy equations implied by the optimal $\alpha's$ are consistent with that behavioral interpretation. Although researchers disagree on the relevance of interpreting particular AR parameter estimates in these set-ups, because our examination of the implied policy equations in the models presented so far did not, in general, hold up to this type of scrutiny, we decided to run a further set of simulations which included beliefs about the relative signs of the contemporaneous policy parameters in our prior. Because we also wanted to check that the above results are not affected by the exclusion of potentially superfluous variables such as commodity prices and the second money aggregate we based this last set of simulations on a smaller system of variables with $y_t = (Y_t, P_t, M2_t, RF_t, R_t^1, R_t^n)$.

Our methodology was to find a set of sign and shape restrictions on the variable impulse responses that was sufficient to obtain reasonable equilibrium paths for the variables following the shock, as well coefficients for M2, Y, and P that were opposite in sign to the coefficient for RF in the policy equation implied by each optimal α :

$$\alpha' H^{-1} y_t = \alpha' \varepsilon_t \tag{4.1}$$

such that the implied policy equations took the form:

$$RF = f(\overset{+}{M}2, \overset{+}{Y}, \overset{+}{P}, 1mo) + \alpha' \varepsilon_t \tag{4.2}$$

where the sign on the one month rate was not part of our prior. We again estimated the system with six lags. The set of identifying restrictions sufficient to obtain optimal cases satisfying this set of priors for the simulations with this smaller data set is listed below Table 11. Figure 4 shows the impulse responses to a policy shock when $\mathrm{R}^n = 60mo$, and Tables 9 and 10 the corresponding

rate was still positive two months after the shock (to obtain persistence in the liquidity effect); and that the initial one month rate response be within 25 basis points of the average actual funds rate response for the preceding month (such that the response in the premium between the one month rate and the funds rate is no more than 25 basis points in magnitude). This last restriction was necessary due to the difficulty in identifying monetary policy in systems with multiple interest rates (see Leeper, Sims, Zha(1996) for discussion).

statistics and coverage intervals for the minimum RMPD cases, and Table 11 the contemporaneous policy parameters for each interest rate combination under this policy modeling strategy. The long rate responses under this identification strategy again show remarkable consistency with the expectations theory. In this case the RMPD's are always below two basis points and account for, at most, 4%, and most often less than 2%, of the variation in long rates conditional on the policy disturbance.

4.2. Does Simultaneity Matter?

Because our identifying restrictions do not limit the nature of the simultaneity between policy and the bond market — policy is always specified to respond contemporaneously to long rates and bond markets to policy — the variable responses in the figures presented here are indeed representative of the effects of policy rather than of policy responses to the bond market.

As a rough measure of the importance of simultaneity for our results, Figures 1 to 4 include the impulse responses to the funds rate shock from recursive identifications using a Cholesky ordering which allows bond market responses to the funds rate but not the reverse.[37] The exact ordering for each set of simulations and the respective results with respect to the expectations theory are presented in the fifth and sixth columns of Tables 3, 5, 7 and 9. It is noteworthy that for the cases of interest (when $R^n < 9mo$ when $\mathrm{R}^m = RF$, and all cases when $\mathrm{R}^m = 1mo$), the premia deviations are virtually everywhere smaller in the minimum RMPD cases (with simultaneity) than in the corresponding recursive cases both in terms of RMPD's and relative premium variances.[38]

A comparison of our results with those from a fully recursive specification can not accurately measure the marginal impact of our allowance for interactions between policy and the bond market however. Whereas the Faust procedure estimates policy behavior in response to all the variables in the system —meaning there are potentially multiple degrees of simultaneity through which our results are effected— a fully recursive system does not allow for simultaneity between any pair of variables. Further, because the Faust algorithm obtains under-identified systems (it obtains estimates for the policy equation only), we can not use it to isolate the effect of any particular channel of simultaneity by comparing results based on the marginal inclusion of a restriction on the contemporaneous correlation between variables.[39]

[37] This ordering is motivated by Evans and Marshall(1998) and Edelberg and Marshall(1996) who assume long rates respond to policy but not vice versa. Our ordering differs from these by also always allowing the short rate to respond to a money aggregate (TR or M2).

[38] The single exception is RV when $R^n = 2mo$ in Table 9.

[39] In this case underidentification implies that two systems estimated conditional on the marginal exclusion/inclusion of policy's response to the bond market also potentially incorporate the effects of other differences in the systems'

To get a better sense of the importance of bond market/policy simultaneity in obtaining our results, we conduct a series of experiments in a conventional, fully identified framework. By moving to a fully identified framework we are able to vary the degree of simultaneity between policy and the bond market on the margin and trace out the effects for model fit with the expectations theory conditional on exogenous monetary policy. Specifically, we first estimate a benchmark Bayesian structural VAR[40] that restricts policy from responding to long-term interest rates but allows long rates responses to policy. We then re-estimate the system including a non-zero prior variance and zero prior mean for the parameter that measures policy's response to long rates. By comparing the long rate responses to a policy shock in these specifications to the predictions of the expectations theory, we can learn whether allowance for simultaneity between policy and the bond market contributes to our success in uncovering evidence for the theory.

The complete benchmark specification is described in detail in Table 12. All of the specifications are based on the system $y_t = (Y_t, P_t, M2_t, RF_t, R_t^1, R_t^n)$. Table 13 shows the parameter estimates for the benchmark specification, and Figure 5 shows the variable responses to the policy shock in the benchmark model when $\mathrm{R}^n = 36mo$. All of the specifications estimated obtained qualitatively reasonable predictions for the effects of the policy shock in line with the results obtained using the Faust procedure. Model diagnostic tests[41] including tests of the over-identifying restrictions where appropriate (in the benchmark model) and evaluation of the orthogonality assumption based on the covariance matrix of the implied structural shocks did not reject any specification estimated.[42]

Table 14 compares the RMPD and relative premium variance statistics for the benchmark specification with those obtained when the prior variance on the long rate parameter in the policy equation is restricted to be a factor, μ_{R_L}, (respectively 5% and 25%) of the prior variances of the other contemporaneous parameters in the system. These asymmetric prior variance restrictions expand/contract the prior distribution for the policy parameter on the long rate around a zero prior mean and are thus referred to as "soft zero" restrictions.[43] When $\mu_{R_L} > 0$, we should expect to obtain non-zero estimates for this parameter if policy responses to the bond market are supported by the data. Then under the hypothesis that recognition of the simultaneity between policy and

structural specifications on the path of long rates. The specification of money demand, for example, is not pinned down using Faust's method and therefore likely to vary between specifications.

[40] See appendix for detailed information on the Bayesian estimation methods used.

[41] These test results are not included here due to space limitations but are available upon request.

[42] This outcome of multiple non-rejections reflects the generic underidentification of policy in the SVAR literature. Again, this underidentification motivated the approach to policy specification based on the Faust procedure in this paper.

[43] Compared to the hard zero restriction in the benchmark specification which imposes a zero prior mean and variance. See Leeper, Sims, Zha(1996) for other examples of BVAR's estimated with soft zero restrictions.

bond markets is important to uncovering evidence for the expectations theory, these non-zero estimates should in turn be associated with smaller estimated premium deviations conditional on a policy shock.

From Table 14 we see that larger μ_{R_L} are consistently associated with lower premium deviations following a policy shock. The greatest improvement in fit with the expectations theory occurs when $\mathrm{R}^n = 120mo$, with the RMPD falling from 1.78 basis point in the benchmark specification to less than one half of one basis point when $\mu_{R_L} = 0.25$, with the relative variance in the premium falling over 80% from 32.54% to 5.61%. Improvement in terms of the RMPD is most statistically significant when the long rate under consideration is considerably long —the RMPD with $\mu_{R_L} = 0.25$ falls outside the benchmark 68% interval when $\mathrm{R}^n > 12mo.$ and outside the 90% interval when $\mathrm{R}^n > 36mo.$[44] This is consistent with the hypothesis that policy responds to the bond market as a source of information about future states of the economy since longer long rates should contain more information in this regard.[45] We believe that these combined results confirm our hypothesis that interactions between policy and the bond market play a role in past failures of the expectations theory in U.S. data as suggested by McCallum(1994), and thus that our recognition of this source of simultaneity played a role in uncovering evidence for the theory in the results presented above.

4.3. Measuring Power

The primary methods employed in this paper look for the best case in favor of the expectations theory conditional on a monetary policy shock by searching for a reasonable specification of policy with the smallest mean squared premium deviation following a policy shock. We argued above that this approach is unbiased because it does not preclude large premium deviations in the minimum cases. Yet it is reasonable to ask whether such an outcome is at all likely in the event that the expectations theory does not hold conditional on a policy shock. As a rough measure of power, several individuals suggested we perform a similar search for evidence of the theory conditional on a non-policy shock. The failure of the unconditional form of the theory implies that we should expect it to fail conditional on at least one type of shock.

[44] The probability intervals reported in Table 14 are from simulated posterior distributions constructed according to methods outlined in Sims and Zha (1998b, 1999).

[45] While the Relative Variance values when $\mu_{R^n} > 0$ do not fall outside the 68% or 95% intervals from the benchmark specification, examination of these posteriors distributions shows them to have relatively fat tails. This may be the result of two factors. First, the posterior spread for both RMPD and Rel Var. increase with n because they are based on impulse responses whose estimation precision decreases with the forecast horizon such that premiums involving longer long rates are also less precisely estimated. Secondly, we might expect greater spread in the Rel. Var. posterior at all long rate maturities since it involves a ratio of variances making very small and very large values more probable - they can now result from either relatively small (large) numerators or relatively large (small) denominators.

To this end we performed the same techniques minimizing the mean squared premium deviations subject to restrictions sufficient to obtain impulse responses consistent with a money demand shock interpretation. In this case the impulse responses were judged reasonable when we observed increases in the money stock and short interest rates, and decreases in prices and output, in response to the demand shock.[46] We did not form any priors or place any restrictions on the behavior of the one month or longer term interest rates. The set of sufficient restrictions in each case are noted at the bottom of Table 15. Table 15 also reports the RMPD and relative variance statistics for the minimum cases obtained for each simulation. Both statistics compare the paths for the long rates listed in column one against their predicted path under the theory with $R^m = 1mo$.

From Table 15 we see that the absolute size of the premium deviations following a demand shock are comparable to those conditional on a policy shock. Relative to the variation in the long rate, however, the premium deviations in response to a demand shock are in general noticeably larger. When the long rate maturity is greater than 6 months, the variance in the premium relative to the long rate is greater than 15%, and as much 46%. These preliminary findings suggest that the expectations theory fails conditional on a money demand shock. More important for the present analysis, the results in Table 15 demonstrate that the search algorithm used in this paper is capable of rejecting the theory when such an outcome is not supported by the data.

4.4. Sensitivity to Subsampling

The fact that our results obtain with estimates from an unbroken data set indicates that non-linearities associated with policy regime changes are not independently relevant to the success or failure of the expectations theory. Some readers may none-the-less find a similar analysis based on a broken data set interesting. We performed the search analysis selectively on data sub-samples from pre-1979 and post-1982 corresponding to those used in Bernanke and Mihov(1998). Table 16 reports results from the minimum RMPD cases for each subsample when $R^n = 3, 6$ and 9 months ($R^m = RF$) and Figures 6 and 7 show the impulse responses for the respective subsamples when $R^n = 6mo$ ($R^m = RF$). From these we see that although the shocks identified in each sub-period yield weaker price, and respectively weaker and stronger output responses relative to those estimated from the full sample,[47] our conclusions about the expectations theory conditional on monetary policy are maintained. In particular, the RMPD in every case is below one basis point

[46] Gali(1992) estimates impulse responses to a money demand shock with the same signs. In that paper, and in our prior, the Fed is assumed to partially accommodate money demand shocks.

[47] The fact that the output and price responses vary in the subsamples should not be taken to mean that there is parameter instability because the systems are underidentified.

and the variance in the term premium accounts for less than five percent of the variation in the long rate in all cases except when $R^n = 9mo$ in which case it accounts for nine percent or less.

5. Conclusions

The results in this paper demonstrate the existence of *structural,* data consistent, models of U.S. economy in which long rate responses to an exogenous change in policy are closely predicted by the expectations theory. This finding is especially relevant to policy makers in that it provides support for a term structure channel of monetary policy. Further, our minimally restrictive approach to the empirical identification of monetary policy, ensures that this evidence is consistent with a broad class of policy specifications found in the current literature.

While our results support a term structure channel for monetary policy, they are inconclusive about the importance of this channel for the determination of either aggregate output or prices. Evidence from the impulse responses and the variance decompositions is decidedly mixed with the output and price effects varying from negligible (with only 5% of the variance in output, and less than 1% of the variance in prices, explained by the policy shock at the forty-eighth month horizon) to more substantial (with almost 40% and 30% respectively explained by policy). This ambiguity with respect to the price and output effects of monetary policy is directly related to the underidentified state of the systems estimated using the Faust procedure, but it also reflects the uncertainty about the quantitative effects of monetary policy current in the literature. Viewed in this light, tighter results on the strength of the output and price responses to policy obtained through additional identifying restrictions, would appear more definitive but, in fact, be no more robust than those we present here.

The good news on the existence of a term structure policy channel is tempered by our consistent finding that this channel never accounted for a majority —and in all simulations for roughly less than 30% — of the variation in long rates. This finding in combination with the unconditional failure of the theory implies a danger to policy makers in interpreting a given (unconditional) increase in long rates as necessarily reflecting market expectations of future rates, and thus of policy or inflation expectations. Although our findings indicate that policy makers can feel more confident in predicting the effect of their interventions on long rates, the expectations theory continues to be an empirically unjustified tool for predicting the non-policy related, majority portion of the variation in long rates.

Perhaps the most important contribution of this paper is that we are able to find evidence for the expectations theory by breaking down the correlation between long and short rates into policy and non-policy related components. In our view, this division and our accompanying success have important implications for the interpretation of previous work in this area. Most importantly, this approach required that we disentangle policy responses to the bond market from bond market responses to policy, whereas much of the previous work in this area is based on single equation regressions or overly restrictive VAR's that do not fully account for simultaneities in the determination of long and short interest rates. Our analysis of the marginal effect of our allowance for such simultaneity demonstrated that these considerations were indeed relevant to uncovering evidence for the theory. Our combined results thus imply that many of the past recorded failures of the theory may be due to inappropriate econometrics.

In contrast, several authors, including Mankiw and Miron(1986), Hamilton(1988), as well as the previously noted body of literature derived from these seminal papers, have suggested that previous failures of the theory are due to Federal Reserve behavior. They claim that short rate smoothing by the Fed or policy regime changes explain the recorded failures of the theory as a predictor for unconditional interest rate variation. These claims are inconsistent with the findings in this paper. Our results are derived from a non-parsimonious estimation of historical Fed behavior and yet find evidence of significant arbitrage activity consistent with the expectations theory following a policy shock. Similarly, if policy regime changes could alone explain the failure of the theory, then we should not be able to uncover evidence for the theory conditional on any type of shock based on a linear model estimated from an unbroken data set.

More constructively, our results suggest a new direction for research on the expectations theory. In finding that the theory seems to hold conditional on exogenous monetary policy, our results imply that the failure of the unconditional theory derives from a non-policy, and likely exogenous, source. Although more extensive analysis is warranted, our preliminary results on the theory conditional on money demand shocks suggest that these shocks are a potential source of the theory's unconditional failure. Whatever the non-policy source, it is likely exogenous because the interest rate paths estimated in this paper incorporate both endogenous policy and private behavior and yet support the theory conditional on a policy shock[48]. All speculation aside however, the results in this paper suggest that future research into the causes of the unconditional failure would benefit from a structural approach to the data.

[48] This presumes –as do VAR's in general– that endogenous behavior is stable in response to other shocks.

6. Data Appendix

1. (Y): log of real GDP, seasonally adjusted, billions of chain 1992 dollars. Source: BEA. Monthly real GDP is interpolated by Leeper, Sims, Zha (1996)

2. (P) : log of CPI, consumer price index for urban consumers, seasonally adjusted. Source: Bureau of Economic Analysis, the Department of Commerce. (BEA)

3. (CP): log of Commodity prices, International Monetary Fund's index of world commodity prices. Source: International Financial Statistics

4. (TR) : log of total reserves stock, break adjusted, seasonally adjusted. Source: Board of Governors of the Federal Reserve System (BOG)

5. (RF) Federal funds effective rate, monthly average. Source: BOG Continuously compounded and converted to 365 day basis.

6. ($M2$) : log of M2 money stock, seasonally adjusted, billions of dollars. Source: BOG

7. (R^n) : Long-Term Interest Rates, zero coupon bond yields, continuously compounded. 1959:1-1991:2 data are from the McColluch and Kwon data set that are also tax adjusted, 1992:2-1995:12 are from Bliss (1994) and are not tax adjusted. Evans and Marshall(1998) check the overlap in the data sets and find the difference in tax treatment in the two sets to be negligible.

7. Bayesian Estimation

The VAR's in this paper are estimated using methods outlined in Sims and Zha(1998b). As discussed in that paper, the joint normal prior for the parameters of each model is constructed, for computational reasons, from a marginal distribution for A_0 and a conditional distribution for $A_s|A_0, s > 0$. The marginal distribution for A_0 is initially specified with a diagonal covariance matrix on the non-zero elements of A_0. The conditional prior mean for $A_1|A_0$ is A_0 itself while the conditional prior means for $A_s|A_0, s > 0$, are zero reflecting an assumption that the reduced form models for individual variables are random walks. The prior standard deviations for the elements of A_s are assumed to shrink with s and the elements of A_s are also initially taken to be uncorrelated. As in Sims and Zha(1998b) I then add dummy observations to the estimation in order to allow for correlation across the elements of A in the prior. The dummy observations reflect the expectation that no-change forecasts of the model's variables are likely to be good and was helpful in correcting for the otherwise common occurrence in these models that the deterministic components of the estimated system explain an implausibly large amount of the historical variation in the data. The posterior distributions estimated based on this prior were then simulated using the Gibbs sampling method for structural VARs developed in Waggoner and Zha(2000).

As noted in the text of this paper, the alternative policy specifications often took the form of asymmetric assumptions on the prior variances for individual elements of A_0 which appeared in the policy equation. This was accomplished by multiplying the prior variance of the variable of interest by an additional parameter,$\mu \in [0, 1]$ which reflected an assumption about its value relative to the other contemporaneous parameters.

Table 1: Determining Lag Length when $R^n = 3mo$
Monetary System: $y_t = \left(Y_t, P_t, PC_t, TR_t, RF_t, M2_t, R_t^3\right)$

# lags	**AIC**	**SC**
1	-54.90	-54.38
2	-55.71*	-54.73*
3	-55.67	-54.24
4	-55.66	-53.76
5	-55.55	-53.20
6	-55.53	-52.73
7	-55.56	-52.29
8	-55.62	-51.89
9	-55.55	-51.35
10	-55.56	-50.89
11	-55.48	-50.35
12	-55.50	-49.90
13	-55.40	-49.32
14	-55.42	-48.87
15	-55.36	-48.33
16	-55.38	-47.88

Table 2: Forecast Error Variance Shares
Monetary System: $y_t = (Y_t, P_t, PC_t, TR_t, RF_t, M2_t, R_t^n)$

R^n	**RF**	**R^n**	**Y**	**P**	**RF**	**R^n**	**Y**	**P**
	3mo	3mo	3mo	3mo	48mo	48mo	48mo	48mo
2mo	.36	.54	.005	.002	.23	.27	.07	.07
3mo	.35	.63	.008	.002	.24	.30	.06	.06
4mo	.33	.58	.007	.001	.23	.28	.06	.05
6mo	.40	.57	.004	.002	.24	.27	.08	.05
9mo	.60	.52	.0006	.005	.30	.26	.10	.11
12mo	.16	.50	.002	.0002	.14	.25	.05	.02
24mo	.09	.44	.001	.0003	.08	.20	.04	.04
36mo	.07	.53	.0005	.0003	.07	.22	.03	.04

Table 3: Point Estimates

Monetary System: $y_t = (Y_t, P_t, PC_t, TR_t, RF_t, M2_t, R_t^n)$

		Min RMPD case		Recursive ID*	
$\mathbf{R}^n$	$C^R\alpha$	**RMPD**	**Relative Var.**	**RMPD**	**Relative Var.**
2 mo	A	.038	6.1%	.074	29.6%
3 mo	B	.032	3.9%	.065	25.5%
4 mo	B	.024	2.2%	.059	21.0%
6 mo	B	.021	1.8%	.049	13.7%
9 mo	C	.036	5.6%	.042	10.5%
12 mo	B	.050	11.8%	.044	13.6%
24 mo	A	.081	43.3%	.067	42.6%
36 mo	A	.100	70.0%	.083	80.3%

* Recursive Ordering : $\{Y_t, P_t, M2_t, TR_t, RF_t, PC_t, R_t^n\}$

Table 4: Coverage Intervals for Min RMPD Cases

Monetary System: $y_t = (Y_t, P_t, PC_t, TR_t, RF_t, M2_t, R_t^n)$

$\mathbf{R}^n$	$C^R\alpha$	**p odds**		**RMPD**			**Relative Var.**	
			25%	**50%**	**75%**	**25%**	**50%**	**75%**
2mo	A	13.71	.011	.024	.039	2.1%	5.5%	15.5%
3mo	B	6.58	.014	.024	.033	2.1%	3.9%	8.2%
4mo	B	4.26	.012	.018	.025	1.4%	2.4%	4.5%
6mo	B	4.21	.009	.015	.023	0.7%	1.4%	3.0%
9mo	C	3.63	.011	.020	.033	1.1%	3.0%	7.0%
12mo	B	3.46	.016	.028	.042	2.7%	8.8%	20.3%
24mo	B	2.82	.025	.039	.057	11.4%	43.7%	94.1%
36mo	A	4.68	.026	.040	.060	23.8%	69.4%	125.9%

RMPD $= [\frac{1}{48}\sum_{t=0}^{47}(R_t^n - \frac{1}{k}\sum_{j=0}^{k-1} RF_{t+j})^2]^{\frac{1}{2}}$

Relative Var. $= \frac{var(premium|\varepsilon_{MP})}{var(R^n|\varepsilon_{MP})} * 100\%$

$A: P_0 = Y_0 = 0; PC_0, M2_0, TR_0 \leqq 0; RF_0 \geqq 0; Y_{60} \leqq 0;$
$P_2 \leqq -.025PC_2; M2_0 \geqq .15TR_{10}.$

$B: A$ except $M2_0 \geqq .10TR_{10}$

$C: B$ with $TR_0 \leqq .4Y_{12}$

Table 5: Point Estimates

Monetary System: $y_t = (Y_t, P_t, PC_t, M2_t, R_t^1, R_t^n)$

		Min RMPD case		Recursive ID*	
$\mathbf{R}^n$	$C^R\alpha$	**RMPD**	**Relative Var.**	**RMPD**	**Relative Var.**
2 mo	D	.0029	.082%	.012	.358%
3 mo	D	.0050	.262%	.019	.976%
4 mo	D	.0056	.354%	.024	1.7%
6 mo	D	.0043	.225%	.038	3.7%
9 mo	D	.0026	.091%	.053	7.2%
12 mo	D	.0030	.122%	.064	11.5%
24 mo	D	.0059	.341%	.100	35.0%
36 mo	D	.0056	.292%	.119	59.5%
48 mo	D	.0049	.225%	.130	80.1%
60 mo	D	.0041	.155%	.133	93.8%
120 mo	D	.0100	.97%	.108	89.7%

* Recursive Ordering: $\{Y_t, P_t, M2_t, R_t^1, PC_t, R_t^n\}$

Table. 6: Coverage Intervals

Monetary System: $y_t = \left(Y_t, P_t, PC_t, M2_t, R_t^1, R_t^n\right)$

$\mathbf{R}^n$	$\mathbf{C}^R\boldsymbol{\alpha}$	**p odds**		**RMPD**			**Relative Var.**	
			25%	**50%**	**75%**	**25%**	**50%**	**75%**
2mo	D	∞	.0017	.0026	.0035	.026%	.065%	.132%
3mo	D	∞	.0030	.0046	.0059	.011%	.213%	.426%
4mo	D	∞	.0035	.0052	.0070	.155%	.316%	.583%
6mo	D	∞	.0032	.0050	.0072	.127%	.326%	.631%
9mo	D	∞	.0036	.0053	.0075	.136%	.359%	.716%
12mo	D	∞	.0038	.0057	.0081	.167%	.349%	.818%
24mo	D	∞	.0050	.0077	.0104	.214%	.506%	1.152%
36mo	D	∞	.0048	.0073	.0103	.181%	.475%	1.418%
48mo	D	∞	.0049	.0074	.0102	.135%	.473%	1.575%
60mo	D	∞	.0037	.0064	.0099	.107%	.368%	1.529%
120mo	D	∞	.0038	.0072	.0135	.147%	.935%	5.233%

RMPD $= [\frac{1}{48}\sum_{t=0}^{47}(R_t^n - \frac{1}{k}\sum_{j=0}^{k-1} R_{t+j}^1)^2]^{\frac{1}{2}}$

Relative Var. $= \frac{var(premium|\varepsilon_{MP})}{var(R^n|\varepsilon_{MP})} * 100\%$

D: $P_0 = Y_0 = 0; PC_0 \leqq 0; M2_0 \leqq 0; R_0^1 \geqq 0$

Table 7: Point Estimates
Monetary System: $y_t = (Y_t, P_t, PC_t, TR_t, RF_t, M2_t, R_t^n, R_t^1)$

		Min RMPD case		Recursive ID*	
$\mathbf{R}^n$	$C^R\alpha$	**RMPD**	**Relative Var.**	**RMPD**	**Relative Var.**
2 mo	A	.0056	0.16%	.0122	1.25%
3 mo	B	.0069	0.33%	.0192	3.17%
4 mo	B	.0068	0.31%	.0247	5.38%
6 mo	A	.0104	.051%	.0334	9.82%
9 mo	A	.0128	0.67%	.0402	15.92%
12 mo	A	0.139	0.79%	.0455	23.66%
24 mo	A	.0212	2.32%	.0656	64.72%
36 mo	C	.0186	1.79%	.0801	109.04%
48 mo	D	.0240	3.28%	.0841	138.87%
60 mo	D	.0265	4.65%	.0830	156.70%

* Recursive Ordering: $\{Y_t, P_t, M2_t, TR_t, RF_t, PC_t, R_t^1, R_t^n\}$

Table. 8: Coverage Intervals
Monetary System: $y_t = (Y_t, P_t, PC_t, TR_t, RF_t, M2_t, R_t^n, R_t^1)$

$\mathbf{R}^n$	$\mathbf{C}^R\boldsymbol{\alpha}$	**p odds**		**RMPD**			**Relative Var.**	
			25%	**50%**	**75%**	**25%**	**50%**	**75%**
2mo	A	∞	.0054	.0067	.0078	.018%	.30%	.48%
3mo	B	∞	.0082	.0095	.0113	.47%	.72%	1.16%
4mo	B	∞	.0085	.0100	.0121	.53%	.81%	1.37%
6mo	A	∞	.0100	.0125	.0150	.58%	1.08%	1.92%
9mo	A	∞	.0116	.0144	.0186	.93%	1.63%	2.98%
12mo	A	∞	.0128	.0170	.0222	1.18%	2.15%	4.23%
24mo	A	∞	.0163	.0227	.0315	2.41%	4.74%	9.76%
36mo	C	∞	.0173	.0232	.0328	2.32%	4.66%	10.72%
48mo	D	∞	.0172	.0245	.0335	2.59%	6.32%	15.63%
60mo	D	∞	.0189	.0256	.0340	3.16%	7.38%	17.46%

RMPD $= [\frac{1}{48}\sum_{t=0}^{47}(R_t^n - \frac{1}{k}\sum_{j=0}^{k-1} R_{t+j}^1)^2]^{\frac{1}{2}}$

Relative Var. $= \frac{var(premium|\varepsilon_{MP})}{var(R^n|\varepsilon_{MP})} * 100\%$

A: $\mathrm{P}_0 = Y_0 = 0; TR_0, PC_0, M2_0 \leqq 0; RF \geqq 0; .75RF_1 \leqq R_0^1 \leqq 1.25RF_1;$
$\mathrm{TR}_0 \leqq Y_1; M2_0 \geqq -TR_6; RF_2 \geqq 0$

B: A with $\mathrm{TR}_0 \leqq Y_{24}$ instead of $\mathrm{TR}_0 \leqq Y_1$

C: A without $RF_2 \geqq 0$

D: C with $\mathrm{TR}_0 \leqq Y_3$ instead of $\mathrm{TR}_0 \leqq Y_1$

Table 9: Point Estimates

Monetary System: $y_t = (Y_t, P_t, M2_t, RF_t, R_t^n, R_t^1)$

		Min RMPD case		Recursive ID*	
R^n	$C^R\alpha$	**RMPD**	**Relative Var.**	**RMPD**	**Relative Var.**
2 mo	A	.0089	1.14%	.0124	.65%
3 mo	A	.0111	1.15%	.0186	1.55%
4 mo	A	.0116	1.53%	.0233	2.55%
6 mo	B	.0130	1.43%	.0299	4.18%
9 mo	C	.0137	1.55%	.0342	5.86%
12 mo	D	.0120	1.61%	.0375	7.66%
24 mo	D	.0095	1.53%	.0591	20.23%
36 mo	E	.0068	1.28%	.0798	37.98%
48 mo	F	.0063	1.19%	.0940	56.30%
60 mo	G	.0061	1.07%	.1031	72.88%
120 mo	H	.0059	3.71%	.1077	102.85%

*Recursive Ordering: $\{Y_t, P_t, M2_t, RF_t, R_t^1, R_t^n\}$

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*Recursive ordering: $\left(Y_t, P_t, M2_t, RF_t, R_t^1, R_t^n\right)$

RMPD $= [\frac{1}{48}\sum_{t=0}^{47}(R_t^n - \frac{1}{k}\sum_{j=0}^{k-1} R_{t+j}^1)^2]^{\frac{1}{2}}$

Rel.Var. $= \frac{var(premium|\varepsilon_{MP})}{var(R^n|\varepsilon_{MP})} * 100\%$

$A: P_0, Y_0, M2_0 \leqq 0;\ RF_0 \geqq 0;\ .75RF_1 \leqq R_0^1 \leqq 1.25RF_1;\ Y_0 \geqq .5M2_0;$
$\quad P_0 \geqq .5M2_0; P_6 \leqq 0;\ RF_0 \geqq -265M2_0$

$B: A$ except $Rf_0 \geqq -125M2_0$

$C: B$ except $Rf_0 \geqq -110M2_0$

$D: P_0, Y_0, M2_0 \leqq 0; RF_0 \geqq 0; Y_0 \geqq .5M2_0, .95RF_1 \leqq R_0^1 \leqq 1.05RF_1; Y_1 \leqq Y_0;$

$E: D$ except$.85RF_1 \leqq R_0^1 \leqq 1.15$

$F: E$ except $.95RF_1 \leqq R_0^1 \leqq 1.05RF_1$ and $M2_0 \geqq 4Y_0$

$G: F$ except $M2_0 \geqq 2Y_0$

$H: G$ except $.98RF_1 \leqq R_0^1 \leqq 1.02RF_1$

Table. 10: Coverage Intervals
Monetary System: $y_t = (Y_t, P_t, M2_t, RF_t, R^n_t, R^1_t)$

				RMPD			**Relative Var.**	
R^n	$\mathbf{C}^R\boldsymbol{\alpha}$	**p odds**	**25%**	**50%**	**75%**	**25%**	**50%**	**75%**
2mo	A	30.25	.0085	.0101	.0145	0.60%	1.14%	1.95%
3mo	A	44.45	.0132	.0156	.0268	1.12%	2.17%	3.78%
4mo	A	165.67	.0114	.0142	.0173	0.99%	2.09%	4.19%
6mo	B	∞	.0121	.0160	.0198	1.30%	2.52%	5.12%
9mo	B	∞	.0132	.0173	.0219	1.69%	3.13%	6.65%
12mo	C	124	.0109	.0143	.0189	1.39%	2.79%	6.067%
24mo	D	70.43	.0100	.0133	.0177	1.68%	4.61%	15.59%
36mo	E	249	.0085	.0113	.0158	1.79%	5.08%	17.64%
48mo	F	∞	.0075	.0099	.0122	1.80%	4.75%	15.74%
60mo	G	∞	.0078	.0099	.0125	1.84%	5.68%	23.18%
120mo	H	∞	.0067	.0083	.0107	2.78%	9.14%	31.71%

RMPD = $[\frac{1}{48}\sum_{t=0}^{47}(R^n_t - \frac{1}{k}\sum_{j=0}^{k-1} R^1_{t+j})^2]^{\frac{1}{2}}$
Relative Var. = $\frac{var(premium|\varepsilon_{MP})}{var(R^n|\varepsilon_{MP})} * 100\%$
$A: P_0, Y_0, M2_0 \leqq 0;\ RF_0 \geqq 0;\ .75RF_1 \leqq R^1_0 \leqq 1.25RF_1;\ Y_0 \geqq .5M2_0;$
$P_0 \geqq .5M2_0; P_6 \leqq 0;\ RF_0 \geqq -265M2_0$
$B: A$ except $RF_0 \geqq -125M2_0$
$C: B$ except $RF_0 \geqq -110M2_0$
$D: P_0, Y_0, M2_0 \leqq 0; Rf_0 \geqq 0; Y_0 \geqq .5M2_0, .95RF_1 \leqq R^1_0 \leqq 1.05RF_1; Y_1 \leqq Y_0;$
$E: D$ except $.85RF_1 \leqq R^1_0 \leqq 1.15$
$F: E$ except $.95RF_1 \leqq R^1_0 \leqq 1.05RF_1$ and $M2_0 \geqq 4Y_0$
$G: F$ except $M2_0 \geqq 2Y_0$
$H: G$ except $.98RF_1 \leqq R^1_0 \leqq 1.02RF_1$

Table 11
Contemporaneous Policy Parameter Estimates
Monetary System: $y_t = (Y_t, P_t, M2_t, RF_t, R_t^n, 1mo_t)$

$\mathbf{R}^n$	**Y**	**P**	**M2**	**RF**	$\mathbf{R}^n$	**1mo**
2mo	-39.47	-86.43	-231.98	1.39	-3.72	3.73
3mo	-25.52	-37.26	-212.89	1.47	-3.19	2.79
4mo	-24.59	-39.08	-233.85	1.40	-2.69	2.31
6mo	-38.49	-0.60	-402.21	0.87	-1.46	1.32
9mo	-41.36	-1.03	-425.13	0.72	-1.05	0.95
12mo	-41.32	-9.66	-433.33	0.47	-0.95	1.04
24mo	-35.67	-10.52	-418.32	0.28	-1.10	1.12
36mo	-22.48	-15.06	-444.49	0.03	-0.88	1.09
48mo	-14.55	-7.95	-448.92	0.06	-0.92	1.01
60mo	-37.85	-12.77	-431.41	0.04	-0.93	1.05
120mo	-48.08	-180.23	-346.81	0.05	-0.69	1.19

Table 12
Contemporaneous Structure of the Benchmark Model

Money Demand:
$a_1 M2 + a_2 RF + a_3 Y + a_4 P = \varepsilon_{MD}$
Monetary Policy:
$a_5 M2 + a_6 RF = \varepsilon_{MP}$
Financial Sector:
$a_7 M2 + a_9 RF + a_{10} Y + a_{11} P + a_{12} R^1 = \varepsilon_{R^1}$
$a_{13} M2 + a_{14} RF + a_{15} Y + a_{16} P + a_{17} R^1 + a_{18} R^n = \varepsilon_{R^n}$
Production Sector:
Lower triangular in order $\{Y, P\}$,
Inertial with respect to Financial and Monetary Sectors

Table 13
Maximum Likelihood Estimates of Contemporaneous Coefficients:
Benchmark Model ($R^n = R^{36}$)
(68% equal tailed probability intervals)

Money Demand:

$$\underset{(50.48,397.85)}{254.11} M2 + \underset{(107.93,189.57)}{171.01} RF - \underset{(-35.23,-11.90)}{26.55} Y - \underset{(-40.8245,9.16)}{17.62} P = \varepsilon_{MD}$$

Monetary Policy:

$$\underset{(-448.90,-227.85)}{-381.84} M2 + \underset{(2.49,157.59)}{90.61} RF = \varepsilon_{MP}$$

Financial Sector:

$$-\underset{(-60.47,-16.69)}{38.06} M2 - \underset{(-117.07,-97.32)}{107.08} RF - \underset{(-17.88,3.76)}{6.81} Y - \underset{(-63.81,-16.69)}{39.43} P + \underset{(182.53,195.25)}{188.89} R^1 = \varepsilon_{R^1}$$

$$-\underset{(-47.19,-2.93)}{24.80} M2 - \underset{(-25.27,-4.34)}{14.68} RF - \underset{(-39.03,-17.38)}{27.80} Y - \underset{(-78.27,-31.53)}{54.34} P - \underset{(-113.93,-94.74)}{103.99} R^1 + \underset{(271.55,290.43)}{281.21} R^{36} = \varepsilon_{R^{36}}$$

68% equal tailed probability intervals based on 50,000 draws from the posterior distribution of model coefficients in parentheses.

Table 14:
Incorporating Policy Responses to the Bond Market:
Implications for the Conditional Expectations Theory
(5%,16%,84%,95%) fractiles

	Benchmark		$\mu_{R^n} = .05$		$\mu_{R^n} = .25$	
R^n	**RMPD**	**Rel. Var.**	**RMPD**	**RV**	**RMPD**	**RV**
2mo	.0029 (.0093,.0129,.0302,.0308)	.22% (.22%,.66%,11.91%,23.48%)	.0028	.20%	.0024	.16%
3mo	.0082 (.0093,.0129,.0302,.0376)	1.91% (.25%,.76%,13.28%,26.17%)	.0079	1.81%	.0063	1.39%
4mo	.0115 (.0093,.0103,.0304,.0376)	3.54% (.26%,.92%,13.80%,26.28%)	.0110	3.40%	.0110	3.40%
6mo	.0160 (.0090,.0126,.0300,.0377)	5.69% (.36%,.83%,12.20%,23.70%)	.0151	5.44%	.0119	4.37%
9mo	.0203 (.0084,.0116,.0280,.0360)	8.49% (.33%,.87%,11.54%,24.18%)	.0190	7.95%	.0142	5.79%
1yr	.0226 (.0085,.0118,.0284,.0365)	11.45% (.47%,1.05%,12.01%,26.36%)	.0208	10.49%	.0143	6.67%
2yr	.0250 (.0105,.0151,.0410.0536)	37.24% (1.15%,2.76%,32.93%,74.61%)	.0227	34.56%	.0135	21.30%
3yr	.0257 (.0114,.0170,.0499,.0660)	48.64% (1.59%,4.25%,59.99%,132.73%)	.0234	46.11%	.0130	30.97%
4yr	.0253 (.0127,.0190,.0571,.0756)	51.31% (2.51%,6.14%,90.47%,139.61%)	.0228	48.41%	.0123	31.48%
5yr	.0238 (.0135,.0206,.0621,.0821)	45.75% (2.88%,7.05%,121.70%,160.13%)	.0212	42.24%	.0109	23.33%
10yr	.0178 (.0162,.0246,.0731,.0971)	32.54% (4.52%,12.05%,150.58%,150.58%)	.0148	26.73%	.0049	5.61%

RMPD = $[\frac{1}{48}\sum_{t=0}^{47}(R_t^n - \frac{1}{n}\sum_{j=0}^{n-1} R_{t+j}^1)^2]^{\frac{1}{2}}$

Relative Var.(RV) = $\frac{var(premium|\varepsilon_{MP})}{var(R^n|\varepsilon_{MP})} * 100\%$

Equal tailed probability intervals based on 50,000 draws from the posterior distribution of model coefficients in parentheses.

Table 15 : Minimum Premium Deviations Conditional on a Money Demand Shock

Monetary System: $y_t = (Y_t, P_t, M2_t, RF_t, R_t^n, R_t^1)$

$\mathbf{R}^n$	$C^R\alpha$	**RMPD**	**Relative Var.**
2 mo	A	.0025	0.55%
3 mo	A	.0040	1.80%
4 mo	A	.0053	3.48%
6 mo	A	.0075	15.05%
9 mo	B	.0083	19.50%
12 mo	B	.0088	24.76%
24 mo	B	.0084	27.09%
36 mo	C	.0082	17.62%
48 mo	C	.0078	26.12%
60 mo	C	.0074	36.45%
120 mo	C	.0049	46.37%

A: $\mathrm{Y}_0 \leqq 0; P_0 \leqq 0; M2_0 \geqq 0; RF_0 \geqq 0; RF_3 \geqq 0; Y_{24} \leqq P_{24}; P_3 \leqq P_0; M2_0 \geqq P_0; P_{36} \leqq 0$

B: $\mathrm{Y}_0 \leqq 0; P_0 \leqq 0; M2_0 \geqq 0; RF_0 \geqq 0; RF_3 \geqq 0; Y_{24} \leqq P_{24};\ P_3 \leqq P_0$

C: $\mathrm{Y}_0 \leqq 0; P_0 \leqq 0; M2_0 \geqq 0; RF_0 \geqq 0; RF_3 \geqq 0; Y_{24} \leqq P_{24}$

Table 16: Selected Subsample Results

Panel A: (Sample: 1959:1 - 1979:10)

$\mathbf{R}^n$	$\mathbf{C}^R\boldsymbol{\alpha}$	**RMPD**	**Relative Var.**	**FEV(RF)***	**FEV($\mathbf{R}^n$)**	**FEV(Y)**	**FEV(P)**
3mo	E	.016	2.8%	.09	.15	.031	.0005
6mo	E	.017	3.9%	.08	.14	.025	.001
9mo	E	.018	9.0%	.09	.08	.006	.002

*FEV(x) = forecast error variance of variable x at the 48th month horizon

RMPD = $[\frac{1}{48}\sum_{t=0}^{47}(R_t^n - \frac{1}{k}\sum_{j=0}^{k-1} RF_{t+j})^2]^{\frac{1}{2}}$

Relative Var. = $\frac{var(premium|\varepsilon_{MP})}{var(R^n|\varepsilon_{MP})} * 100\%$

E: $P_0 = Y_0 = 0; PC_0, M2_0, TR_0 \leqq 0; RF_0 \geqq 0; Y_{12} \leqq 0;$
$P_{24} \leqq 0; TR_0 \leqq .25PC_{12};$

Panel B: (Sample: 1982:10 - 1995:12)

$\mathbf{R}^n$	$C^R\alpha$	**RMPD**	**Relative Var.**	**FEV(RF)***	**FEV($\mathbf{R}^n$)**	**FEV(Y)**	**FEV(P)**
3mo	F	.010	2.4%	.17	.14	.19	.013
6mo	F	.011	4.3%	.14	.09	.17	.004
9mo	G	.016	8.7%	.17	.10	.14	.009

*FEV(x) = forecast error variance of variable x at the 48th month horizon

RMPD = $[\frac{1}{48}\sum_{t=0}^{47}(R_t^n - \frac{1}{k}\sum_{j=0}^{k-1} RF_{t+j})^2]^{\frac{1}{2}}$

Relative Var. = $\frac{var(premium|\varepsilon_{MP})}{var(R^n|\varepsilon_{MP})} * 100\%$

F:$P_0 = Y_0 = 0; PC_0, M2_0, TR_0 \leqq 0; RF_0 \geqq 0; Y_{60} \leqq 0;$
$P_{12} \leqq 0; M2_0 \geqq .10TR_{10}; M_{12} \leqq 0;$ TR$_0 \leqq Y_{12}$

G: F without $P_{12} \leqq 0$

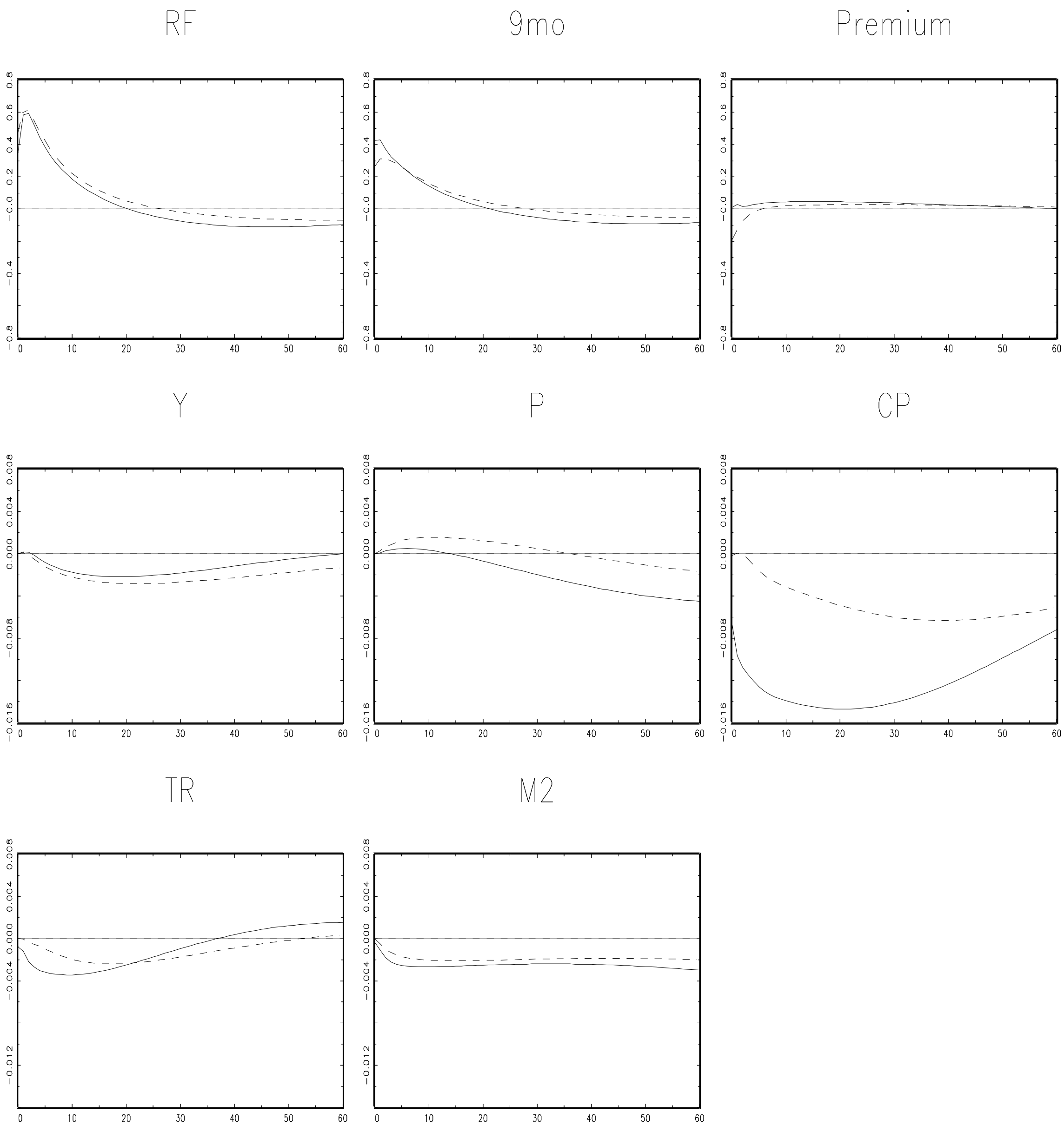

Figure 1: Impulse Responses to a Contractionary Policy Shock: percents or Δlog levels ; $y_t = \left(Y_t, P_t, PC_t, TR_t, RF_t, M2_t, R_t^9\right)$;
—Min RMPD - - - Recursive

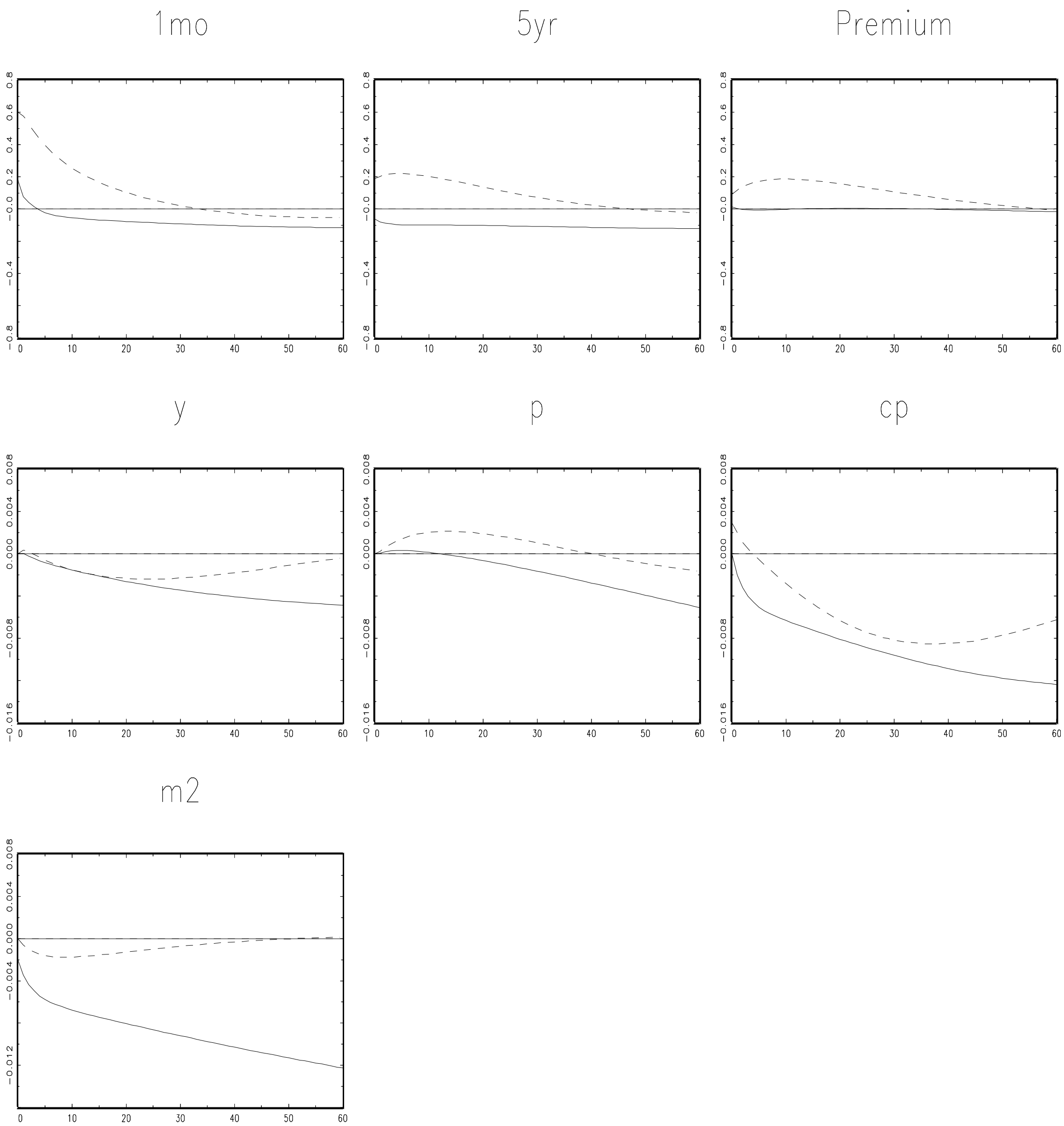

Figure 2: Impulse Responses to a Contractionary Policy Shock: percents or Δlog levels ;
$y_t = \left(Y_t, P_t, PC_t, M2_t, R_t^1, R_t^{60}\right)$;
—Min RMPD - - - Recursive

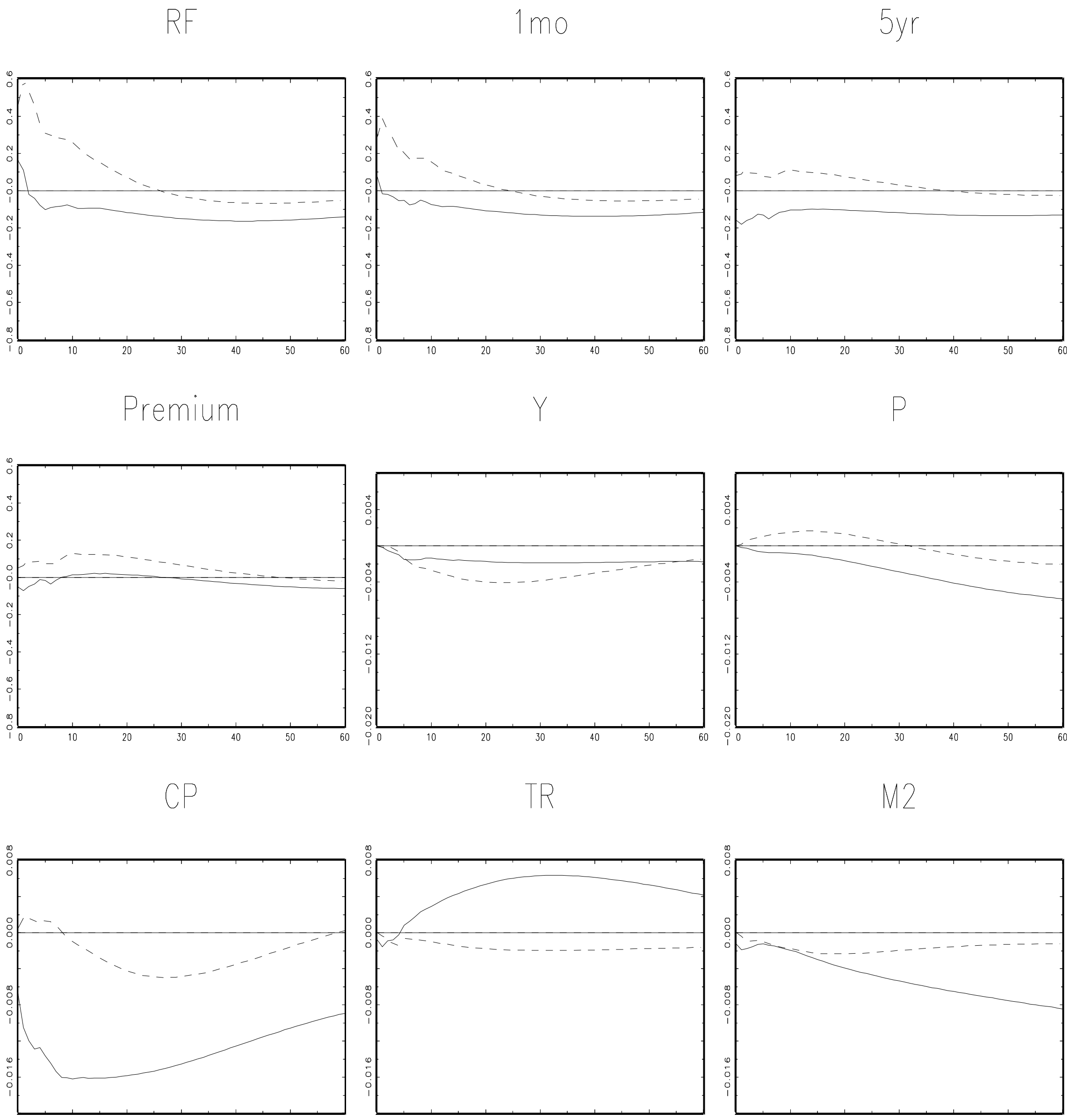

Figure 3: Impulse Responses to a Contractionary Policy Shock: percents or Δlog levels ; $y_t = (Y_t, P_t, PC_t, TR_t, Rf_t, M2_t, R_t^{60}, R_t^1)$;
—Min RMPD - - - Recursive

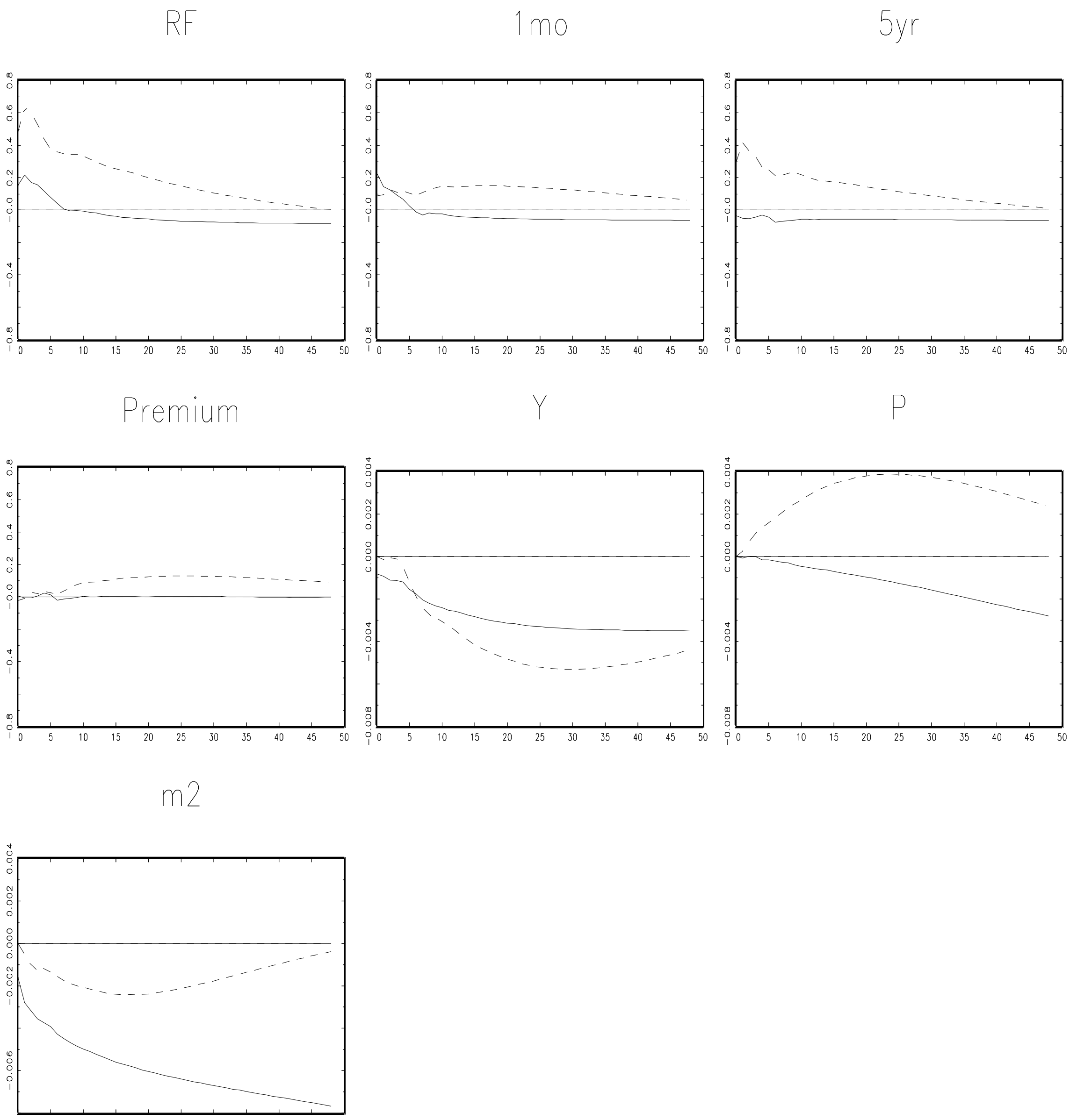

Figure 4: Impulse Responses to a Contractionary Policy Shock: percents or Δlog levels ;
$y_t = (Y_t, P_t, M2_t, Rf_t, R_t^1, R_t^{60})$;
—Min RMPD - - - Recursive

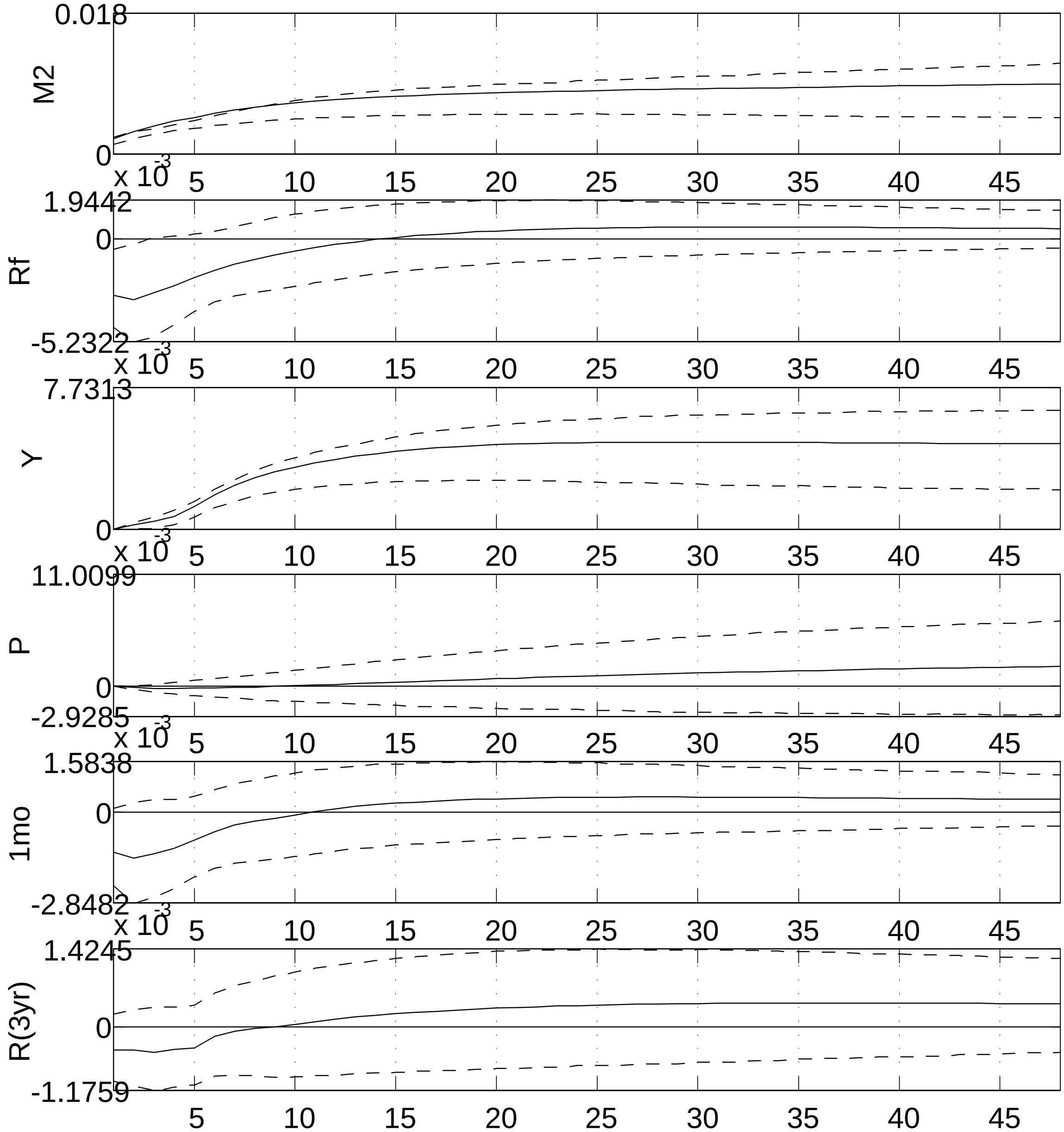

Figure 5: Impulse Responses to an Expansionary Policy Shock in the Benchmark Model (Rn=36mo)

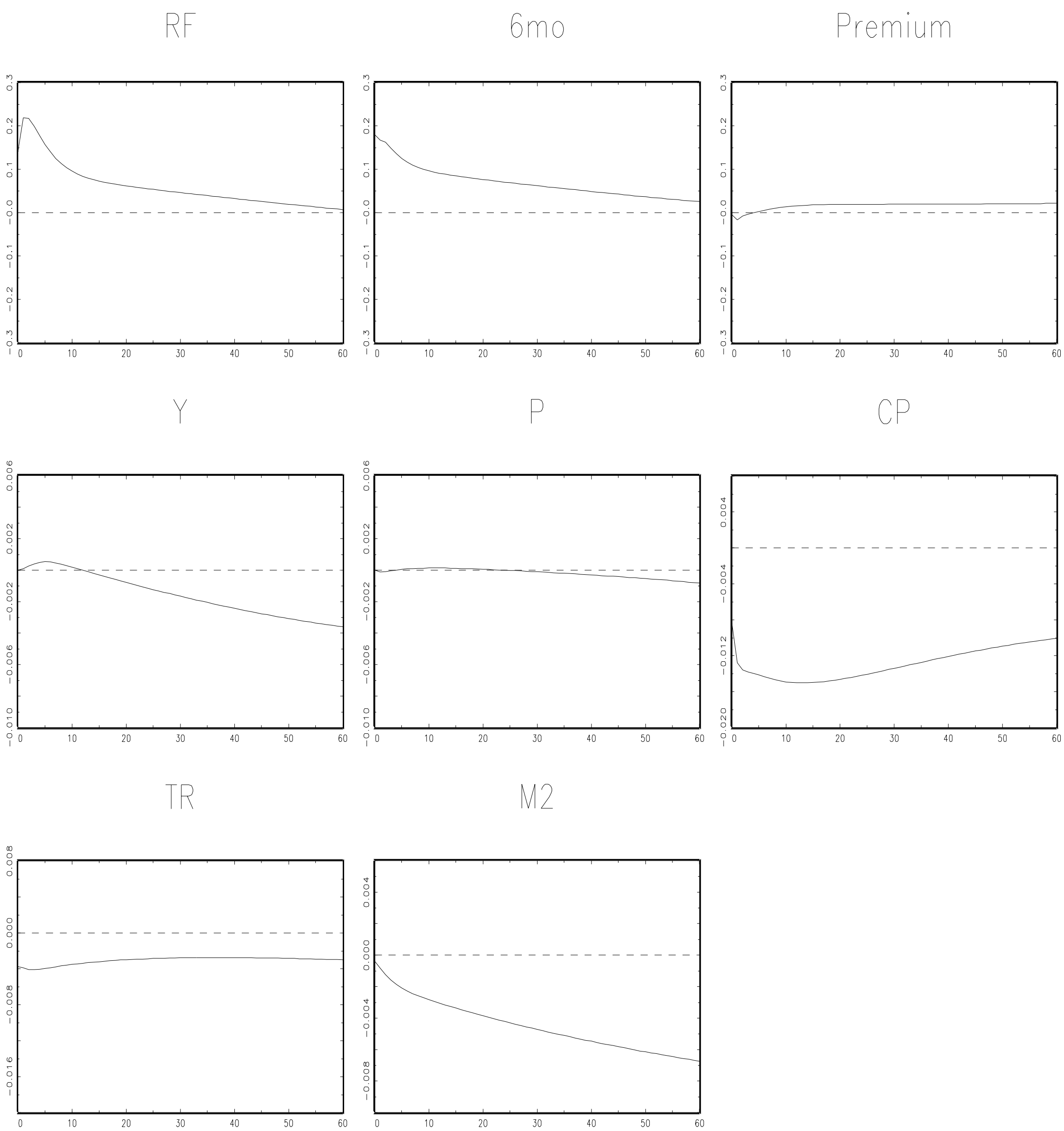

Figure 6: Impulse Responses to a Contractionary Policy Shock (data sample:1959:1-1979:10): percents or Δlog levels ; $y_t = \left(Y_t, P_t, PC_t, TR_t, RF_t, M2_t, R_t^6\right)$; —Min RMPD - - - Recursive

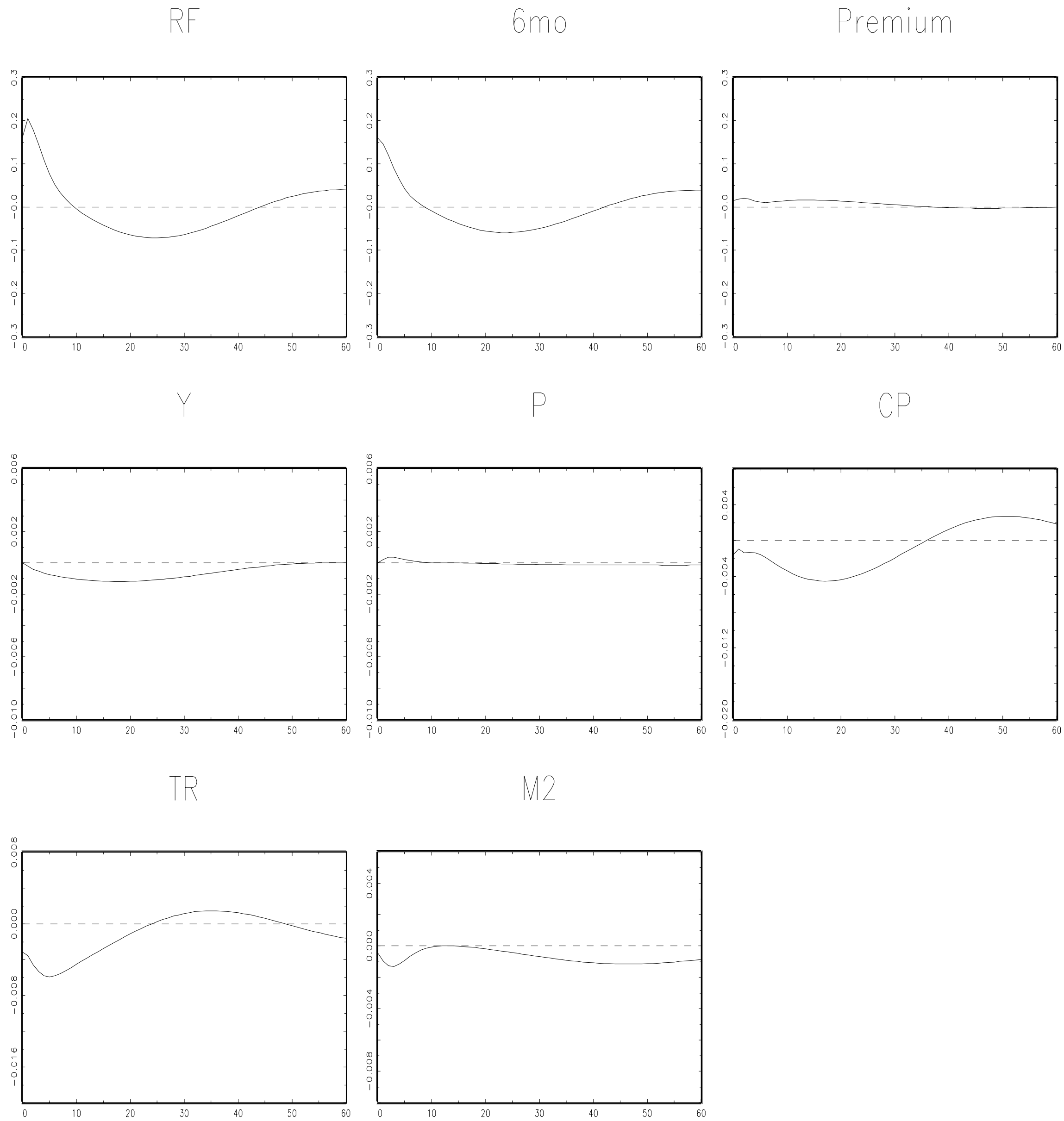

Figure 7: Impulse Responses to a Contractionary Policy Shock (data sample:1982:10 -1995:2): percents or Δlog levels ; $y_t = \left(Y_t, P_t, PC_t, TR_t, RF_t, M2_t, R_t^6\right)$; ——Min RMPD - - - Recursive

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