# CREDIT AND ECONOMIC ACTIVITY: SHOCKS OR PROPAGATION MECHANISM?


Nathan S. Balke

and

Chih-Ping Chang


November 1995

**RESEARCH DEPARTMENT**

**WORKING PAPER**

**95-19**

**Federal Reserve Bank of Dallas**

**Credit and Economic Activity:**
**Shocks or Propagation Mechanism?***

Nathan S. Balke
and
Chih-Ping Chang

Southern Methodist University
Federal Reserve Bank of Dallas

September 1995

Abstract In many models with imperfect capital markets, credit plays an important role in the propagation of shocks. Furthermore, this propagation mechanism often implies nonlinear dynamics in the form of asymmetry and regime switching. In this paper, we examine empirically whether credit plays a separate role as a propagator of shocks. We model this propagation empirically as a threshold model in which the dynamics of output growth changes if the commercial paper/treasury bill spread exceeds a critical threshold. We test and estimate both a single equation threshold model for output growth and a threshold vector autoregression that includes output growth, inflation, a monetary variable, and the paper-bill spread and find evidence of a threshold structure. Using nonlinear impulse response functions, we evaluate the dynamics implied by the threshold model. These suggest that money and paper-bill shocks have a larger effect on output in the "tight" credit regime than is normally the case and that negative money shocks typically have a larger effect than positive shocks. Finally, using a nonlinear version of historical decompositions, we examine post-1960 macroeconomic history through the lens of our threshold vector autoregression.

Key words: credit, threshold, vector autoregression, nonlinear impulse response

* A previous version of this paper was presented at the November 1994 Southern Economic Association Meetings in Orlando, Florida. We thank Herman Bierens, Simon Potter, and seminar participants at S.M.U. for helpful comments. The views expressed in this paper are solely those of the authors and not those of the Federal Reserve Bank of Dallas or the Federal Reserve System.

## I. Introduction

The 1990-91 recession and its relatively slow recovery has brought an increased attention on the effect that credit, and more generally, financial conditions have on economic activity. The traditional 'money view' holds that bank loans have no independent effects and only reflect the effect of monetary policy. This view maintains that money and other assets are perfect substitutes and that banks affect economic activity by their ability to create deposits. Alternatively, proponents of the 'credit view' maintain that banks' ability to extend credit is a separate and important source of economic fluctuations. Due to imperfect substitution between nonbank financing and bank loans, the availability and/or the desirability of bank loans has consequences for firms' and households' financing of investment and consumption and, in turn, on aggregate economic activity.

Many recent empirical studies have examined the relationship between credit, money, and output.[1] For the most part, the evidence at the aggregate level of a separate credit channel is mixed at best. The results vary depending on which variables are used to capture credit conditions and across sample periods. For example, Ramey (1993) finds that credit variables such as credit velocity and loan-security ratio provide little additional predictive content for output above and beyond that contained in money. On the other hand, Stock and Watson (1989) and Friedman and Kuttner (1992, 1993a) find that the spread between commercial paper and T-Bill rates has significant predictive content for output. However, this

[1] See for example Bernanke, 1986; King, 1986; B. Friedman, 1988; Bernanke and Blinder, 1992; Gertler and Gilchrist, 1993; Kashyap, Stein, and Wilcox, 1993; Friedman and Kuttner, 1993b; Ramey,1993

result may not be robust across different sample periods.[2] Kashyap, Stein, Wilcox (1993) proxy credit conditions with the bank loans as a fraction of total short-term external finance. They interpret the significance of this variable in the investment equation as the evidence of the loan-supply channel of monetary-policy transmission.

In general, one can think of credit conditions affecting the economy in two (and not mutually exclusive) ways. The first is as a source of shocks to the economy. For example, imposition of credit controls, bank capital shocks, or a decrease in bank reserves (say through open market operations) may cause banks to reduce the amount of credit supplied. Impulse response functions and variance decompositions from vector autoregressions are an attempt to assess the effect of "exogenous" shocks to credit on economic activity.

Alternatively (or in addition), credit conditions might play an important role in the propagation of shocks. Blinder (1987) develops a model in which credit rationing has aggregate supply effects. In this model, monetary shocks may have very different effects when the economy is in a credit rationing regime than at other times. Bernanke and Gertler (1989) construct a model in which, due to the presence of credit frictions (not necessarily credit rationing), changes in the balance sheet condition of firms gives rise to a "financial accelerator" which amplifies fluctuations in output. In Bernanke and Gertler's model exogenous "technology" shocks have possibly asymmetric effects as negative shocks are likely to have a greater effect than positive shocks. Azariadis and Smith (1994) develop a model in which presence of credit markets give rise to endogenous fluctuations. In fact, in the context of their model, it is possible for the economy to switch back and forth between a Walrasian regime and

[2]For robustness of predictive power of the spread on output, see Gray and Thoma (1994) and Emery (1994). Bernanke(1990) also finds that the information content of the spread has fallen off significantly in the 1980's.

a credit rationing regime. In all of these models, credit conditions need not be an important source of shocks but are, nonetheless, an important propagator of shocks. In addition, these models typically imply nonlinear dynamics characterized by regime switching and asymmetries.

While there is some evidence at the microeconomic level that financial considerations have an important role in the propagation of shocks,[3] there is little evidence that these effects are important at the macro level. One reason is that the macro evidence is based almost entirely on linear regressions or linear vector autoregressions (VAR). Within the context of these models, researchers typically examine whether credit fluctuations predict ("cause") changes in economic activity or examine the response of output to an "exogenous" change in credit. Yet, standard linear time series may have difficulty distinguishing the (possibly) separate effects of shocks and propagation mechanism. For example, in a model in which credit shocks play no direct role such as Bernanke and Gertler, credit aggregates might have little predictive content for output even though credit allocation is a crucial part of the propagation of shocks. Or in the model examined by Kiyotaki and Moore (1993), credit aggregates might actually lag output even though credit creation also plays a key role in economic fluctuations.

In this paper we attempt to shed light on credit's role as a shock or a propagator of shocks by employing nonlinear time series analysis to analyze the relationship between credit conditions and economic activity. Specifically, we examine a model in which output responds

[3] See for example Gertler and Gilchrist (1993), Kashyap, Lamont, and Stein (1993), Oliner and Rudebusch (1993). In an interesting paper similar in spirit to approach taken here, Vijverberg (1994) examines a switching regression model for firm level investment in which credit conditions cause firms to alter their investment behavior.

differently to monetary and credit shocks if the commercial paper/treasury-bill spread exceeds a critical threshold. This simple threshold model captures some of the flavor of the models described above in that it implies switching between regimes depending on credit conditions and it allows exogenous shocks to have asymmetric effects. The model also reflects the less formal notion that the effect of monetary and other shocks on output might be different if credit is "tight".

We examine the presence of threshold credit regimes both in a single equation model for output and a vector autoregression that includes output, inflation, a monetary variable (either M2 growth or the Fed Funds rate) and the commercial/paper T-Bill spread. The threshold vector autoregression allows us to consider a model in which the credit regime is endogenous. Here, unlike a Markov regime switching model, shocks to other variables such as money or output as well as credit can cause a switch in regimes. Furthermore, the threshold VAR allows credit conditions, through regime switching, to have an effect independent of "shocks" to the VAR. While interpretation of reduced form models is always tenuous, the presence and importance of switching credit regimes would be consistent with a separate role for credit as a propagator of shocks.

We find, in both a single equation model of output growth and a vector autoregression, significant evidence of a regime switch when the paper-bill spread exceeds a critical threshold. We find evidence that monetary shocks (whether reflected in fed funds rate shocks or M2 growth shocks) as well as credit shocks have larger effects in the so-called tight credit regime. In addition, we find evidence of asymmetry in that contractionary monetary and credit shocks have proportionately larger effects. Finally, we review post-1960 macroeconomic history in the U.S. through the lens of the threshold VAR by examining nonlinear analogues of historical decompositions. We hope that these may tell us something about the source of macroeconomic fluctuations as well as the shocks that drove the economy into so-called "tight" credit regimes.

Before moving on to the body of the paper, a brief discussion of some related literature is relevant. Most of the nonlinear time series models of output have been univariate threshold autoregressions (for example, Teräsvirta and Anderson (1992), Potter (1995), and Pesaran and Potter (1995)) and, as a result, have not focused on role of credit conditions. One important exception is McCallum (1991). McCallum takes an approach very similar to ours in that he estimates a threshold model in which the coefficients on money in an output equation change depending on credit conditions. In fact, he too finds evidence that output behaves differently to monetary shocks in so-called tight credit periods. Our work differs from his in three respects. We use as our measure of credit conditions the commercial paper/treasury bill spread which has been the focus of much of recent analysis of the role of credit. Second, testing for unknown thresholds involves nonstandard statistical inference because the threshold parameter is not identified under the null hypotheses of no threshold. As a result, we adapt the simulation methodology proposed by Hansen (1994) in order to conduct proper inference. Third, by estimating a threshold vector autoregression we allow switching into the tight credit regime to be endogenous. The threshold VAR still allows us to conduct impulse response analysis in order to evaluate the effect of monetary and credit shocks.

Our paper is also related to the more informal literature on role of credit "crunches" and the business cycle. Eckstein and Sinai (1986) argue that some type of credit crunch precedes every post-war recession. The problem is that their identification was in some sense ex post;

that is, their search for a credit crunch may have been conditioned on knowledge of when recessions occurred. When Owens and Schreft (1995) conduct a detailed examination of the historical record to identify so-called credit crunches, they find that the link between credit crunches and subsequent recessions is substantially weaker. While we do not focus exclusively on credit crunches (as defined by non-price rationing of credit), we do interpret periods in which the spread exceeds the critical threshold as episodes of "tight" credit. And while our method of identifying tight credit regimes is also data dependent and, hence, not strictly ex ante, our statistical inference takes account of this. We do take the fact that the estimated threshold yields episodes consistent with previous descriptions of tight credit periods as evidence for the plausibility of our identification.

The plan for the rest of this paper is as follows. In section 2, we discuss our choice of the commercial paper/t-bill spread as an indicator of credit conditions. Section 3 presents the econometric methodology of estimating and testing for univariate and multivariate threshold models. Section 4 outlines the univariate threshold model for output growth. Within the context of this single equation model, we examine the predictive content of the paper-bill spread for output growth. In section 5, we test for and estimate a threshold vector autoregression. To understand the dynamics implied by the model, we calculate nonlinear impulse response functions. In section 6, we evaluate recent macroeconomic history in light of our nonlinear model by examining nonlinear versions of historical decompositions. Section 7 contains concluding remarks.

## II. Paper-Bill Spread as an Indicator of Credit Market Conditions

In the literature, variables such as commercial paper/t-bill spread (Bernanke (1990)), the mix of bank loans and commercial paper (Kashap, Stein, and Wilcox (1993)), quantity of bank or commercial loans (Friedman (1988)), loan velocity (Ramey (1993)) have all been used to measure credit conditions. In this paper, we use the commercial paper(4-6 month)/T-Bill(6 month) spread (denoted by CPBILL) as our indicator of credit conditions. There is a large (and still growing) literature evaluating the ability of the paper-bill spread to predict economic activity.[4] Similarly, considerable effort has been devoted to trying to interpret the fairly robust forecasting ability of the paper-bill spread. Friedman and Kuttner (1993b) suggest several different interpretations for the predictive content of the paper-bill spread for output. These include: the default-risk hypothesis in which the default premium on commercial paper rises in anticipation of a contraction; the cash-flow hypothesis in which the paper-bill spread rises as product demand falls because firms turn to the commercial paper market to finance inventory accumulation; and a "credit" channel hypothesis in which monetary or bank capital shocks cause banks to banks curtail their lending, this forces firms' to shift to the commercial paper market which in turn causes the paper rate to rise relative to the government securities' rates.

While Friedman and Kuttner find evidence consistent with all three interpretations, it still seems plausible that the paper-bill spread primarily reflects a credit story. Bernanke (1990) has argued that the actual default rate on commercial paper is too small to generate large swings in the paper-bill spread seen in the data. In addition, even the cash-flow

[4] See for example Stock and Watson (1989) and Friedman and Kuttner (1992), (1993a), (1993b).

hypothesis has an element of the credit story in it. In a model such as Bernanke and Gertler's (1989) financial accelerator model, a cash flow shock increases the agency costs implied by financial contracting under asymmetric information. As a consequence, bank loans do not increase as much as commercial paper--high quality firms can still obtain funds by issuing commercial paper. Thus, the higher paper-bill spread reflects the relative tightness in bank credit as well as overall demand for short-term financing.

Our choice of the paper-bill spread as our measure of credit conditions was also determined on practical grounds. First, in order to maintain parsimony in the nonlinear models both for testing and estimating, we wanted a single variable to measure aggregate credit conditions. Given the success of paper-bill spread in linear models at predicting economic activity, it seems to be an ideal candidate for capturing credit conditions. Second, we needed a long enough sample period in order for meaningful estimation of the nonlinear model. The sample lengths of variables such as the "mix" variable of Kashap, Stein, and Wilcox (1993) are not long enough for us to confidently apply the nonlinear methodology.

## III. Empirical Methodology: Testing and Estimating Threshold Models

In this paper, we attempt to capture the separate role that credit may play as a propagation mechanism by testing and estimating single and multiple equation threshold models. As suggested above some of the models (but not all) in which credit acts as a propagator of shocks imply phenomena such as regime switching and asymmetry. Threshold models are a relatively simple and intuitive way to capture some of the nonlinearity implied by these models. In addition, the threshold model allows credit conditions through its effect on determining regimes to affect economic activity independent of credit shocks.

Consider the following single equation threshold model for output growth:

$$\Delta y_t = A^0(L)\Delta y_{t-1} + B^0(L)X_t + [A^1(L)\Delta y_{t-1} + B^1(L)X_t]\, I[c_t \geq \gamma] + \varepsilon_t$$

where $X_t$ is a vector of exogenous (or predetermined) variables, $A^0(L)$, $A^1(L)$, $B^0(L)$, and $B^1(L)$ are lag polynomials, $c_t$ is a measure of credit conditions, and I[ . ] is an indicator function that equals 1 when $c_t \geq \gamma$ and zero otherwise.[5] This model allows the dynamics of output to change if the credit conditions variable, $c_t$, exceeds a critical threshold value, $\gamma$.

If the threshold variable, $c_t$, and the threshold value, $\gamma$, were known, then to test for threshold behavior in output all one needs to do is to test the hypothesis that $A^1(L) = B^1(L) = 0$. Unfortunately, the threshold variable and the parameter are typically not known a priori and must be estimated. In this case, testing the hypothesis $A^1(L) = B^1(L) = 0$ involves non-standard inference because $c_t$ and $\gamma$ are not identified under the null hypothesis of no threshold behavior.[6]

In order to test for thresholds when $c_t$ and $\gamma$ are not known, we estimate the threshold model by least squares for possible combination of threshold variable and threshold value. For each combination, the Wald statistic testing the hypothesis of no difference between regimes was calculated. Three separate test statistics for threshold behavior were then calculated: (i) sup-Wald which is the maximum Wald statistic over all possible threshold variables and threshold values; (ii) avg-Wald which is the average Wald statistic over all possible threshold

---

[5] The single equation threshold models examined here are similar to those examined by McCallum (1991).

[6] There is a recent and growing literature on the problem of testing hypothesis in which nuisance parameters are not present under the null. See, for example, Davies (1977, 1987), Andrews (1993), Andrews and Ploberger (1992), and Hansen (1994).

variables and threshold values; (iii) exp-Wald which is a function of the sum of exponential Wald statistics.[7] To conduct inference, we employed the simulation method of Hansen (1994) which involves simulating an empirical distribution of sup-Wald, avg-Wald, and exp-Wald statistics. The statistical inference takes into account that we searched over different possible threshold variables and threshold values.

The estimated threshold variable and threshold value are those values that minimize the sum of squared residuals. As described in the previous section, we take as our measure of credit conditions the spread between the commercial paper/T-Bill rates (CPBILL). Because the effects of tight credit conditions may take some time to manifest themselves, $c_t$ might actually be lagged values of the paper-bill spread or its moving average. Formally, we consider six alternative threshold variables:

$$c_t \in \{ {}_{j=0}\Sigma^{k-1} \ CPBILL_{t-i-j}/k \text{ for } (k=1,\ i=1,2,3),\ (k=2,\ i=1,2),\ (k=3,\ i=1) \}.$$

We also restricted the possible values of $\gamma$ so that at the minimum number of observations in a regime was the number of parameters to be estimated plus 5% of the observations for the single equation model.

We can generalize the above threshold model so that the credit regime is endogenous. This can be achieved by introducing the credit variable into the dynamic system. In its most general form, we consider a threshold vector autoregression (TVAR) in which the credit conditions variable enters into the system

$$X_t = C^0(L)X_{t-1} + [C^1(L)X_{t-1}]\ I[c_t > \gamma] + \varepsilon_t,$$

where $X_t$ is a vector of time series that includes growth rate of output and the paper-bill spread

[7] Andrews and Ploberger (1992) suggest the "avg" and "exp" versions of Wald test.

as well as inflation, and an indicator of monetary policy. Because $c_t$ is a function of lags of the paper-bill spread and the paper-bill spread is also is one of the elements in $X_t$, the threshold VAR describes both the evolution of $X_t$ and the credit regimes. That is, shocks to output, inflation, money, as well as to credit can determine whether the economy is in a tight credit regime.[8]

We modify the single equation approach for testing for threshold behavior to the multi-equation case. The estimated threshold variable and threshold value are determined by searching over $c_t$ and $\gamma$ in order to minimize log $|_t\Sigma\ \varepsilon_t'\varepsilon_t|$ where $\varepsilon_t$ is the vector of residuals from the threshold VAR.. Wald statistics for the hypothesis $C^1(L) = 0$ were calculated and Hansen's simulation method is then used to calculate p-values for the sup-Wald, avg-Wald, and exp-Wald statistics. To guard against over-fitting, we restricted the possible threshold values so that at least 10% of the observations plus the number of parameters (for an individual equation) were in each regime.

## IV. Results from Single Equation Model

To gain some insight into the possibly non-linear effects of credit on output, we start by estimating a linear model similar to Friedman and Kuttner (1992, 1993a). They regress real GDP growth on four lags of itself, inflation (implicit GDP deflator), M2 growth, and the commercial paper/T-Bill spread (CPBILL). In their output growth equation, the paper-bill was found to have strong predictive content. Bernanke and Blinder (1992) suggest that the Federal Funds rate indicates the stance of monetary policy better than monetary aggregates. Therefore,

---

[8] This is in contrast to regime switching models such as Hamilton (1989) in which the regimes are determined by an Markov process that is independent of other shocks to the system.

we also conduct analysis where M2 growth is replaced by the Federal Funds.

Taking the linear Friedman-Kuttner as the null model, we tested for threshold behavior in output. Table 1 reports tests of linearity against the alternative of a threshold model. The Sup-Wald, Avg-Wald, and Exp-Wald statistics, their p-values, and the estimated threshold variable and threshold value are presented. All tests reject the null hypothesis of linearity against the threshold alternative at the 5% level. In the model with M2 growth as the monetary variable, the estimated threshold variable is $CPBILL_{t-3}$; output switches regimes if $CPBILL_{t-3}$ exceeds 0.8733. When the Fed Funds rate is the monetary variable, the estimated threshold variable is found to be $CPBILL_{t-2}$ and the threshold value is 0.7830. The estimated delays of two or three quarters are consistent with previous work that suggested monetary innovations begin to have an effect on bank loans after a six month delay.[9]

To understand the effect of the credit regimes on output better, we further investigate the predictive content of each variable in the output equation over different regimes. We estimate the following switching regression:

$$\Delta y_t = D_1 \sum_{i=1}^{4} (\alpha_0 + \alpha_i^y \Delta y_{t-i} + \alpha_i^p \Delta p_{t-i} + \alpha_i^m m_{t-i} + \alpha_i^c CPBILL_{t-i}) +$$
$$D_2 \sum_{i=1}^{4} (\beta_0 + \beta_i^y \Delta y_{t-i} + \beta_i^p \Delta p_{t-i} + \beta_i^m m_{t-i} + \beta_i^c CPBILL_{t-i}) + \varepsilon_t$$

where $D_1$ is a dummy variable equal to 1 when the threshold variable exceeds the threshold and 0 otherwise. $D_1$ indicates the "tight" regime while $D_2$ indicates the "normal" regime. The monetary variable, $m_t$, is M2 growth or the Federal Funds rate.

[9]Bernanke and Blinder (1992) did not find a significant response of bank loans to Funds rate shock until six months later.

Table 2 displays the sums of coefficients as well as exclusion test for the lagged variables. Only in the "tight" credit regime does the monetary variable have predictive power for output. The presence of feedback from the paper-bill spread to output is also much stronger in the tight regime than the normal regime regardless of the choice of monetary variables. The sum of coefficients and its standard error are reported respectively in the second and third columns of Table 2. In the model with the M2 growth, the sum of coefficients for CPBILL is not only significant but nearly six times greater in the "tight" regime than in the normal regime. For the model with Fed Funds rate, the sum of coefficients for the monetary variable is negative and statistically significant. The fact the predictive power of the paper-bill spread is substantially weaker for the "normal" credit regime is consistent with results of Gray and Thoma (1994) and Emery (1994) who show that much of explanatory power of the paper-bill spread for output growth is due to episodes in the mid 1970s and early 1980s. Our interpretation of their results is that they are indirectly picking up the change in regime brought about by high values of the paper-bill spread that occurred during these time periods.

## V. Endogenous regimes: Threshold Vector Autoregression.

One of the drawbacks of a single equation approach is that it fails to capture the dynamic interaction of output, inflation, money, and credit conditions. It is possible that money, price, or output shocks could affect credit conditions as well as for credit to affect economic activity. To better capture these interactions, we test for and estimate a threshold vector autoregression (TVAR) in which the entire vector autoregression changes structure depending on the value of the paper-bill spread. The vector autoregression includes four lags each of output growth, inflation, a monetary variable (either M2 growth or the Fed Funds rate), and the paper-bill spread.

Table 3 presents tests of a linear VAR against a threshold alternative. As in the single equation case, we can reject the null hypothesis of linearity in favor of the threshold alternative. For the model with M2 growth as its monetary variable, the estimated threshold variable (MA(2) of CPBILL at t-1) is slightly different than in the single equation case, in part owing to the smaller window over which threshold values were searched and to the fact that additional equations have been added. For the Fed Funds rate, the threshold variable, $CPBILL_{t-2}$, is the same as in the single equation case and the threshold value is nearly identical. To make sure that the results were not overly influenced by the extremely high value of the CPBILL in 1974:3, we conducted the tests for threshold nonlinearity with this observation dropped from the sample. Again, we reject the hypothesis of equality across regimes.[10] Thus, for both monetary measures, the structure of the VAR appears to change when CPBILL spread is "high".

### 5.1 Impulse Response Analysis

To gain some insight into the dynamic properties of this nonlinear VAR, one would like to examine what effects shocks have on the dynamics of the system. In our application, two difficulties present themselves. First, the relatively small number of observations in the "tight" credit regime makes the unparsimonious vector autoregression an unattractive model of the

---

[10] When dropping 1974:3, the p-values for the Sup-Wald, Avg-Wald, and Exp-Wald tests were less than 0.001 for both the model with M2 and the model with the Fed Funds rate. The estimated threshold variable and thresholds were identical to full sample estimates.

dynamics in the upper regime. This was particularly true for the TVAR that includes the Federal Funds rate as a monetary variable. In fact, the unrestricted TVAR that includes the Federal Funds rate was unstable.[11] As a result, the we estimated a restricted TVAR in which we used the Schwartz Information Criterion (SIC) to select the specification for each equation in the tight credit regime. For the system that includes M2 growth as a monetary variable, the unrestricted TVAR was stable, so we present the results for that model below.

Second, the nonlinear structure of the model makes impulse response and variance decomposition analysis substantially more complex than in the linear case.[12] The impulse response function (IRF) is the change in the forecasted valued for $X_{t+k}$ as a result of knowing the value of an exogonous shock $u_t$, or

$$E[X_{t+k}|\Omega_{t-1},u_t] - E[X_{t+k}|\Omega_{t-1}]$$

where $\Omega_{t-1}$ is the information set at time t-1 and $u_t$ is a particular realization of exogenous shocks.[13] Typically, the effect of a single exogenous shock is examined at a time, so that $u_t' = (0,..0, u^i_t, 0, ...,0)$ where $u^i_t$ is a shock to the ith exogenous variable. The difficulty arises because in the threshold VAR, with the exception of current period shocks, the moving average representation is not linear in the shocks (either across shocks or across time). As a result, unlike linear models, the impulse response function for the nonlinear model is in general

[11] To evaluate stability, we simulated the model for 1000 time periods taking as initial conditions the sample means from the data. We repeated this 500 times. The model was deemed unstable if at least one replication yielded exploding values of the variables.

[12] We thank Herman Bierens for making these difficulties clearer to us. See also Potter (1995) and Gallant, Rossi, and Tauchen (1993) for a discussion of nonlinear impulse response analysis.

[13] The model is assumed to be known, so the only source of uncertainty is the realization of future shocks.

conditional on the entire past history of the variables and the size and direction of the shock.[14]

Operationally then, nonlinear impulse analysis requires specifying the nature of the shock (i.e. its size and sign) and the initial condition, $\Omega_{t-1}$. In addition, because the moving average representation of $X_{t+k}$ for the threshold model is not linear in the $u_t$'s, the conditional expectations, $E[X_{t+k}|\Omega_{t-1}, u_t]$ and $E[X_{t+k}|\Omega_{t-1}]$, must be calculated by simulating the model. We do this by randomly drawing vectors of shocks $u_{t+i}$, $i = 1$ to $k$. In fact, for each vector of random shocks, $u_{t+i}$, we also simulate the model for $-u_{t+i}$. This enables us to eliminate any asymmetry that might arise from finite sample variation. This is repeated 100 times and the resulting average is the estimated conditional expectation.

To assess the sensitivity of the impulse response functions to alternative initial conditional and type of shocks, we consider several alternative impulse response experiments for the threshold VAR; these are described in more detail below. To save space, we display impulse response functions for the model that includes M2 growth as the monetary variable. Where there is a qualitative difference between that model and the model that includes the fed funds rate as the monetary variable, we describe the difference in the text.[15] Finally, as a comparison, we also present in Figure 1. the impulse response function (to positive and negative one standard deviation shocks) for a linear VAR. Of special interest is the response of output to money and CPBILL shocks. In the linear model, output growth increases

---

[14] We allowed the contemporaneous VAR\COV matix of the residuals to change across regimes. That is, while we kept the Choleski ordering the same across regimes we allowed the "structural" relationship to change. The ordering is: output, inflation, monetary variable, CPBILL.

[15] Impulse response diagrams for the model that includes the fed funds rate are available upon request.

(decreases) in the short run in response to a positive shock in M2 growth (CPBILL) but quickly returns to zero.

## 5.2 Experiment 1: Average Impulse Response Functions Conditional on Size of Shock

In the first set of impulse response exercises, we calculate the average response to one and two standard deviation shocks. This exercise is closest to the standard impulse response analysis of a linear VAR. Because the impulse response function is likely to be different depending on the past history of the variables, we calculate the average impulse response function where the initial condition, $\Omega_{t-1}$, is essentially drawn from its unconditional distribution. This is done by simulating the model (taking the actual sample means as start-up values) and taking the 500th observation as the initial condition. We then examine the response of the system to positive and negative, one and two standard deviation shocks. We repeat the experiment 500 times and calculate the average impulse response function. The impulse response functions for positive and negative two standard deviation shocks for the model with M2 growth are presented in Figure 2.

Figure 2 suggests some asymmetry, at least for large shocks, for the impulse response function on average. Interestingly, the asymmetries are most evident for large money and CPBILL shocks. Large contractionary monetary shocks (a negative M2 growth shock or a positive Fed Funds shock) have a larger effect on output than positive monetary shocks. In contrast to monetary shocks, the average effect of positive and negative CPBILL shocks are sensitive the choice of monetary variable in the model. Large positive CPBILL shocks have a larger effect, on average, than do positive shocks when M2 is the monetary variable while for the model with the Fed Funds rate large negative CPBILL shocks have a relatively larger effect.

### 5.3 Experiment 2: Impulse Response Functions Conditional on Regime

In order to better understand the dynamics implied by the different regimes, we conduct a second impulse response exercise: we calculate the average impulse response functions conditional on the initial state being in the tight or normal credit regimes. Once again the initial conditions are determined by simulating the model, only now when calculating the response in the tight (normal) regime we use only replications where the economy was in the tight (normal) regime after 500 periods. Again, 500 replications for each regime are used to calculate the average of impulse responses. The response of output to monetary and CPBILL shocks in an economy starting with the tight credit and normal credit regimes are displayed in Figure 3.

Depending on regime, large CPBILL shocks and monetary shocks have very asymmetric effects. In the tight credit regime, positive two standard deviation shocks to the CPBILL spread yield substantially different (and larger) effects on output than do negative shocks. Even in the normal credit regime the responses of output to paper-bill shocks and, to a lesser extent, monetary shocks are asymmetric, as large positive CPBILL shocks can push the economy into the tight credit regime. In addition, shocks to the monetary variable generate a substantially stronger effect on output in the tight credit regime than in the normal credit regime. This evidence is consistent with the findings in the previous section for the single-equation threshold model and with those of McCallum (1991). Furthermore, when in the tight credit regime, large contractionary monetary shocks (negative M2 shocks and positive fed funds shocks) have a larger effect on output than do expansionary shocks. This is consistent with the results of Cover (1992) who found asymmetric effects of money upon output. While the Cover results were motivated in terms of an asymmetric aggregate supply curve, here the interaction between the monetary shocks and the credit regimes generates the asymmetry.

### 5.4 Experiment 3: Unconditional Impulse Response Functions

Finally, as the previous figures suggest, the response of the system may depend on the size of the shock. Restricting shocks to four categories--negative or positive and one or two standard deviations--may unduly limit our understanding of the dynamics implied by the model. As a result, in addition to the experiments considered above, we calculate the analog of a unconditional impulse response function. That is, what is the expected effect of a shock when the size of the shock is not known a priori?

For this experiment, we conducted impulse response analysis in which we simulate the model 500 time periods and then examine the response of the system to a shock. Rather than specify the size of the shock, the shock is now drawn randomly from a normal distribution. We do this 500 times for both positive and negative shocks and calculate the distribution of impulse response functions. For comparison, we also do this for the linear VAR. Figures 4 and 5 plot the average, 25th and 75th percentiles from this distribution for the linear and threshold VAR for two the alternative vector autoregression.

By construction the average response to shocks in the linear VAR is zero and the distribution of responses is symmetric. For the threshold VAR, the average response to shocks is slightly asymmetric (i.e. not equal to zero) and the 25th and 75th percentiles are not symmetric around zero. Note that the shocks in the threshold model tend to have a smaller variance than those of the linear model, yet at horizons 6 through 16 the interior 50% of the distribution of impulse responses is wider for the nonlinear as compared to the linear VAR. Thus, shocks have a large effect on output at horizons greater than six quarters for the threshold VAR than for the linear VAR, even though the original shocks in the threshold model are typically smaller. This is suggestive that the presence of the credit regime helps to propagate not only the shocks to the paper-bill spread but the other shocks as well.

In sum, the three impulse response experiments revealed some interesting nonlinear dynamics in the threshold vector autoregression. Large monetary and credit shocks appear substantially more potent in the tight credit regime than in the normal credit regime. Furthermore, there is evidence of asymmetry as negative monetary shocks have relatively larger effects than do negative shocks. Finally, it appears the shocks in the TVAR get amplified relative to shocks in the linear VAR. All of these are consistent with models in which credit is a propagator of shocks.

## VI. Analysis of Tight Credit Episodes

While the impulse response analysis is suggestive of the role that credit conditions might play as a propagator of shocks, to what extent have credit conditions contributed, either as a source or a propagator shocks, to fluctuations in economic activity? In this section, we explore the implications of the threshold model for understanding economic fluctuations. We do this by first relating how the "tight" credit regimes identified by the TVAR correspond to particular historical tight credit or money episodes discussed in the literature. Second, we reexamine post-1960 macroeconomic history within the context of the TVAR by calculating a nonlinear analog of historical decompositions. Third, we examine two particular episodes in which the economy entered the so-called tight credit regime, yet in which the subsequent path of the economy was very different.

### 6.1 Identification

Figure 6 shows the plot of the two-quarter moving average of paper-bill spread and its associated threshold value[16]. In Panel A the NBER recession periods are shaded, in Panel B the Eckstein and Sinai (1986) precrunch/crunch periods are shaded, and in Panel C the Romer and Romer (1989,1992) dates for Federal Reserve contractionary monetary actions. With the one exception, each NBER recession was preceded by and to large extent coincided with periods in which the credit threshold variable exceeded its threshold value. The lone exception is the 1990-1991 recession. Eckstein and Sinai (1986) identified a credit crunch as "a credit crisis stemming from the collision of an expanding economy with a financial system that has been depleted of liquidity". For our model, periods in which the threshold value is exceeded typically overlap with the precrunch/crunch periods identified by Eckstein and Sinai (1986), although the beginning of the Eckstein-Sinai episodes tend to lead periods in which the credit threshold is exceeded. Owens and Schreft (1995) using a more stringent definition of a credit crunch finds the link between credit crunches and recessions to be weaker. Owens and Schreft define a credit crunch to be "a period of sharply increased nonprice credit rationing."

[16] The plot of the threshold variable and value for the model that contains the fed funds rate instead of M2 growth is qualitatively similar.

The Owens and Schreft credit crunch dates are: 1966:2-1966:3, 1969:2-1969:4, 1980:1-1980:2, and 1990:2-1992:4. All but the 1990-1992 credit crunch are reflected in the "tight" credit regimes identified in this paper. Finally, Romer and Romer identify those dates from both the published accounts of the decisions of the FOMC and the minutes of the FOMC meetings. The "tight" credit regime coincides with four of the five Romer/Romer episodes.

### 6.2 Nonlinear Historical Decompositions

To better understand the contribution of the credit regimes to actual economic fluctuations, we consider a nonlinear analog of the standard historical decomposition typically employed by VAR practitioners. The idea is to use the model as lens through which to view recent macroeconomic history. In particular, we hope to shed light, within the context of our model, on the relative importance of credit conditions as a source of shocks or a propagator of shocks during this period.

As in impulse response analyses, historical decompositions in a nonlinear setting are substantially more complicated than in a linear setting. Consider the k horizon forecast error:

$$X_{t+k} - E[X_{t+k}|\Omega_t]$$

For the linear model, this can be broken into the contribution attributable to various realized exogenous shocks. For the threshold model, while we can extract the realized shocks from the one step ahead forecast errors (i.e. the residuals), the nonlinear nature of the moving average representation precludes breaking up forecast errors into orthogonal contributions. Nonetheless, we can still get an indication of how important particular shocks were to explaining historical episodes. It amounts to answering the question: How much would the forecast change if one had information about the exogenous shocks?[17] By examining how knowledge of the shocks changes the forecast we can get an idea of how those shocks affected actual fluctuations during this time period.

More formally, the change in forecast function (CFF) is defined as

$$CFF(t,k,i) = E[X_{t+k}|\Omega_t,u^i_{t+1},u^i_{t+2},\ldots,u^i_{t+k}]-E[X_{t+k}|\Omega_t]$$

where $\Omega_t$ is the information set at time t, k is the forecast horizon, and $u^i_{t+j}$ is the ith exogenous shock at time t+j. For a linear model, the CFF is identical to the standard historical decomposition. Unlike linear model, for the threshold model the sum of the individual change in forecast functions for the different exogenous shocks is not necessarily equal to the forecast error. The difference between the sum of the individual forecast changes and the actual forecast error reflects the interaction among the shocks that is inherent in the nonlinear moving average representation implied by the threshold model.

Figure 7 presents change in forecast functions for output over the entire sample when M2 growth is the monetary variable. The forecast horizon is set at twelve quarters, so that the change in forecast reflects the shocks that occurred over that twelve quarter interval. The periods of NBER recessions are also shaded in the diagram. To save space we present the change in forecasts only for the model that includes M2 growth as the monetary variable. For the most part, the change in forecast functions for the model with the fed funds rate as the monetary variable are qualitatively similar to those presented here. The exceptions are

[17] An alternative way to get a feel for the importance of realized shocks is to ask the question: What is the forecast error due to not knowing the values of one of the exogenous shocks? While for the linear model this is identical to the change in forecast function (CFF) described in the text, this can yield substantially different results for the nonlinear model. It is also, however, more difficult to interpret and as a result we do not present it in the paper.

mentioned in the text.

Interestingly, despite the presence of the tight credit regime, CPBILL shocks themselves appear to have contributed to less than expected output growth in only three or four instances. The first is in 1969Q3 which is the quarter preceding the 1969-1970 recession. In 1969Q3, the economy was in the tight credit regime--the tight credit threshold had been exceeded in 1969Q2 (recall that the effects of exceeding the threshold occur with a one quarter lag). This quarter also coincides with periods of credit crunches identified by Eckstein and Sinai and Owens and Schreft.[18] The second major episode is during the later half of the 1973-1975 recession. This period saw a dramatic increases in the paper-bill spread, with the spread reaching an all time high in 1974Q3. The negative contribution of CPBILL shocks persists after the recession. The third episode occurs during the 1979-1981 period. During most of this period, the model indicates that the tight credit regime is active. CPBILL shocks do not, however, appear to be important for the latter part of the 1981-1982 recession. Nor do CPBILL shocks appear to have contributed much to the 1990-1991 recession. This is consistent with the generally poor performance of the paper-bill spread in predicting the most recent recession (see Stock and Watson (1992)).

As for monetary shocks, they are relatively important in explaining slower than expected output growth during 1969-1970 recession and to a lesser extent during the 1973-1975 recession. For the model that includes M2 growth as the monetary variable, monetary shocks did not appear to play a major role in the 1980 and 1981-1982 recessions. For the 1981-1982 recession, this is somewhat surprising given the large role that the "Volcker Disinflation" was

[18] When the fed funds rate is in the model the contribution of CPBILL shocks are more important in the subsequent 1969-1970 recession, but for the model with M2 the CPBILL shocks are not a major contributor.

presumed to have played in that recession.[19] Monetary shocks do not appear to be important for the onset of the 1990-1991 recession, but M2 shocks seem to have contributed later in the recession. Finally, perhaps not surprisingly since they come first in the Choleski ordering, output and/or price shocks play an important role in every recession with the exception of the 1969-1970 recession.

Recall that in a nonlinear model, the sum of the change in forecasts functions (CFFs) need not add up to the actual forecast error; the difference to some extent reflects the nonlinear propagator of the shocks. The bottom panel of Figure 7 shows the actual forecast error and the sum of all the individual CFFs. The difference between the two is the result of the interaction between the threshold structure and various shocks that occurred over the twelve quarter interval. For the most part, the actual forecast error and the sum of individual CFFs coincide. The are two interesting exceptions. The first is after the 1973-1975 recession. Here output growth was substantially greater than that implied by the sum of the individual change in forecast functions. Apparently, the threshold nature of the model and the interaction of shocks over this period gave rise to a "bounce-back" from the 1973-1975 recession that is not implied by the individual shocks themselves.[20] To a lesser degree, the model also implies a "bounce-back" from the 1969-1970 recession. The second set of episodes occurs during the 1980 and 1981-1982 recessions. Here actual output growth is substantially less than would be implied by the effect of the individual shocks. The presence of the tight credit regime actually seemed to exacerbate the effect of the individual shocks making these recessions more severe.

---

[19] When the fed funds rates is the monetary variable, fed funds shocks play a more prominent role during these recessions.

[20] See Wynne and Balke (1992) on more evidence of a bounceback effect.

What can the model say about the causes of tight credit regimes? Figure 8 displays the change in forecast function for the two-quarter moving average of the paper-bill spread. The shaded regions in the diagram represent periods of in which the moving average exceeds the estimated threshold value. It appears that paper-bill and money shocks are the major contributors to the episodes of tight credit. The output and price shocks do appear to have contributed to high paper-bill spreads during the tight credit periods, 1973-75 and 1980. This suggests that monetary policy may have been an important contributor to episodes of tight credit identified by the threshold model.

### 6.3 A Tale of Two Regimes

In this section, we use nonlinear historical decompositions to examine in more detail two episodes of in which the economy was in the "tight credit" regime. The first is the 1969-1970 period. Here the tight credit regime preceded a recession. The second episode is the 1987-1989 period during which the tight credit regime was entered into, yet the economy failed to enter a recession. Can the model shed any light why in one case the "tight" credit regime foreshadowed a recession while in the other it did not?

Figure 9 plots the estimated exogenous (orthogonal) shocks to each of the variables in the system for both time periods. Figure 10 plots the change in forecast functions of output, starting in 1969:1 and 1987:1 respectively, for shocks to output, M2, the paper-bill spread, as well as the actual forecast error and the sum of the change in forecast functions implied by the individual shocks (including inflation)[21]. Figure 11 plots the change in forecast functions

[21] Inflation shocks did not have an important contribution in either period so in order to save space we did not report them separately.

of the credit conditions threshold variable (here the two quarter moving average of the paper-bill spread lagged once). In all three figures, the shaded region indicates the tight credit regime.

From Figure 9, we observe that negative money and positive paper-bill shocks preceded the both episodes of tight credit regimes; the positive CPBILL shock in 1969:2 is quite large--over two standard deviations. These were enough to propel our credit conditions variable into the "tight" regime for both episodes. Despite that common feature, the pattern of shocks in the two episodes differs in two important respects. First, in mid-1969 negative and relatively large output shocks occurred while the opposite occurred in mid-1987. Second, once the tight credit regime was entered, negative M2 shocks continue in the 1969 episode but not in 1987 episode. The positive output shocks in the 1987 episode offset the initial negative paper-bill and money shocks while output, money, and paper-bill all shocks contributed to less than expected output growth in the 1969 episode (see Figure 10). Furthermore, continued negative M2 shocks in 1969 and early 1970 contributed both to the tight credit conditions and lower than expected output growth. These continuing negative monetary shocks were not present during the 1987 episode.

Again, by comparing the forecast error implied by the model with the sum of the change in forecast functions for the individual shocks, we get a sense of the role that the threshold structure for propagating shocks (recall that for a linear model the sum of the individual change in forecast functions equals the actual forecast error). For the 1969-1971 episode, with the exception of 1969:2 and 1971:1, output growth was lower than that implied by sum of the effects of the individual shocks. This suggests that the presence of the tight credit regime on balance caused output to lower than would be implied by the shocks themselves. The 1971:1 represents the first quarter of the subsequent recovery, and the higher growth than that implied by the effects of the shocks may reflect a "bounce back" effect in which output grows faster in the early stages of a recovery. For the credit conditions variable, the presence of the threshold resulted in higher paper-bill spreads that those implied by the individual shocks suggesting the nonlinear nature of the credit affect increased the duration of the tight credit regime. For the 1987-1989 episode, the actual forecast error and the change in forecast functions are fairly close to one another implying that the nonlinear nature of the model was not as important in explaining fluctuation in output as in the previous episode.

**VII. Conclusion**

In this paper, we attempt to evaluate the role that credit conditions play in determining economic activity and whether they act as a propagator of shocks in addition to being a source of shock. With this goal in mind, we employ nonlinear time series models, univariate and multivariate, in which a regime change occurs if commercial paper/T-Bill spread exceeds a critical threshold. These threshold models are attractive because they are capable of generating behavior such as regime switching and asymmetry that are characteristic of models of credit frictions. In a single equation model, we find that the effect on output growth of the paper-bill spread and money growth is significantly larger, and that they have more predictive content in the "tight" credit regime than in the "normal" regime. We also endogenize the credit regimes by employing a threshold vector autoregression; here shocks to other variables in the system (output, money, and inflation) as well as to the paper-bill spread can cause the credit regime to switch. We conduct several nonlinear impulse response experiments in order to understand the effect that the switching credit regimes have on output dynamics. We find that the response of output growth to monetary shocks and shocks in the paper-bill spread are asymmetric; in particular, in the "tight" credit regime negative monetary shocks have a larger effect than do positive shocks. Furthermore, the presence of the "tight" credit regime tends to amplify shocks relative to a linear VAR. We also examine a nonlinear analog of historical decompositions to see the relative contribution of various shocks to fluctuations in output over the sample and for evidence that the switching regime structure played an important role in the propagation of these shocks. On balance, the both the impulse response and historical decomposition analyses are consistent with credit being a propagator of shocks as well as a source of shocks.

In future research, we would like to consider a measure of credit conditions that would reflect not only the paper-bill spread but also other credit conditions indicators used in the literature such as credit velocity, the ratio between securities and loans in banks' portfolios (Ramey (1993)), and the 'mix' between loans and commercial papers issuance (Kashyap, Stein, and Wilcox (1993)). Perhaps, a linear combination of these alternative indicators (as implied by dynamic index model (Sargent and Sims (1977)) might be a better indicator of credit conditions than the paper-bill spread alone.

## References

Andrews, Donald (1993) "Tests for Parameter Instability and Structural Change with Unknown Change Point," *Econometrica*, 61(4), 821-856.

Andrews, Donald and Werner Ploberger (1992) "Optimal Tests When a Nuisance Parameter Is Present Only under the Alternative," Cowles Foundation for Research in Economics, manuscript.

Azariadis, Costas and B. Smith (1994) "Financial Intermediation and regime Switching in Business Cycles," Working Paper.

Bernanke, Ben (1990) "On the Predictive Power of Interest Rates and Interest Rate Spreads," *New England Economic Review*, November/December, 51-68.

Bernanke, Ben (1986) "Alternative Explanations of the Money-Income Correlation," *Carnegie-Rochester Conference Series on Public Policy*, 25, 49-100.

Bernanke, Ben and Alan Blinder (1992) "The Federal Funds Rate and the Channels of Monetary Transmission," *American Economic Review*, 82, 901-21.

Bernanke, Ben and Mark Gertler (1989) "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review*, 79, 14-31.

Blinder, Alan (1987) " Credit Rationing and Effective Supply Failures," *Economic Journal*, 97, 327-52.

Chan, K. S. (1993) "Consistency and Limiting Distribution of the Least Squares Estimator of a Threshold Autoregressive Model," *The Annals of Statistics*, 21, 520-33.

Cover, James Peery (1992) "Asymmetric Effects of Positive and Negative Money Supply Shocks," *Quarterly Journal of Economics*, 107, 1261-1282.

Davies, R. B. (1977) "Hypothesis Testing when a Nuisance Parameter Is Present Only under the Alternative," *Biometrica*, 64, 247-54.

______ (1987) "Hypothesis Testing when a Nuisance Parameter Is Present Only under the Alternative," *Biometrica*, 74, 33-43.

Eckstein, Otto and Allen Sinai (1986) "The Mechanisms of the Business Cycle in the Postwar Era," *American Business Cycles*, ed. R. Gordon, 39-122.

Emery, Ken (1994) "The Information Content of the Paper-Bill Spread," Federal Reserve Bank of Dallas, Working Paper 94-12.

Friedman, Benjamin (1983) "Monetary Policy with a Credit Aggregate Target," *Carnegie-Rochester Conference Series on Public Policy*, 18, 117-148.

Friedman, Benjamin and Kenneth Kuttner (1992) "Money, Income, Prices, and Interest Rates," *American Economic Review*, 82, 472-92.

______ (1993a) "Another Look at the Evidence on Money-Income Causality," *Journal of Econometrics*, 57, 189-203.

______ (1993b) "Economic Activity and the Short-term Credit Markets: An Analysis of Prices and Quantities," *Brookings Paper on Economic Activity*, 2, 193-283.

Gallant, A. Ronald, Peter E. Rossi, and George Tauchen (1993) "Nonlinear Dynamic Structures," *Econometrica*, 61(4), 871-908.

Gertler, Mark (1988) "Financial Structure and Aggregate Economic Activity: An Overview," *Journal of Money, Credit, and Banking*, 20(3), 559-88.

Gertler, Mark and Simon Gilchrist (1993) "The Role of Credit Market Imperfections in the Monetary Transmission Mechanism: Arguments and Evidence," *Scandinavian Journal of economics*, 95(1), 43-64.

Gertler, Mark and R. Hubbard and A. Kashyap (1990) "Interest Rate Spreads, Credit Constraints, and Investment Fluctuations: An Empirical Investigation," Manuscript.

Gray, Joanna and Mark A Thoma (1994) "On Leading Indicators: Getting It Straight," 1994 Texas Conference on Monetary Economics, Paper No. 4.

Hansen, Bruce (1994) "Inference When a Nuisance Parameter Is Not Identified Under the Null Hypothesis," Working Paper.

Kashyap, Anil and J. Stein, D. Wilcox (1993) "Monetary Policy and Credit Conditions: Evidence from the Composition of External Finance," *American Economic Review*, 83, 78-98.

King, Stephen R. (1986) "Monetary Transmission: Through Bank Loans or Bank Liabilities?" *Journal of Money, Credit, and Banking*, 18(3), 290-303.

Kiyotaki, N. and J. Moore (1993) "Credit Cycles," University of Minnesota mimeo.

McCallum, John (1991) "Credit Rationing and the Monetary Transmission mechanism," *American Economic Review*, 81, 946-51.

Owens, Raymond E. and Stacey L. Schreft (1995) "Identifying Credit Crunches," *Contemporary Economic Policy*, 13(2), 63-76.

Potter, Simon (1995) "A Nonlinear Approach to US GNP," *Journal of Applied Econometrics*, 10, 109-125.

Ramey, Valerie A. (1993) "How Important Is the Credit Channel in the Transmission of Monetary policy?" NBER Working Paper #4285.

Romer Christina D. and David Romer (1989) "Does Monetary Policy Matter? A New test in the Spirit of Friedman and Schwartz," *NBER Macroeconomics Annual*, 4, 121-70.

______ (1990) "New Evidence on the Monetary Transmission Mechanism," *Brookings Paper on Economic Activity*, 1, 149-213.

Sargent, Thomas J. and Christopher A. Sims (1977) "Business Cycle Modelling Without Pretending to Have Too Much A Priori Economic Theory," In *New Methods in Business Cycle Research*, ed. Christopher A. Sims, Minneapolis: Federal Reserve Bank of Minneapolis.

Stock, James and Mark Watson (1989) "New Indexes of Coincident and Leading Economic Indicators," *NBER Macroeconomics Annual*, 351-394.

Stock, James and Mark Watson (1989) "Interpreting the Evidence on Money-Income Causality," *Journal of Econometrics*, 40, 161-81.

Strongin, Steven (1992) "The Identification of Monetary Policy Disturbance: Explaining the Liquidity Puzzle," Federal Reserve Bank of Chicago, Working Paper 92-27.

Vijverberg, Chu-Ping (1994) "Credit Rationing and Firm Investment - A Switching Regression Model," unpublished manuscript, University of Texas at Dallas.

Wynne, Mark A. and Nathan S. Balke (1992) "Are Deep Recessions Followed by Strong Recoveries," *Economics Letters*, 39(2), 183-189.

## TABLE 1: TESTS OF NON-LINEARITY IN OUTPUT

**Model with M2 Growth as the Monetary Variable:**

**Test Statistics:**

| | Statistic | P-value |
|---|---|---|
| Sup-Wald | 51.62 | 0.038 |
| Avg-Wald | 20.02 | 0.048 |
| Exp-Wald | 20.66 | 0.042 |

| Threshold Variable | Maximum Wald for Individual Threshold Variable | $\gamma$ |
|---|---|---|
| CPBill(t-1) | 44.34 | 0.8667 |
| CPBill(t-2) | 38.97 | 0.8733 |
| **CPBill(t-3)** | **51.62** | **0.8733** |
| CPBill MA(2)(t-1) | 41.53 | 0.8550 |
| CPBill MA(2)(t-2) | 47.43 | 0.8617 |
| CPBill MA(3)(t-1) | 46.36 | 0.8567 |

**Model with Fed Fund Rate as the Monetary Variable:**

**Tests of Linearity:**

| | Statistic | P-value |
|---|---|---|
| Sup-Wald | 57.10 | 0.010 |
| Avg-Wald | 30.27 | 0.000 |
| Exp-Wald | 23.69 | 0.000 |

| Threshold Variable | Maximum Wald for Individual Threshold Variable | $\gamma$ |
|---|---|---|
| CPBill(t-1) | 51.57 | 0.2700 |
| **CPBill(t-2)** | **57.10** | **0.7831** |
| CPBill(t-3) | 40.09 | 0.3120 |
| CPBill MA(2)(t-1) | 46.16 | 0.8550 |
| CPBill MA(2)(t-2) | 47.59 | 0.8942 |
| CPBill MA(3)(t-1) | 51.57 | 0.7932 |

**Notes**: Hansen's (1993) method of inference with 500 replications is applied to find the critical values.

**TABLE 2: Single Equation Output Regression Results**

**MODEL: Threshold Model with M2 Growth as Monetary Variable**

| Lagged Variable | Sum | S.E. | Exclusion F(4,103) | P-value |
|---|---|---|---|---|
| Tight Regime ($CPBILL_{t-3} \geq 0.8733$) | | | | |
| $\Delta y$ | -0.647 | 0.424 | 3.261** | 0.015 |
| $\Delta p$ | -0.194 | 0.555 | 1.981 | 0.103 |
| $\Delta m$ | -0.272 | 0.571 | 3.092** | 0.019 |
| CPBILL | -8.501** | 3.784 | 5.864*** | 0.000 |
| Normal Regime ($CPBILL_{t-3} < 0.8733$) | | | | |
| $\Delta y$ | 0.211 | 0.181 | 0.386 | 0.818 |
| $\Delta p$ | -0.434*** | 0.156 | 2.566** | 0.042 |
| $\Delta m$ | 0.285** | 0.112 | 1.664 | 0.164 |
| CPBILL | -1.594 | 0.473 | 1.583 | 0.184 |

**MODEL: Threshold Model with Fed Funds Rate as Monetary Variable**

| Lagged Variable | Sum | S.E. | Exclusion F(4,103) | P-value |
|---|---|---|---|---|
| Tight Regime ($CPBILL_{t-2} \geq 0.7831$) | | | | |
| $\Delta y$ | 0.241 | 0.470 | 4.412*** | 0.002 |
| $\Delta p$ | 0.742 | 0.525 | 1.437 | 0.229 |
| Fed Funds Rate | -1.165*** | 0.378 | 7.972*** | 0.000 |
| CPBILL | -4.213 | 2.700 | 8.794*** | 0.000 |
| Normal Regime ($CPBILL_{t-2} < 0.7831$) | | | | |
| $\Delta y$ | 0.152 | 0.206 | 0.204 | 0.936 |
| $\Delta p$ | -0.074 | 0.188 | 1.171 | 0.328 |
| Fed Funds Rate | -0.101 | 0.143 | 1.000 | 0.411 |
| CPBILL | -1.736 | 1.799 | 2.855*** | 0.027 |

**Notes**: 'Sum' is the sum of coefficients of the lagged variable, and the p-value is based on the t-statistics for 'sum' equal to 0. Reported F-statistics results from testing whether the coefficients of the lagged variable are jointly significant.
*** indicates significance at the 1% level.
** indicates significance at the 5% level.
* indicates significance at the 10% level.

## TABLE 3: TESTS OF NON-LINEARITY IN VECTOR AUTOREGRESSION

**Model with M2 Growth as the Monetary Variable:**

**Tests of Linearity:**

| | Statistic | P-value |
|---|---|---|
| Sup-Wald | 208.17 | 0.00 |
| Avg-Wald | 92.09 | 0.00 |
| Exp-Wald | 98.69 | 0.00 |

| Threshold Variable | Maximum Wald for Individual Threshold Variable | $\gamma$ |
|---|---|---|
| CPBill(t-1) | 201.46 | 0.7267 |
| CPBill(t-2) | 164.25 | 0.7844 |
| CPBill(t-3) | 188.42 | 0.7844 |
| **CPBill MA(2)(t-1)** | **208.17** | **0.7621** |
| CPBill MA(2)(t-2) | 190.73 | 0.7783 |
| CPBill MA(3)(t-1) | 194.69 | 0.8144 |

**Model with Fed Fund Rate as the Monetary Variable:**

**Tests of Linearity:**

| | Statistic | P-value |
|---|---|---|
| Sup-Wald | 248.46 | 0.00 |
| Avg-Wald | 118.54 | 0.00 |
| Exp-Wald | 118.21 | 0.00 |

| Threshold Variable | Maximum Wald for Individual Threshold Variable | $\gamma$ |
|---|---|---|
| CPBill(t-1) | 243.75 | 0.7844 |
| **CPBill(t-2)** | **248.46** | **0.7844** |
| CPBill(t-3) | 193.72 | 0.7844 |
| CPBill MA(2)(t-1) | 210.28 | 0.7933 |
| CPBill MA(2)(t-2) | 236.05 | 0.7621 |
| CPBill MA(3)(t-1) | 233.05 | 0.6989 |

**Notes**: Hansen (1991) method of inference with 100 replications is applied to find the critical values. We start the 'window' in the Wald test with the number of parameters plus 10 percent of the whole sample.

**Figure 1. Impulse Response Function for Linear VAR**

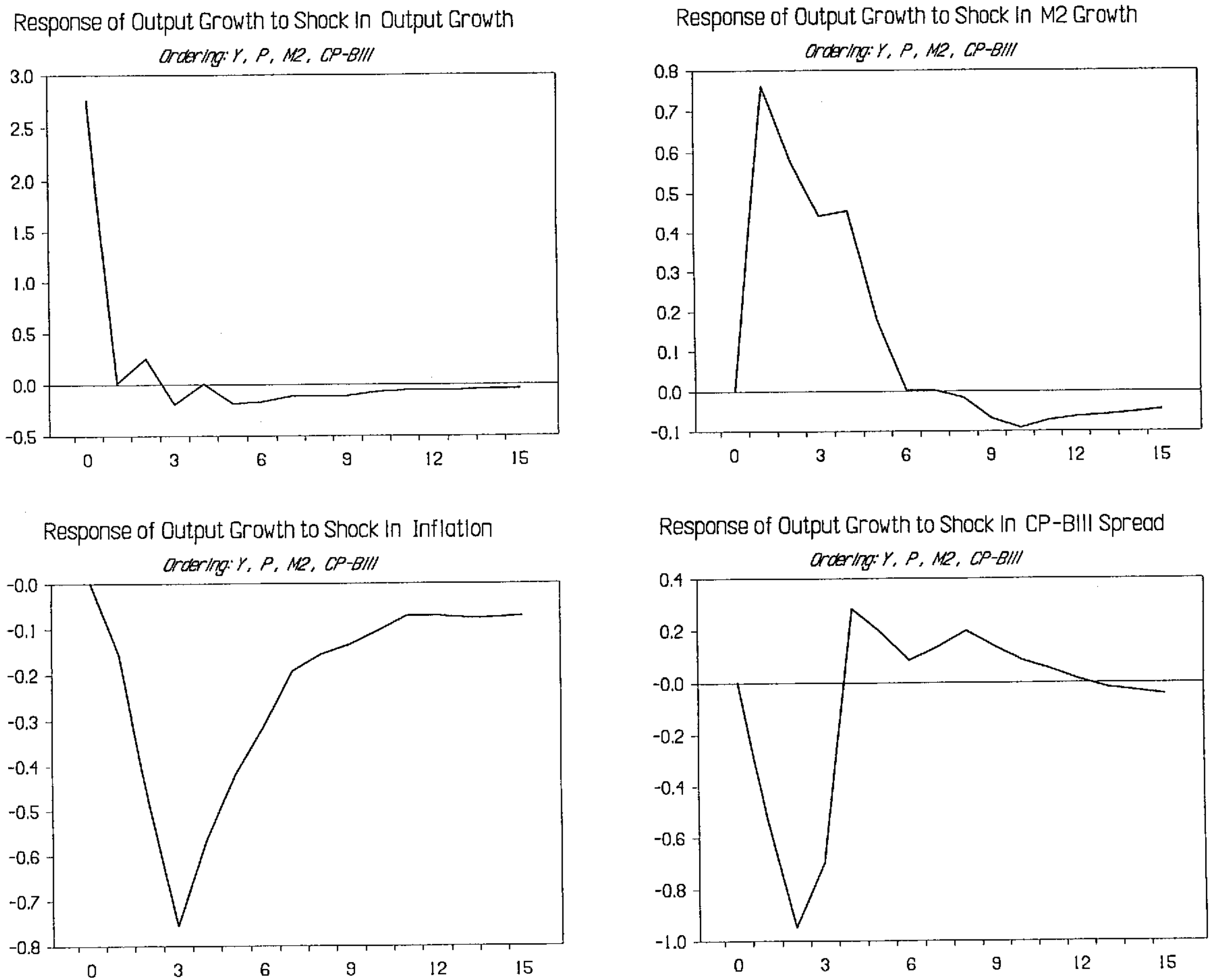


**Figure 2. Average Impulse Response for Threshold VAR**

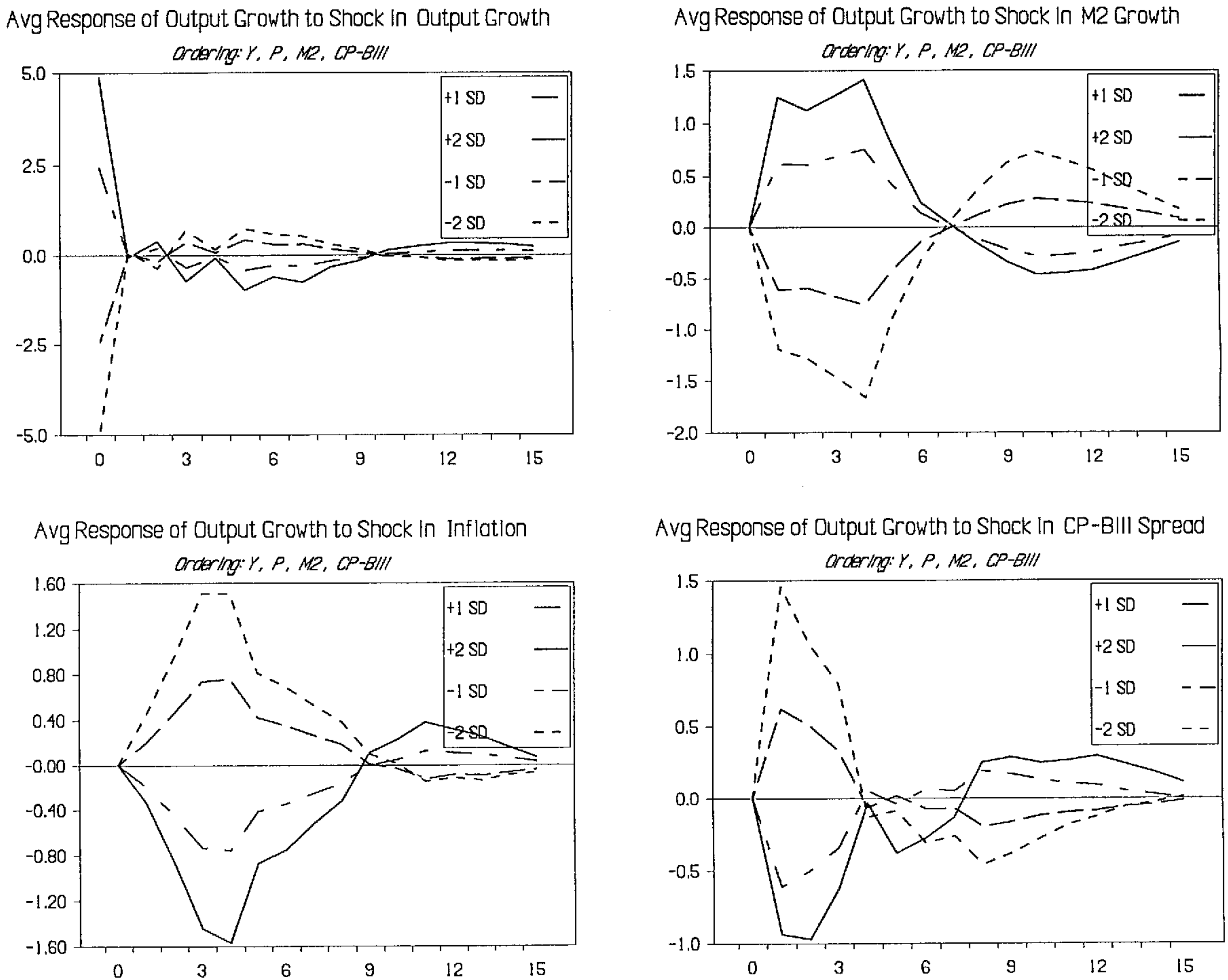


**Figure 3. Response of Output Growth to M2 Growth and Paper-Bill Shocks, Conditional on Regime**

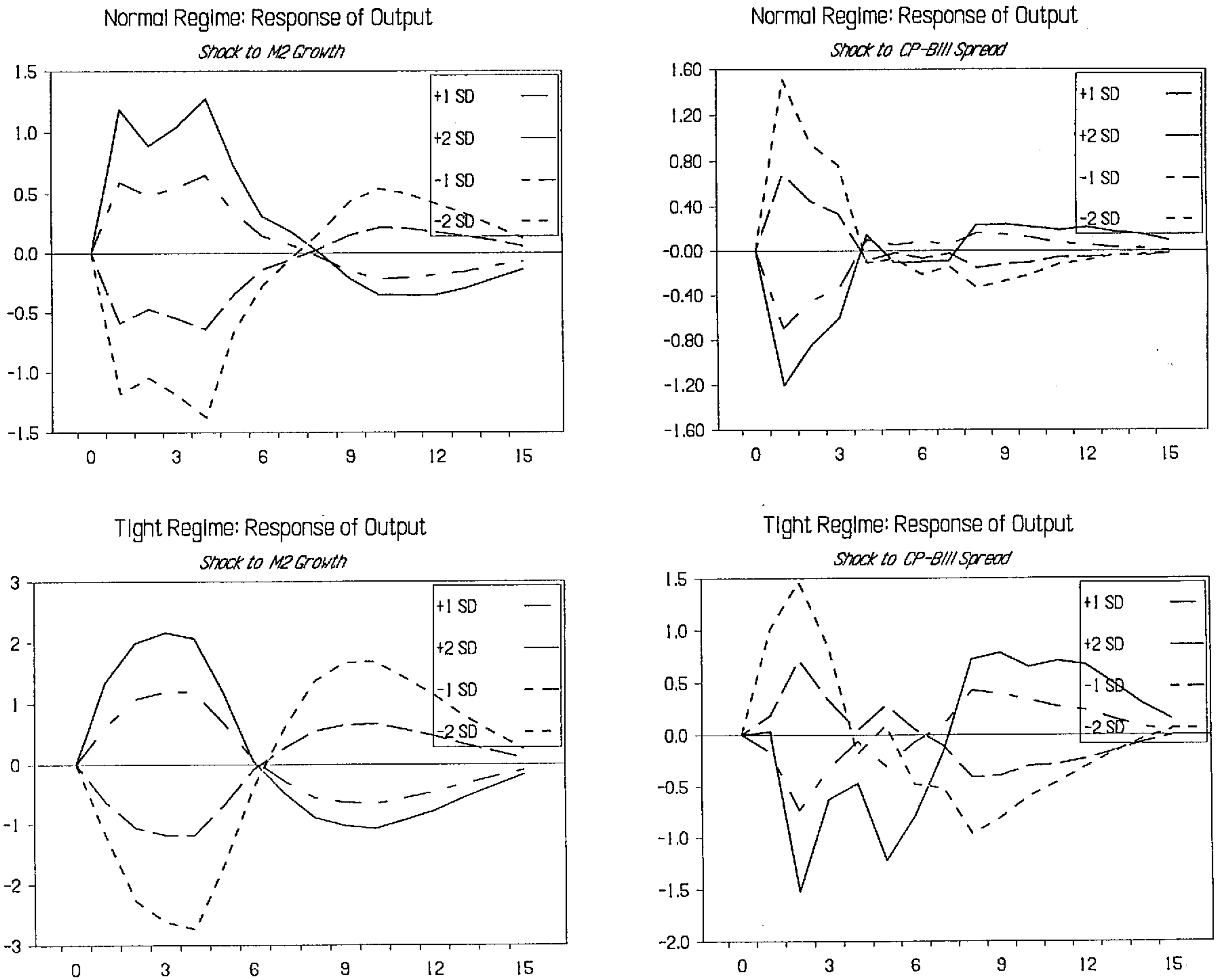


**Figure 4. Distribution of Impulse Responses for Linear VAR**

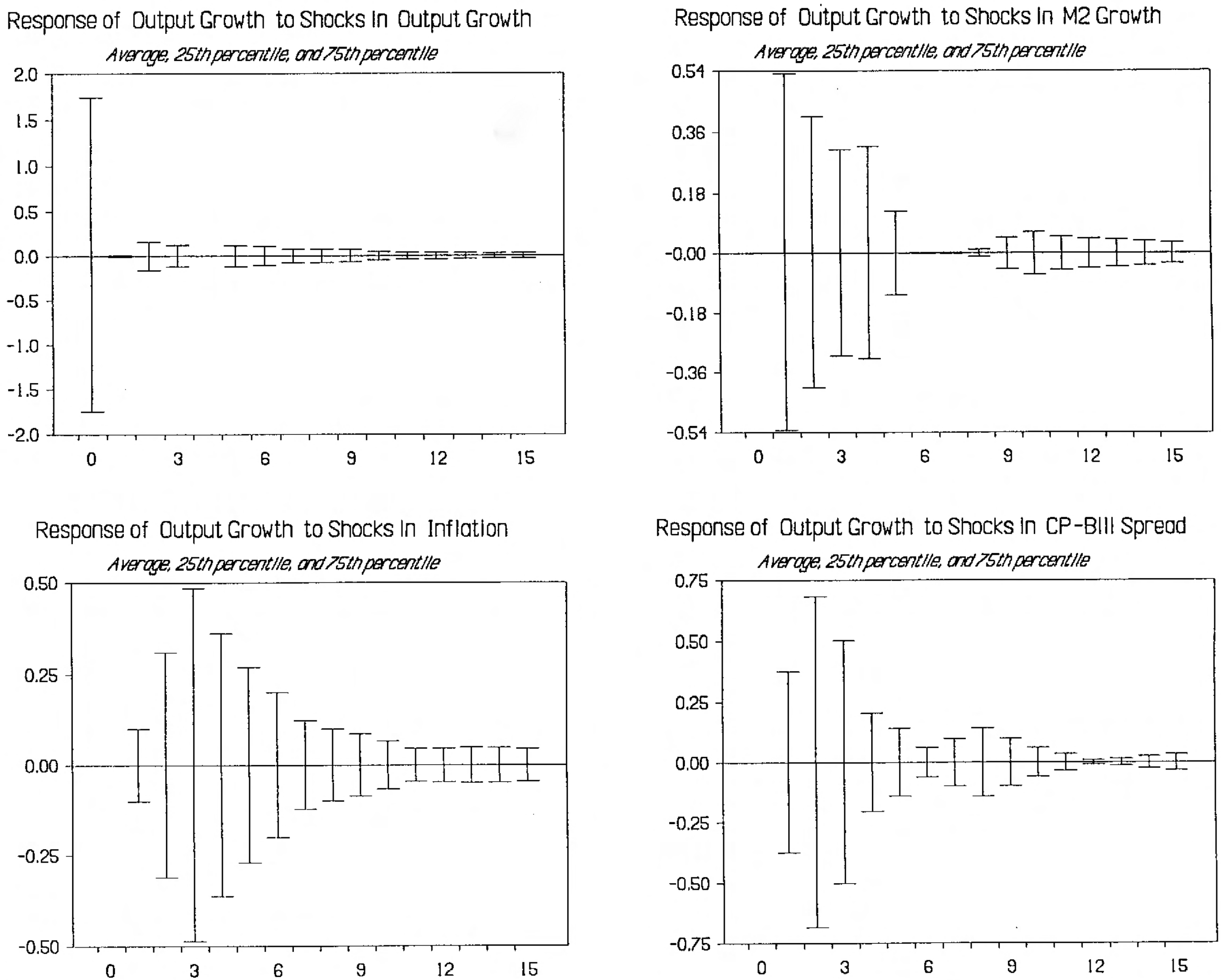


**Figure 5. Distribution of Impulse Responses for Threshold VAR**

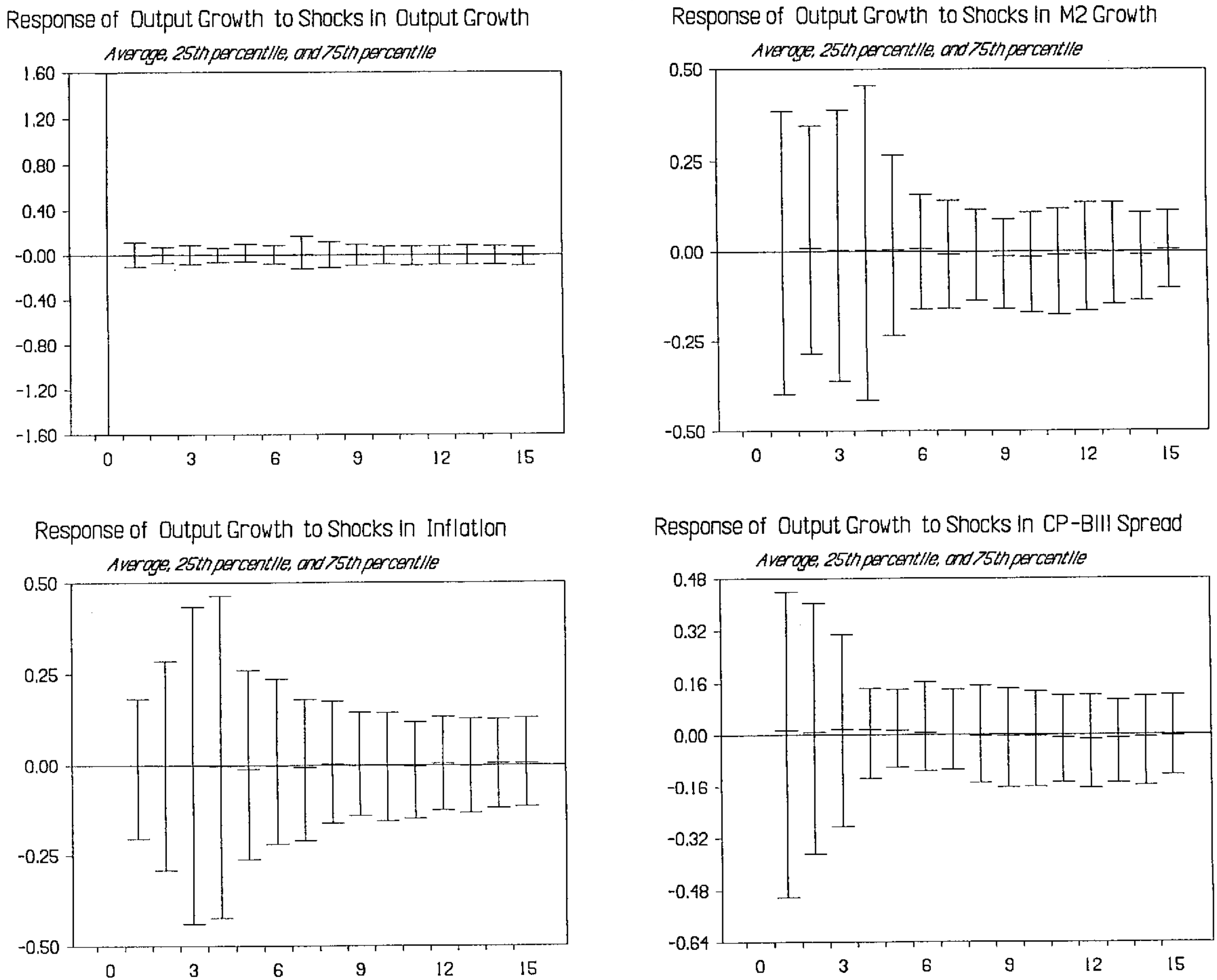
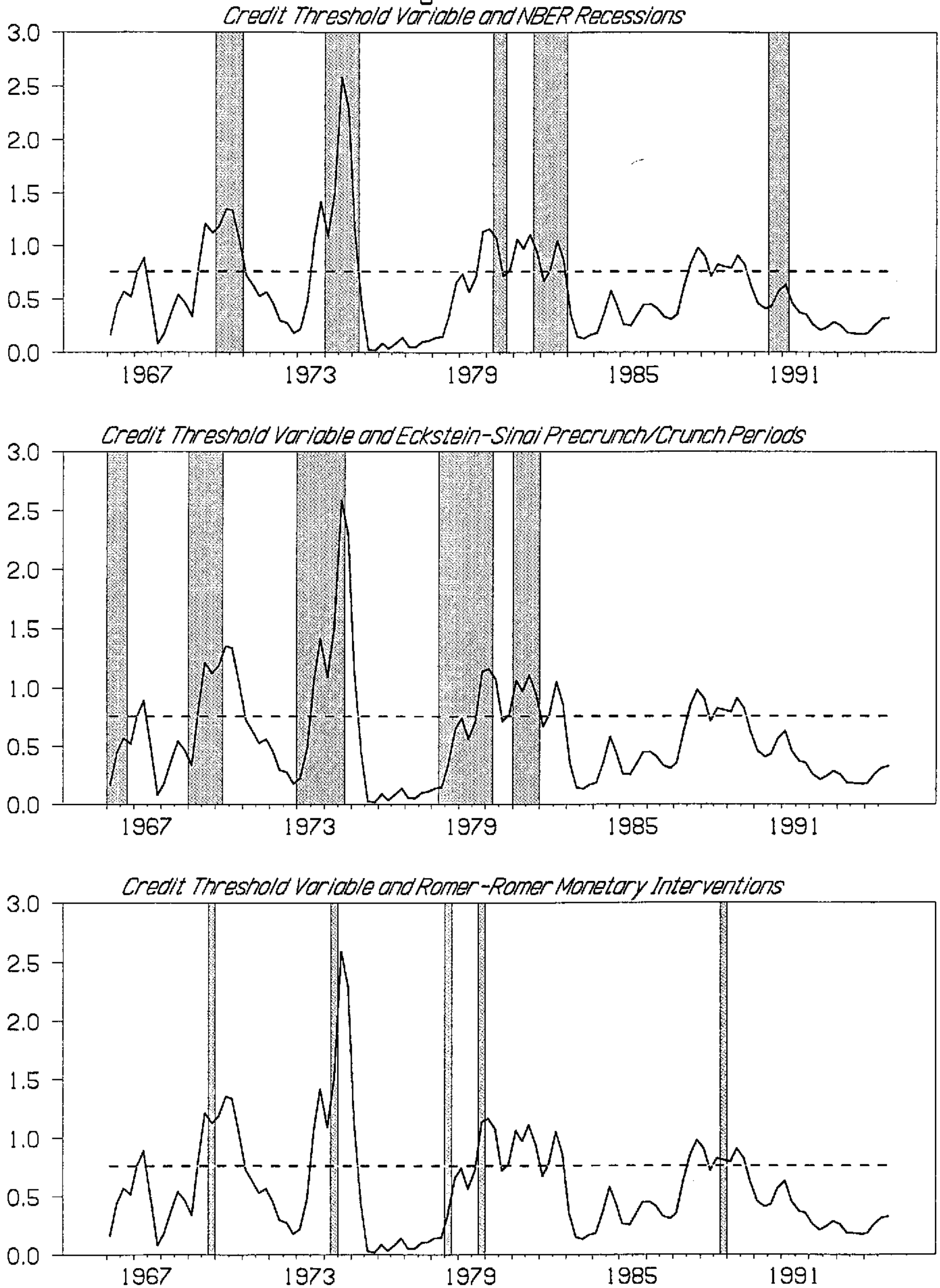


Figure 6.


Credit Threshold Variable and NBER Recessions
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1967
1973
1979
1985
1991
Credit Threshold Variable and Eckstein-Sinai Precrunch/Crunch Periods
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1967
1973
1979
1985
1991
Credit Threshold Variable and Romer-Romer Monetary Interventions
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1967
1973
1979
1985
1991

# Figure 7. Change in Forecast Functions for Output Growth

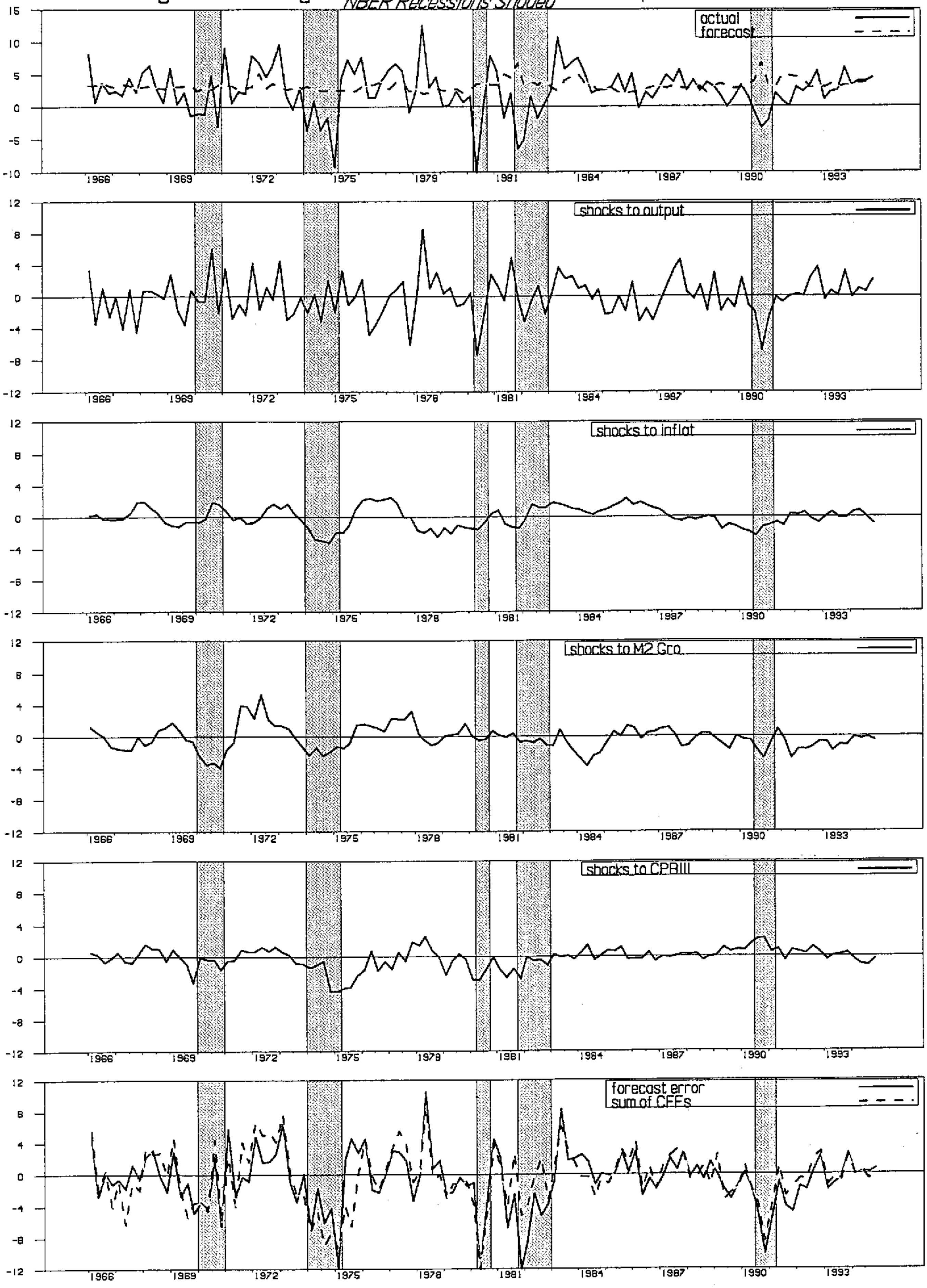


Figure 8. Change in Forecast Functions for Credit Threshold Variable

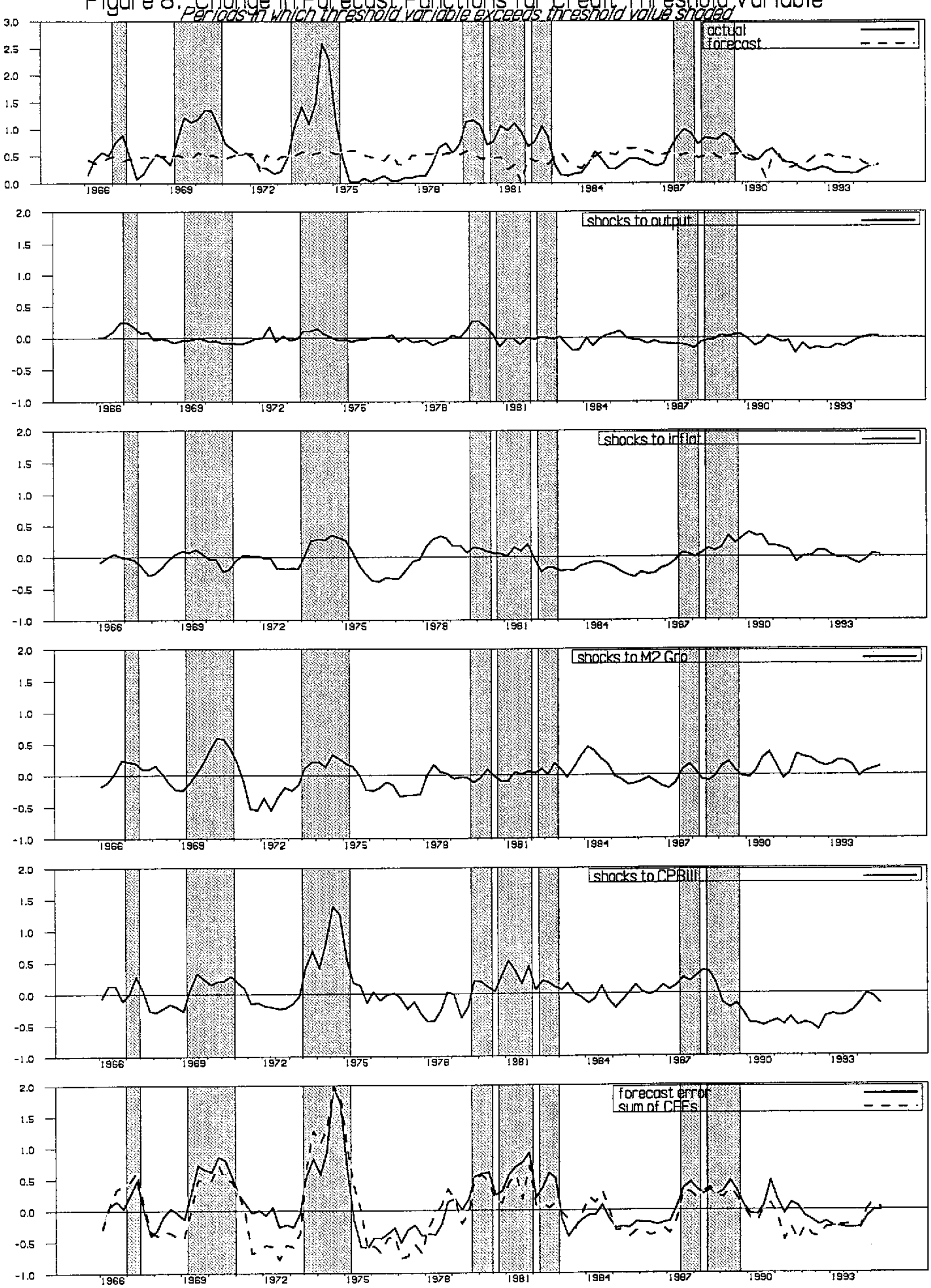


**Figure 9. "Structural" Shocks for 1969-1970 and 1987-1989.**

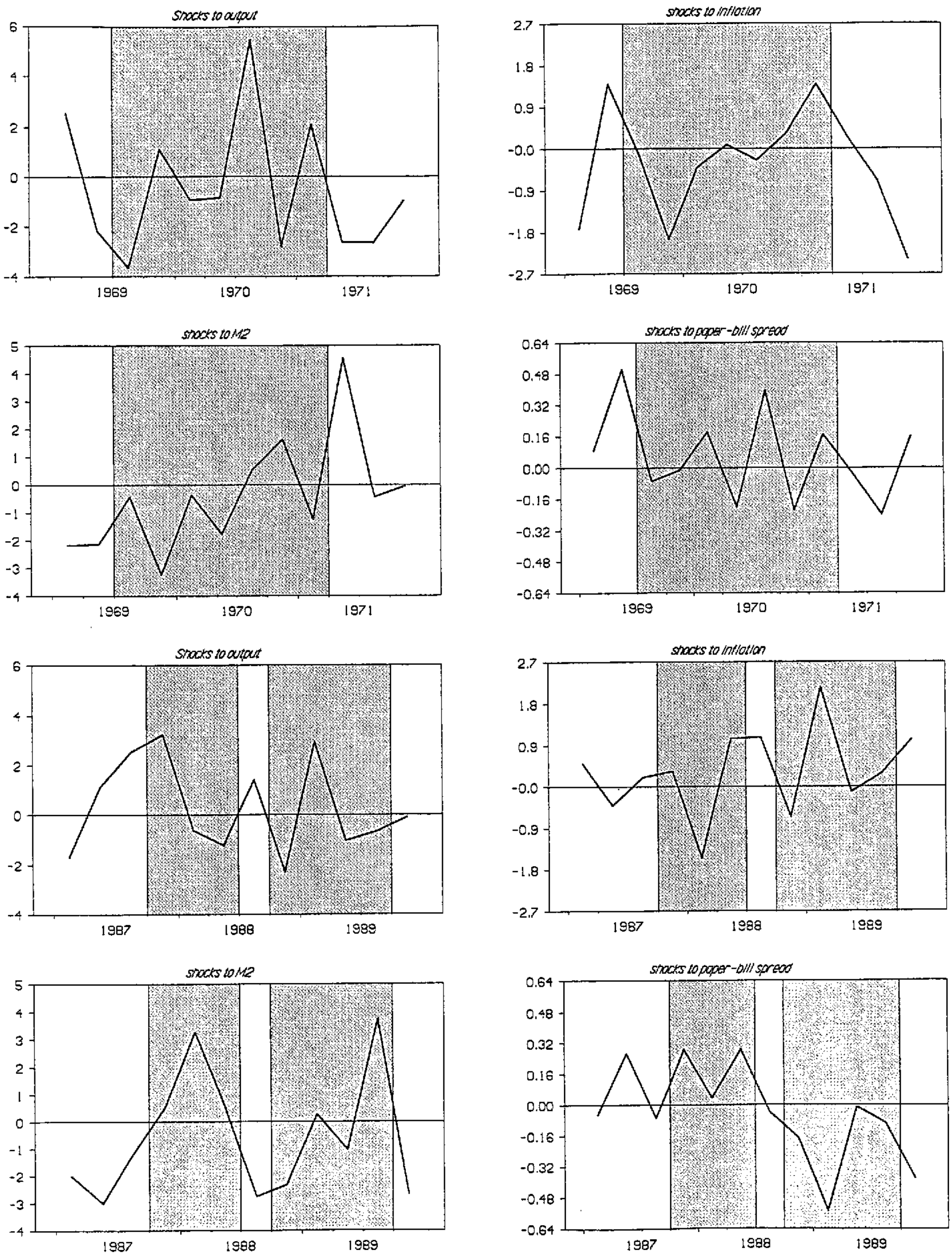


**Figure 10. Change in Forecast Function for Output, 1969-1971 and 1987-1989.**

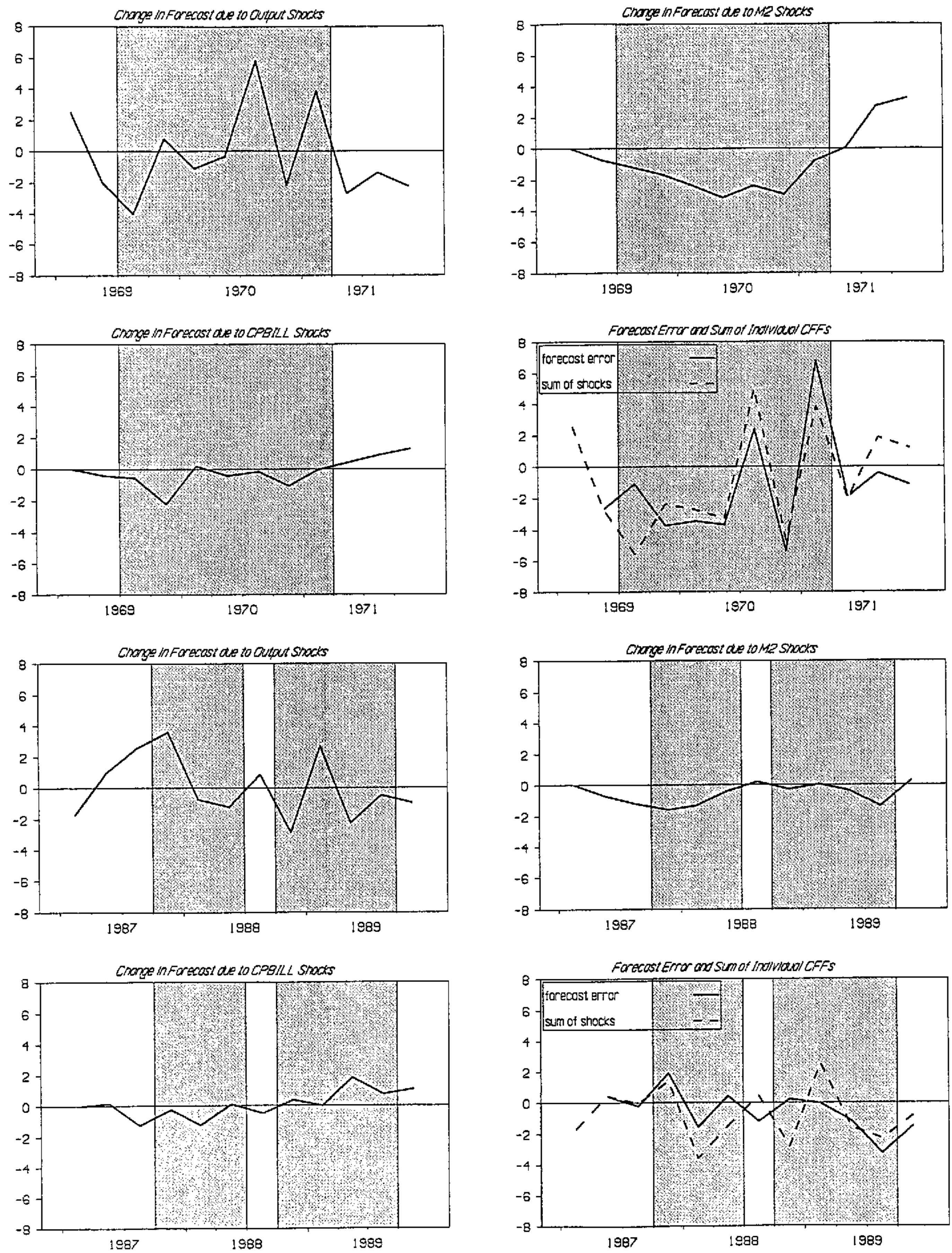
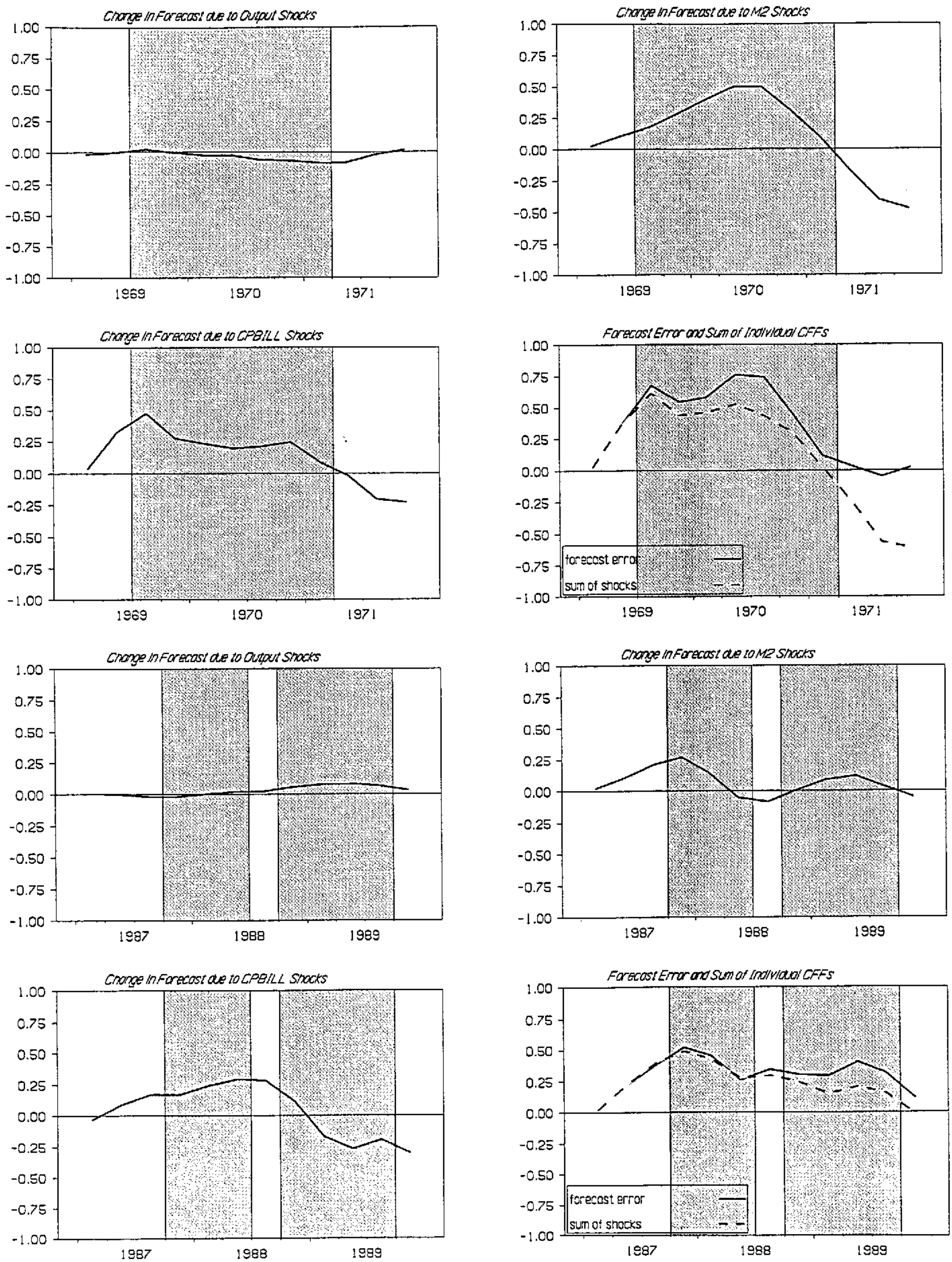


**Figure 11. Change in Forecast Function for Credit Threshold Variable, 1969-1971 and 1987-1989.**



RESEARCH PAPERS OF THE RESEARCH DEPARTMENT
FEDERAL RESERVE BANK OF DALLAS

Available, at no charge, from the Research Department
Federal Reserve Bank of Dallas, P. O. Box 655906
Dallas, Texas 75265-5906

Please check the titles of the Research Papers you would like to receive:

___ 9201 Are Deep Recessions Followed by Strong Recoveries? (Mark A. Wynne and Nathan S. Balke)
___ 9202 The Case of the "Missing M2" (John V. Duca)
___ 9203 Immigrant Links to the Home Country: Implications for Trade, Welfare and Factor Rewards (David M. Gould)
___ 9204 Does Aggregate Output Have a Unit Root? (Mark A. Wynne)
___ 9205 Inflation and Its Variability: A Note (Kenneth M. Emery)
___ 9206 Budget Constrained Frontier Measures of Fiscal Equality and Efficiency in Schooling (Shawna Grosskopf, Kathy Hayes, Lori L. Taylor, William Weber)
___ 9207 The Effects of Credit Availability, Nonbank Competition, and Tax Reform on Bank Consumer Lending (John V. Duca and Bonnie Garrett)
___ 9208 On the Future Erosion of the North American Free Trade Agreement (William C. Gruben)
___ 9209 Threshold Cointegration (Nathan S. Balke and Thomas B. Fomby)
___ 9210 Cointegration and Tests of a Classical Model of Inflation in Argentina, Bolivia, Brazil, Mexico, and Peru (Raul Anibal Feliz and John H. Welch)
___ 9211 Nominal Feedback Rules for Monetary Policy: Some Comments (Evan F. Koenig)
___ 9212 The Analysis of Fiscal Policy in Neoclassical Models[1] (Mark Wynne)
___ 9213 Measuring the Value of School Quality (Lori Taylor)
___ 9214 Forecasting Turning Points: Is a Two-State Characterization of the Business Cycle Appropriate? (Kenneth M. Emery & Evan F. Koenig)
___ 9215 Energy Security: A Comparison of Protectionist Policies (Mine K. Yücel and Carol Dahl)
___ 9216 An Analysis of the Impact of Two Fiscal Policies on the Behavior of a Dynamic Asset Market (Gregory W. Huffman)
___ 9301 Human Capital Externalities, Trade, and Economic Growth (David Gould and Roy J. Ruffin)
___ 9302 The New Face of Latin America: Financial Flows, Markets, and Institutions in the 1990s (John Welch)
___ 9303 A General Two Sector Model of Endogenous Growth with Human and Physical Capital (Eric Bond, Ping Wang, and Chong K. Yip)
___ 9304 The Political Economy of School Reform (S. Grosskopf, K. Hayes, L. Taylor, and W. Weber)
___ 9305 Money, Output, and Income Velocity (Theodore Palivos and Ping Wang)
___ 9306 Constructing an Alternative Measure of Changes in Reserve Requirement Ratios (Joseph H. Haslag and Scott E. Hein)
___ 9307 Money Demand and Relative Prices During Episodes of Hyperinflation (Ellis W. Tallman and Ping Wang)
___ 9308 On Quantity Theory Restrictions and the Signalling Value of the Money Multiplier (Joseph Haslag)
___ 9309 The Algebra of Price Stability (Nathan S. Balke and Kenneth M. Emery)
___ 9310 Does It Matter How Monetary Policy is Implemented? (Joseph H. Haslag and Scott Hein)
___ 9311 Real Effects of Money and Welfare Costs of Inflation in an Endogenously Growing Economy with Transactions Costs (Ping Wang and Chong K. Yip)
___ 9312 Borrowing Constraints, Household Debt, and Racial Discrimination in Loan Markets (John V. Duca and Stuart Rosenthal)
___ 9313 Default Risk, Dollarization, and Currency Substitution in Mexico (William Gruben and John Welch)
___ 9314 Technological Unemployment (W. Michael Cox)
___ 9315 Output, Inflation, and Stabilization in a Small Open Economy: Evidence from Mexico (John H. Rogers and Ping Wang)
___ 9316 Price Stabilization, Output Stabilization and Coordinated Monetary Policy Actions (Joseph H. Haslag)
___ 9317 An Alternative Neo-Classical Growth Model with Closed-Form Decision Rules (Gregory W. Huffman)
___ 9318 Why the Composite Index of Leading Indicators Doesn't Lead (Evan F. Koenig and Kenneth M. Emery)

___ 9319 Allocative Inefficiency and Local Government: Evidence Rejecting the Tiebout Hypothesis (Lori L. Taylor)
___ 9320 The Output Effects of Government Consumption: A Note (Mark A. Wynne)
___ 9321 Should Bond Funds be Included in M2? (John V. Duca)
___ 9322 Recessions and Recoveries in Real Business Cycle Models: Do Real Business Cycle Models Generate Cyclical Behavior? (Mark A. Wynne)
___ 9323* Retaliation, Liberalization, and Trade Wars: The Political Economy of Nonstrategic Trade Policy (David M. Gould and Graeme L. Woodbridge)
___ 9324 A General Two-Sector Model of Endogenous Growth with Human and Physical Capital: Balanced Growth and Transitional Dynamics (Eric W. Bond, Ping Wang,and Chong K. Yip)
___ 9325 Growth and Equity with Endogenous Human Capital: Taiwan's Economic Miracle Revisited (Maw-Lin Lee, Ben-Chieh Liu, and Ping Wang)
___ 9326 Clearinghouse Banks and Banknote Over-issue (Scott Freeman)
___ 9327 Coal, Natural Gas and Oil Markets after World War II: What's Old, What's New? (Mine K. Yücel and Shengyi Guo)
___ 9328 On the Optimality of Interest-Bearing Reserves in Economies of Overlapping Generations (Scott Freeman and Joseph Haslag)
___ 9329* Retaliation, Liberalization, and Trade Wars: The Political Economy of Nonstrategic Trade Policy (David M. Gould and Graeme L. Woodbridge) (Reprint of 9323 in error)
___ 9330 On the Existence of Nonoptimal Equilibria in Dynamic Stochastic Economies (Jeremy Greenwood and Gregory W. Huffman)
___ 9331 The Credibility and Performance of Unilateral Target Zones: A Comparison of the Mexican and Chilean Cases (Raul A. Feliz and John H. Welch)
___ 9332 Endogenous Growth and International Trade (Roy J. Ruffin)
___ 9333 Wealth Effects, Heterogeneity and Dynamic Fiscal Policy (Zsolt Becsi)
___ 9334 The Inefficiency of Seigniorage from Required Reserves (Scott Freeman)
___ 9335 Problems of Testing Fiscal Solvency in High Inflation Economies: Evidence from Argentina, Brazil, and Mexico (John H. Welch)
___ 9336 Income Taxes as Reciprocal Tariffs (W. Michael Cox, David M. Gould, and Roy J. Ruffin)
___ 9337 Assessing the Economic Cost of Unilateral Oil Conservation (Stephen P.A. Brown and Hillard G. Huntington)
___ 9338 Exchange Rate Uncertainty and Economic Growth in Latin America (Darryl McLeod and John H. Welch)
___ 9339 Searching for a Stable M2-Demand Equation (Evan F. Koenig)
___ 9340 A Survey of Measurement Biases in Price Indexes (Mark A. Wynne and Fiona Sigalla)
___ 9341 Are Net Discount Rates Stationary?: Some Further Evidence (Joseph H. Haslag, Michael Nieswiadomy, and D. J. Slottje)
___ 9342 On the Fluctuations Induced by Majority Voting (Gregory W. Huffman)
___ 9401 Adding Bond Funds to M2 in the P-Star Model of Inflation (Zsolt Becsi and John Duca)
___ 9402 Capacity Utilization and the Evolution of Manufacturing Output: A Closer Look at the "Bounce-Back Effect" (Evan F. Koenig)
___ 9403 The Disappearing January Blip and Other State Employment Mysteries (Frank Berger and Keith R. Phillips)
___ 9404 Energy Policy: Does it Achieve its Intended Goals? (Mine Yücel and Shengyi Guo)
___ 9405 Protecting Social Interest in Free Invention (Stephen P.A. Brown and William C. Gruben)
___ 9406 The Dynamics of Recoveries (Nathan S. Balke and Mark A. Wynne)
___ 9407 Fiscal Policy in More General Equilibriium (Jim Dolman and Mark Wynne)
___ 9408 On the Political Economy of School Deregulation (Shawna Grosskopf, Kathy Hayes, Lori Taylor, and William Weber)
___ 9409 The Role of Intellectual Property Rights in Economic Growth (David M. Gould and William C. Gruben)
___ 9410 U.S. Banks, Competition, and the Mexican Banking System: How Much Will NAFTA Matter? (William C. Gruben, John H. Welch and Jeffery W. Gunther)
___ 9411 Monetary Base Rules: The Currency Caveat (R. W. Hafer, Joseph H. Haslag, andScott E. Hein)
___ 9412 The Information Content of the Paper-Bill Spread (Kenneth M. Emery)
___ 9413 The Role of Tax Policy in the Boom/Bust Cycle of the Texas Construction Sector (D'Ann Petersen, Keith Phillips and Mine Yücel)
___ 9414 The P* Model of Inflation, Revisited (Evan F. Koenig)
___ 9415 The Effects of Monetary Policy in a Model with Reserve Requirements (Joseph H. Haslag)

___ 9501 An Equilibrium Analysis of Central Bank Independence and Inflation (Gregory W. Huffman)
___ 9502 Inflation and Intermediation in a Model with Endogenous Growth (Joseph H. Haslag)
___ 9503 Country-Bashing Tariffs: Do Bilateral Trade Deficits Matter? (W. Michael Cox and Roy J. Ruffin)
___ 9504 Building a Regional Forecasting Model Utilizing Long-Term Relationships and Short-Term Indicators (Keith R. Phillips and Chih-Ping Chang)
___ 9505 Building Trade Barriers and Knocking Them Down: The Political Economy of Unilateral Trade Liberalizations (David M. Gould and Graeme L. Woodbridge)
___ 9506 On Competition and School Efficiency (Shawna Grosskopf, Kathy Hayes, Lori L. Taylor and William L. Weber)
___ 9507 Alternative Methods of Corporate Control in Commercial Banks (Stephen Prowse)
___ 9508 The Role of Intratemporal Adjustment Costs in a Multi-Sector Economy (Gregory W. Huffman and Mark A. Wynne)
___ 9509 Are Deep Recessions Followed By Strong Recoveries? Results for the G-7 Countries (Nathan S. Balke and Mark A. Wynne)
___ 9510 Oil Prices and Inflation (Stephen P.A. Brown, David B. Oppedahl and Mine K. Yücel)
___ 9511 A Comparison of Alternative Monetary Environments (Joseph H. Haslag))
___ 9512 Regulatory Changes and Housing Coefficients (John V. Duca)
___ 9513 The Interest Sensitivity of GDP and Accurate Reg Q Measures (John V. Duca)
___ 9514 Credit Availability, Bank Consumer Lending, and Consumer Durables (John V. Duca and Bonnie Garrett)
___ 9515 Monetary Policy, Banking, and Growth (Joseph H. Haslag)
___ 9516 The Stock Market and Monetary Policy: The Role of Macroeconomic States (Chih-Ping Chang and Huan Zhang)
___ 9517 Hyperinflations and Moral Hazard in the Appropriation of Seigniorage: An Empirical Implementation With A Calibration Approach (Carlos E. Zarazaga)
___ 9518 Targeting Nominal Income: A Closer Look (Evan F. Koenig)
___ 9519 Credit and Economic Activity: Shocks or Propagation Mechanism? (Nathan S. Balke and Chih-Ping Chang)

| | |
|---|---|
| **Name:** | **Organization:** |
| **Address:** | **City, State and Zip Code:** |
| **Please add me to your mailing list to receive future Research Papers:** _____ **Yes** _____ **No** | |

Research Papers Presented at the
1994 Texas Conference on Monetary Economics
April 23-24, 1994
held at the Federal Reserve Bank of Dallas, Dallas, Texas

Available, at no charge, from the Research Department
Federal Reserve Bank of Dallas, P. O. Box 655906
Dallas, Texas 75265-5906

Please check the titles of the Research Papers you would like to receive:

____ 1 A Sticky-Price Manifesto (Laurence Ball and N. Gregory Mankiw)

____ 2 Sequential Markets and the Suboptimality of the Friedman Rule (Stephen D. Williamson)

____ 3 Sources of Real Exchange Rate Fluctuations: How Important Are Nominal Shocks? (Richard Clarida and Jordi Gali)

____ 4 On Leading Indicators: Getting It Straight (Mark A. Thoma and Jo Anna Gray)

____ 5 The Effects of Monetary Policy Shocks: Evidence From the Flow of Funds (Lawrence J. Christiano, Martin Eichenbaum and Charles Evans)

| | |
|---|---|
| Name: | Organization: |
| Address: | City, State and Zip Code: |
| Please add me to your mailing list to receive future Research Papers: | _____Yes _____ No |