Credit and Economic Activity: Credit Regimes and Nonlinear Propagation of Shocks

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CREDIT AND ECONOMIC ACTIVITY: CREDIT REGIMES AND NONLINEAR PROPAGATION OF SHOCKS

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Abstract—In this paper, we examine empirically whether credit plays a role as a nonlinear propagator of shocks. This propagation takes the form of a threshold vector autoregression in which a regime change occurs if credit conditions cross a critical threshold. Using nonlinear impulse-response functions, we evaluate the dynamics implied by the threshold model. These suggest that shocks have a larger effect on output in the "tight" credit regime than is normally the case, and that contractionary monetary shocks typically have a larger effect than expansionary shocks. Finally, using a nonlinear version of historical decompositions, we attempt to determine the relative contribution to output growth of shocks and the nonlinear structure.

I. Introduction

In much of the recent literature on financial market frictions, credit acts as a nonlinear propagator of shocks. For example, Bernanke and Gertler (1989) construct a model in which the balance-sheet conditions of firms can amplify fluctuations in output and in which negative shocks are likely to have a greater effect than positive shocks. Azariadis and Smith (1998) develop a model in which it is possible for the economy to switch back and forth between a Walrasian regime and a credit-rationing regime. Blinder (1987) develops a model in which monetary shocks have different effects when the economy is in a credit-rationing regime than at other times. In all of these models, credit conditions need not be an important source of shocks but are, nonetheless, an important propagator of shocks. Interestingly, these models imply nonlinear dynamics such as regime switching and asymmetric responses to shocks.

Empirical evidence of the importance of credit conditions for aggregate economic fluctuations is mixed.[1] Ramey (1994) finds that credit variables such as credit velocity and the loan-to-securities ratio provide little additional predictive content for output above and beyond that contained in money. Alternatively, Stock and Watson (1989), Friedman and Kuttner (1992, 1993), and Kashyap, Stein, and Wilcox (1993) find evidence that other proxies for credit conditions such as the spread between commercial paper and treasury bills—or the fraction of bank loans as a fraction of total short-term external finance—do have predictive content for economic activity.[2] Perhaps one reason for the mixed evidence is that it is based almost entirely on linear regressions or linear vector autoregressions (VAR). Standard linear time series may have difficulty detecting credit's role as a nonlinear propagator of shocks as envisioned in much of the recent theoretical literature on the role of credit.

In this paper, we employ nonlinear time-series analysis to examine credit's role as a nonlinear propagator of shocks. Specifically, we test for and estimate a threshold vector autoregression that changes "structure" if credit market conditions cross a critical threshold. Here, credit regime changes can be endogenous as shocks to other variables, such as the Fed funds rate, can result in a switch in regimes. Using nonlinear impulse-response analysis, we attempt to isolate the relative effects of shocks and the nonlinear structure on the time-series behavior of output. Among the findings, it appears that shocks during a "tight" credit regime have a larger effect on output than do shocks in the "normal" regime. Furthermore, there is evidence that contractionary Fed funds shocks have larger effects than do expansionary shocks. Finally, we calculate nonlinear analogs of historical decompositions to examine the role that tight credit regimes played in the propagation of macroeconomic fluctuations.

The analysis in this paper is related to that in McCallum (1991) in that he estimates a threshold model in which the coefficients on money in an output equation change depending on credit conditions. However, we examine three alternative measures of credit conditions that have been the focus of much of the recent analysis on the role of credit for fluctuations. Second, we adapt the simulation methodology proposed by Hansen (1996) in order to conduct proper inference. Third, by estimating a threshold vector autoregression, we allow switching into and out of the tight credit regime to be endogenous.

II. Empirical Methodology: Testing and Estimating Threshold Models

In this paper, the separate role that credit may play as a nonlinear propagator of shocks is captured by a threshold vector autoregression (TVAR) model. A TVAR is a relatively simple and intuitive way to capture nonlinearity such as regime switching, asymmetry, and multiple equilibria (which, in a time-series context, might be reflected in multimodal stationary distributions) implied by theoretical models of credit and macroeconomic activity. In addition, a TVAR allows credit regimes to switch as a result of shocks to other variables besides credit, so that credit regimes are themselves endogenous.

Consider the following "structural" threshold vector autoregression:

$$Y_t = A^1Y_t + B^1(L)Y_{t-1} + (A^2Y_t + B^2(L)Y_{t-1})I(c_{t-d} > \gamma) + U_t.$$

where Y_t is a vector containing output growth, inflation, the Fed funds rate, and a measure of credit market conditions. $B^1(L)$ and $B^2(L)$ are lag polynomial matrices while U_t are structural disturbances. c_{t-d} is the threshold variable that determines which regime the system is in, and $I[c_{t-d} > \gamma]$ is an indicator function that equals 1 when $c_{t-d} > \gamma$, and 0 otherwise. Because the threshold variable, c_{t-d}, is a function of credit market conditions (which in turn is an element in Y_t), the TVAR describes both the evolution of Y_t and the credit regimes. This implies that shocks to output, inflation, Fed funds, as well as to credit can determine whether the economy is in a tight credit regime.

In addition to the lag polynomials changing across on regimes, contemporaneous relationships between variables may change as well. A^1 and A^2 reflect the "structural" contemporaneous relationships in the two regimes respectively. We assume that A^1 and A^2 have a recursive

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[1] Evidence at the micro level for the importance of credit conditions appears to be stronger. See for example, Fazzari, Hubbard, and Peterson (1988) and Whited (1992).

[2] Other macro studies include Bernanke (1986), King (1986), Bernanke and Blinder (1992), Gertler and Gilchrist (1993), and Bernanke, Gertler, and Gilchrist (1996).

TABLE 1.—TESTS FOR THRESHOLD VAR
SYSTEM INCLUDES: GDP GROWTH, GDP DEFLATOR INFLATION, THE FED FUNDS RATE, AND A CREDIT VARIABLE

		Nonstructural VAR: No Threshold Effect in Contemporaneous Relationships			"Structural" VAR: Allow Threshold Effect in Contemporaneous Relationships		
		Wald Statistics			Wald Statistics		
Threshold Variable:	Estimated Threshold Value	Sup-	Avg-	Exp-	Sup-	Avg-	Exp-
CPBILL		207.44	149.85	100.29	233.07	156.22	113.07
$MA(2), d = 1$	$\gamma = 0.6649$	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
MIX		218.71	146.78	105.86	308.17	166.57	150.00
$MA(6), d = 1$	$\gamma = -3.8467$	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Small minus large firm debt growth		132.67	100.27	62.70	159.23	110.31	75.76
$MA(6), d = 1$	$\gamma = -0.00340$	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Notes: Sample period is 1960:1–1997:3 for models with CPBILL and MIX and 1960:1–1991:4 for models with small-large firm debt.
The delay for the threshold variable is given by d.
A threshold variable that is a moving average of length k is denoted as $MA(k)$.
P-values based on Hansen's (1996) method of inference with 500 replications are in parentheses.

structure with the causal ordering of output growth, inflation, the Fed funds rate, and finally a credit conditions variable. While this recursive structure is not without controversy, much of the recent VAR literature uses a similar recursive ordering.[3] We do consider alternative orderings in our testing for a threshold structure and in the impulse response and historical decomposition analysis discussed below. As far as testing for a nonlinear structure, it turns out that the choice of alternative orderings makes little difference.

If the threshold value, γ, were known, then to test for threshold behavior all one needs to do is to test the hypothesis that $A^2 = B^2(L) = 0$. Unfortunately, the threshold value is typically not known a priori and must be estimated. In this case, testing involves nonstandard inference because γ is not identified under the null hypothesis of no threshold behavior. In order to test for thresholds when γ is not known, the threshold model is estimated by least squares for all possible threshold values. For each possible threshold value, the Wald statistic testing the hypothesis of no difference between regimes was calculated. Three separate test statistics for threshold behavior were then calculated: sup-Wald, which is the maximum Wald statistic over all possible threshold values; avg-Wald, which is the average Wald statistic over all possible threshold values; and exp-Wald, which is a function of the sum of exponential Wald statistics.[4] The simulation method of Hansen (1996)—which involves simulating an empirical distribution of sup-Wald, avg-Wald, and exp-Wald statistics—was used to conduct inference. The estimated threshold values are those that maximized the log determinant of the "structural" residuals.[5] To guard against overfitting, the possible threshold values were restricted so that at least 15% of the observations plus the number of parameters (for an individual equation) were in each regime.

III. Tests for TVAR and Estimated Threshold Values

Because there is little consensus in the literature on a single measure of credit conditions, in this paper we consider three alternative measures of credit market conditions: the commercial paper (four-to-six month)/T-Bill (six month) spread, the mix of bank loans and commercial paper in total firm external finance (Kashyap, Stein, and Wilcox (1993)),[6] and difference between the growth rates in the short-term debt of small and large manufacturing firms (Gertler and Gilchrist (1994)). While each of these indicators of credit conditions is not without controversy, Bernanke, Gertler, and Gilchrist (1996) argue that all three variables reflect a "flight to quality" effect implied by models of financial contracting under asymmetric information.

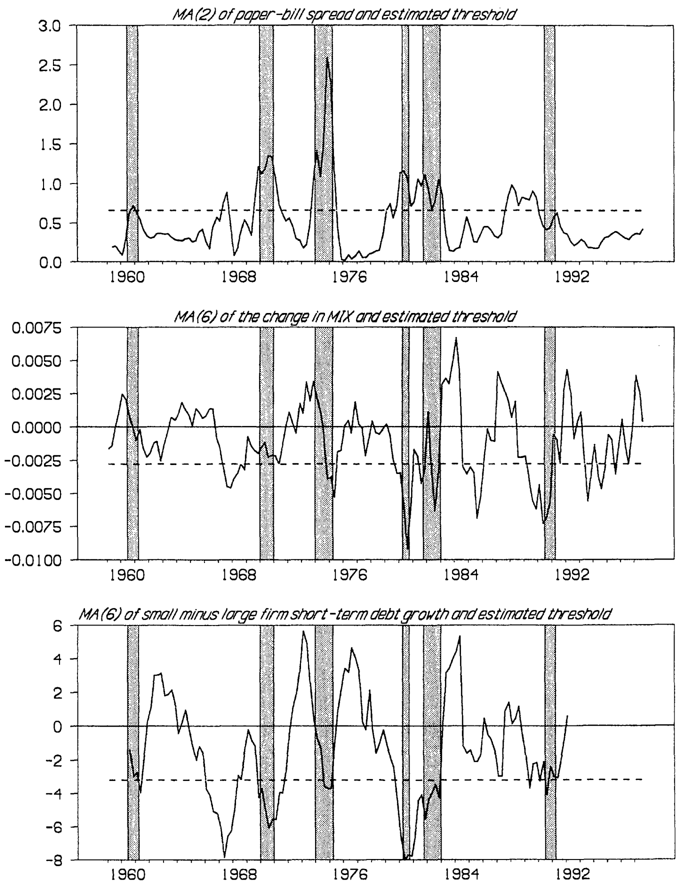
Because the three credit proxies are very different with respect to their persistence, we use as threshold variables (c_{t-d}) moving averages of the credit proxies.[7] We use a two-quarter moving average as the threshold variable for paper-bill spread (CPBILL), while six-quarter moving averages are used as threshold variables for both the change in MIX and growth of small relative to large firm debt. Note that the credit variables enter the vector autoregression directly in their original form, not as a moving average.

Table 1 presents tests of a linear VAR against a threshold alternative.[8] As table 1 shows, there is strong evidence of threshold effects for all three measures of credit conditions. This is true regardless if we allow for the contemporaneous correlation between variables to change or not. Table 1 also shows the estimated threshold values for the three models. To put these into perspective, figure 1 shows a plot of the threshold credit variables and their threshold values for the three different (structural) TVARs. For reference, the NBER recession periods are shaded.

For the most part, the episodes of tight credit indicated by the three alternative measures of credit variables coincide with one another. Of the three threshold variables, CPBILL seems to indicate tight-credit regimes before the other threshold variables, yet there is still substantial overlap. Furthermore, each NBER recession was preceded by (or contemporaneous) with periods in which at least one of the models indicates a tight-credit regime. In addition to recessionary periods, the variables also indicate other periods of tight-credit conditions. All three credit conditions variables indicate a tight-credit episode in 1967

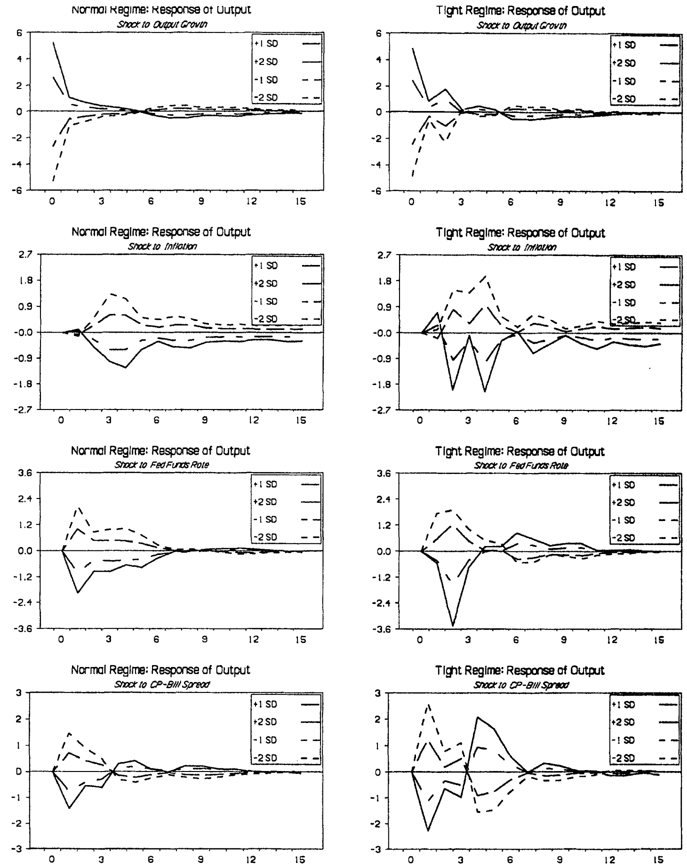
[3] For example, Bernanke, Gertler, and Watson (1997) and Leeper, Sims, and Zha (1996) both have roughly recursive structures that have the form: output, prices, monetary policy variables, and financial market variables.
[4] Andrews and Ploberger (1994) suggest the "avg" and "exp" versions of Wald test.
[5] The estimated threshold was robust to alternative structural orderings or to whether the contemporaneous relationships were allowed to change or not.
[6] This variable is bank loans/(banks loans plus commercial paper issued). Because the MIX variable has a downward trend over the sample, we actually use the first difference in our empirical analysis.
[7] The MIX variable and small relative to large firm debt growth have much higher quarter-to-quarter variability that the CP-Bill spread and would imply implausibly frequent regime changes. The lengths of the moving averages were set so that all three credit threshold variables had similar autocorrelation functions.
[8] The number of lags in the VAR was set at four.

FIGURE 1.—ALTERNATIVE THRESHOLD VARIABLE AND ESTIMATED THRESHOLD VALUES



The dashed line in each figure is the estimated threshold value. The shaded regions represent NBER recessions.

FIGURE 2.—RESPONSE OF OUTPUT GROWTH TO SHOCKS, CONDITIONAL ON REGIME



+1 SD represents the response to a positive one-standard-deviation shock, +2 SD represents the response to a positive two-standard-deviation shock, −1 SD is the response to a negative one-standard-deviation shock, and −2 SD is the response to a negative two-standard-deviation shock.

and 1968 which follows closely the credit-crunch period identified by Eckstein and Sinai (1986) and Owens and Schreft (1995).[9]

IV. Nonlinear Impulse Responses

To gain some insight into the dynamic properties of the nonlinear VARs, we conduct impulse-response analysis. Unfortunately, the nonlinear structure of the model makes impulse-response analysis substantially more complex than in the linear case.[10] The impulse-response function (IRF) is the change in the conditional expectation of Y_{t+k} as a result of knowing the value of an exogenous shock u_t, or

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

where Ω_{t-1} is the information set at time $t - 1$ and u_t is a particular realization of exogenous shocks. Typically, the effect of a single exogenous shock is examined at a time, so that value of the i^{th} element in u_t, u_t^i is set to a specific value. The difficulty arises because, in the threshold VAR, 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 conditional on the entire past history of the variables and the size and direction of the shock.

Therefore, calculating a nonlinear impulse-response function requires specifying the nature of the shock (that is, its size and sign) and the initial condition, Ω_{t-1}. In addition, the conditional expectations, $E[Y_{t+k}|\Omega_{t-1}, u_t]$ and $E[Y_{t+k}|\Omega_{t-1}]$, must be calculated by simulating the model. We do this by randomly drawing vectors of shocks u_{t+j}, $j =$ 1 to k and then simulating the model conditional on an initial condition (Ω_{t-1}) and a given realization of u_t. We repeat the simulation for $-u_{t+j}$ in order to eliminate any asymmetry that might arise from sampling variation in the draws of u_{t+j}. This is repeated 500 times, and the resulting average is the estimated conditional expectation.

Figure 2 displays for the model that includes **CPBILL** as the credit-conditions variable the response of output growth to shocks conditional on initially being in a normal or a tight-credit regime.[11] What is striking about figure 2 is that, with the exception of output shocks, shocks have substantially larger effects on output growth when the system is in the tight-credit regime.[12] This is particularly true for large (two-standard-deviation) shocks. The fact that Fed funds rate

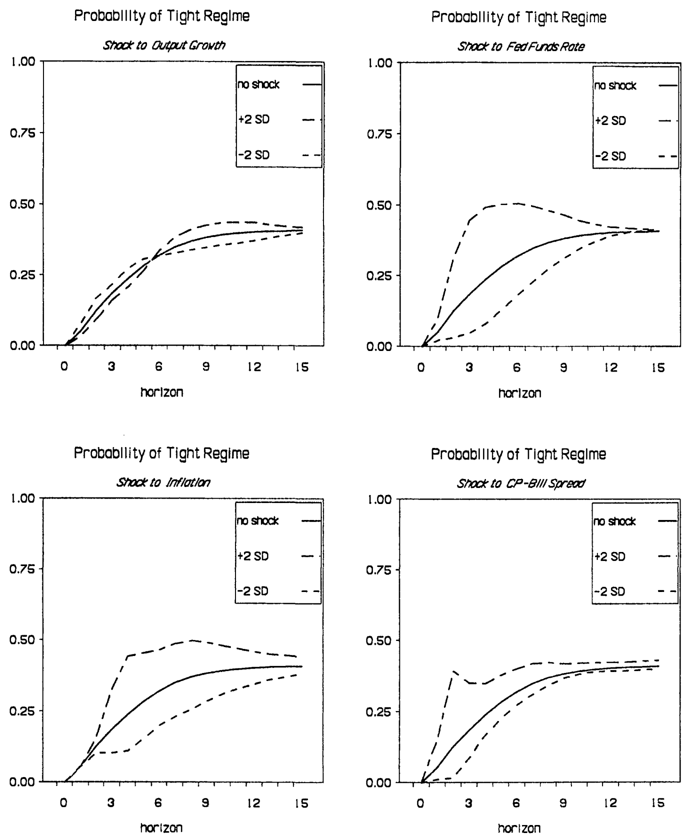
[9] For our three credit variables, periods in which the tight-credit threshold value is crossed typically overlap with the precrunch/crunch periods identified by Eckstein and Sinai (1986).

[10] See Koop, Pesaran, and Potter (1996) and Gallant, Rossi, and Tauchen (1993).

[11] Here we calculate impulse responses taking as the initial condition actual observations during which the economy was in a "normal" or "tight" regime, respectively.

[12] This result holds for the other credit threshold models and for alternative contemporaneous orderings.

FIGURE 3.—PROBABILITY OF A TIGHT-CREDIT REGIME, CONDITIONAL ON STARTING IN THE NORMAL-CREDIT REGIME



"No shock" represents the probability of being in tight credit given that the economy is initially in the normal regime. +2 SD represents the probability of being in the tight-credit regime given a positive two-standard-deviation shock and the economy initially being in the normal regime. −2 SD represents the probability of being in the tight-credit regime given a negative two-standard-deviation shock and the economy initially being in the normal regime.

shocks are more potent in periods of tight credit are consistent with the findings of McCallum (1991) who also found that output responded more to monetary policy in periods of tight credit.[13]

Figure 2 also suggests the existence of asymmetric responses, particularly to Fed funds rate shocks. In particular, large contractionary (two-standard-deviation) Fed funds shocks have a larger effect on output growth than expansionary shocks.[14] This asymmetric response of output to monetary shocks is consistent with the results of Cover (1992) who also found asymmetric output effects of money. While Cover argued in terms of an asymmetric aggregate supply curve, here the interaction between the monetary shocks and the credit regimes generates the asymmetry.

To examine what types of shocks are most likely to determine whether the system is in a tight credit regime, we calculate how the ex ante probability of being in the tight-credit regime responds to various types of exogenous shocks, or $E[I(c_{t+k-1} > \gamma)|\Omega_{t-1}, u_t]$. Figure 3 plots the probability of being in the tight-credit regime (conditional on the economy initially being in the normal credit regime) for positive and negative two-standard-deviation shocks. For comparison, the probability of being in the tight regime in the absence of a shock, or $E[I(c_{t+k-1} > \gamma)|\Omega_{t-1}]$, is also plotted. From figure 3, one observes that, in addition to CPBILL shocks, large positive shocks to the Fed funds rate and to inflation can substantially increase the likelihood of being in the tight-credit regime. Keeping in mind that identification of "structural" shocks in a vector autoregression is always tenuous, these results suggest that monetary policy and other economic shocks feed back into credit market conditions and, thus, play a role in the evolution of credit regimes.[15]

V. The Contribution of Credit to Economic Fluctuations

To better understand the contribution of credit regimes to actual economic fluctuations, we consider a nonlinear analog of a historical decomposition. The idea is to use the model to help determine the relative importance of credit conditions as a source of shocks and/or as a nonlinear propagator of shocks.

One way to get a sense of how various types of shocks have contributed to actual fluctuations is to examine how the forecast of output growth would change if one had information about the actual exogenous shocks. More formally, define the change in forecast function (CFF) as

$$CFF(\Omega_{t-1}, k, i) = E[Y_{t+k}|\Omega_{t-1}, u_t^i, u_{t+1}^i, \ldots, u_{t+k}^i] - E[Y_{t+k}|\Omega_{t-1}]$$

where Ω_{t-1} is the information set at time $t - 1$,
$k + 1$ is the forecast horizon, and
u_{t+j}^i is the i^{th} exogenous shock at time $t + j$.

The CFF is like an impulse-response function in which we condition on the realized shocks to a variable over the entire forecast horizon. For a linear model, the CFF is identical to the standard historical decomposition. However, for the TVAR, unlike a linear VAR, the sum of the individual change in forecast functions for the different exogenous shocks is not necessarily equal to the forecast error. We define a remainder as the difference between the sum of the individual forecast changes and the actual forecast error, or

$$R_m(\Omega_{t-1}, k) = Y_{t+k} - E[Y_{t+k}|\Omega_{t-1}] - \sum_{i=1}^{N} CCF(\Omega_{t-1}, k, i)$$

This remainder term reflects the interaction among the shocks that is inherent in the nonlinear structure of the threshold VAR and would be zero for a linear VAR.

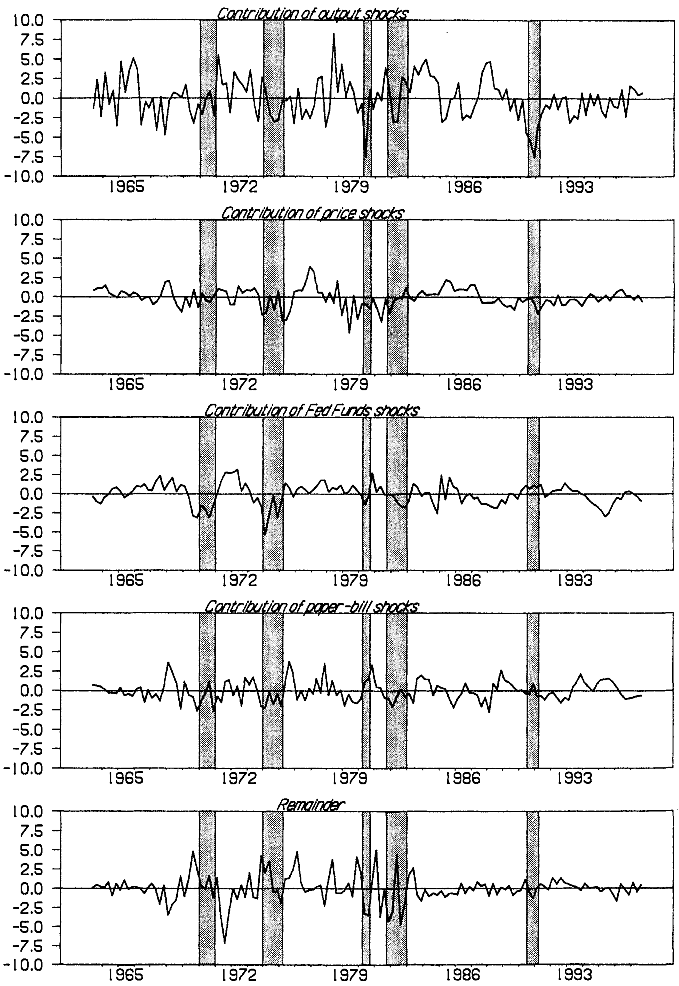
Figure 4 shows the change in forecast functions for output for the TVAR with the paper-bill spread. The forecast horizon is set at twelve quarters, so that the change in forecast reflects shocks that occurred over the twelve previous quarters. The periods of NBER recessions are shaded in the diagram for reference. Keeping in mind the usual caveat about interpreting reduced-form time-series models, linear or nonlinear, a few interesting episodes stand out in figure 4. First, with the exception of the 1990–1991 recession, Fed funds shocks led to lower than predicted output growth during each of the recessionary periods, particularly the 1969–1970 and 1973–1975 recessions. Second, CPBILL shocks appear to have contributed to less-than-expected output growth during the 1969–1970, 1973–1975, and 1981–1982 recessions, but their overall contribution is relatively modest. In fact,

[13] The increased potency of monetary policy also shows up in the fact that the *p*-values for excluding the Fed funds rate and CPBILL from the output equation in the tight-credit regime were 0.01 and 0.03, respectively, while in the normal regime they were 0.12 and 0.04, respectively.

[14] This asymmetry, while still present, is not as pronounced if CPBILL precedes the Fed funds rate in the contemporaneous ordering.

[15] Not surprisingly, feedback from the Fed funds rate is smaller when the paper-bill spread comes before the funds rate in the contemporaneous ordering, but it is still substantial. For the other credit variables, we also find feedback from other shocks to the credit regime, although the feedback is substantially smaller when the MIX variable is used.

FIGURE 4.—CHANGE IN FORECAST OF OUTPUT GROWTH AS A RESULT OF SHOCKS DURING THE PREVIOUS TWELVE QUARTERS



The shaded regions represent period of NBER recessions. The remainder term is the difference between the actual forecast error and the sum of the contributions of the individual exogenous shocks.

the remainder term has arguably as large as a contribution as the CPBILL shocks themselves. From figure 4, the remainder term is large during the 1979–1980, and 1981–1982 recessions, rivaling the contribution of output shocks over these periods. (Recall that the remainder term represents, in part, the contribution of switching credit regimes to the nonlinear propagation of shocks.) This suggests that the tight credit regime exacerbated the effect of the individual shocks making these recessions more severe.[16]

[16] The historical decompositions for the TVAR models with MIX variable or small/large firm debt growth as measures of credit conditions are roughly consistent with those presented above. The models do, however, tell a slightly different story for the 1990–1991 recession. The paper-bill spread indicated a "tight" credit regime well in advance of the 1990–1991 recession but not during it. Furthermore, the contribution of paper-bill shocks and the remainder are relatively small for that recession. Our other measures of credit conditions, on the other hand, did indicate the existence of a tight credit regime before and during the 1990–1991 recession and these models attribute a larger contribution to credit conditions (particularly the remainder term) during these periods. These additional historical decompositions are available upon request.

VI. Conclusion

The analysis in the paper attempted to evaluate whether credit conditions are a nonlinear propagator of shocks. Using a threshold vector autoregression to capture nonlinear relationships in the data, we find evidence of switching credit regimes. Among the implications of this threshold vector autoregression are that shocks are more potent in the tight-credit regime and that contractionary monetary shocks have a larger effect on output than do expansionary shocks. Nonlinear historical decompositions suggest that the nonlinearity implied by regime switching was as important a contributor to output fluctuations as were credit shocks themselves.

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