ARE THE EFFECTS OF MONETARY POLICY ASYMMETRIC?

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By building on the Hamilton (1989) Markov switching model, we examine questions like: Does monetary policy have the same effect in expansions and recessions? Given that the economy is currently in a recession, does a fall in interest rates increase the probability of an expansion? Does monetary policy have an incremental effect on the growth rate within a given state, or does it only affect the economy if it is sufficiently strong to induce a state change (e.g., from recession to expansion)? As suggested by models with sticky prices or finance constraints, interest rate changes have larger effects during recessions. (*JEL* E52, E32)

> Much of the recent work [in macroeconomics] has proceeded . . . under the assumption that variables follow linear stochastic processes with constant coefficients. . . . [As a result] some of the richness of the Burns-Mitchell analysis, such as its focus on asymmetries between recessions and expansions . . . may well have been lost.
> —Blanchard and Fischer (1989, 7)

I. INTRODUCTION

For decades macroeconomists have debated whether monetary policy has the same effect on real ouput in expansions and recessions. As far back as the 1930s, Keynes and Pigou debated whether monetary policy would have less effect on output during a severe economic downturn. In the 1960s, there were active debates on a very different proposition, namely, whether the rightward portion of the aggregate supply curve was vertical, so that monetary policy would have less effect on real output during expansions. In this article, we provide a new type of evidence on whether monetary policy has different effects depending on whether the economy is in an expansion or recession.

Empirical evidence on this issue is particularly relevant in light of new theoretical work in macroeconomics that predicts asymmetric effects of demand shocks conditional on the state of the economy. Two examples of this work are S-s-type models of price adjustment and models in which there are agency costs of financial intermediation.[1]

The intuition for the latter class of models is simple.[2] When there is information asymmetry in financial markets, agents may behave as if they were constrained. For a variety of reasons, these finance constraints are more likely to bind during recessions when the net worth of agents is low. An increase in interest rates will then have two effects on investment: the standard effect of increasing the cost of capital and therefore reducing investment demand and an additional effect of reducing liquidity (e.g., by increasing debt service obligations) and thus reducing

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1. There are other types of models in which asymmetries arise, such as the board class of aggregate models with multiple equilibria. If one thinks of good equilibria as corresponding to expansions and bad equilibria to recessions, our empirical results provide evidence on whether changes in interest rates: (1) affect the economy within a given equilibrium and/or (2) move the economy from one equilibrium to the other. In a different approach, Auger and Beaudry (1994) present a model where technology (U-shaped cost curves) and market structure (imperfect competition) lead monetary shocks to have asymmetric effects.

2. Bernanke and Gertler (1989) and Kiyotaki and Moore (1993) outline models in which agency costs (or finance constraints) affect aggregate output. See also the survey by Gertler (1988).

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investment demand for constrained agents. As a result, monetary policy actions that change interest rates will have greater effects during a recession.[3] The S-s-type price adjustment models of Ball and Mankiw (1994), Caballero and Engel (1992), and Tsiddon (1993) lead to a convex aggregate supply curve and therefore also imply that monetary policy will have stronger effects during recessions.

One of the more frequently cited empirical papers on the potentially asymmetric effects of monetary policy is Cover (1992), which finds evidence that positive monetary shocks have different effects from negative monetary shocks. We are looking at a different type of asymmetry—namely, between booms and recessions.

We study asymmetries using an extension of the Markov switching model developed by Hamilton (1989), estimated over the period 1955–93. In Hamilton's econometric specification, the growth rate of output depends on a state variable that corresponds to an expansion or recession. This approach has several advantages. First, unlike linear projections, it allows for nonlinearities and asymmetries. Second, in estimating the recession coefficients, it gives greater relative weight to observations that most clearly correspond to recessions (and similarly for the expansion coefficients). Third, the Hamilton algorithm determines the optimal recession dating based on the data.

We extend the Hamilton (1989) Markov switching model in two directions. First, we allow monetary policy to affect the growth rate of output. Second, we allow the probability of moving from one state to another (e.g., from an expension to a recession) to depend on monetary policy.[4]

By building on the basic Markov switching model introduced by Hamilton, we can examine questions like the following: Does monetary policy have the same effect regardless of the current phase of economic fluctuations? Given that the economy is currently in a recession, does a fall in interest rates increase the probability of an expansion? Does monetary policy have an incremental effect on the growth rate within a given state, or does it only affect the economy if it is sufficiently strong to induce a state change (e.g., from recession to expansion)?

We also employ a simple alternative to the Hamilton (1989) specification, namely, linear regressions with an indicator variable for expansion periods based on the National Bureau of Economic Research business cycle dating. In practice, the main conclusions are the same for specifications based both on Hamilton (1989) and on the NBER dates, as well as an intermediate approach based on the Hamilton (1991) technique.[5]

An important issue is how to measure the stance of monetary policy. For several reasons, we emphasize changes in the Fed funds rate. For most of the past half century, the Fed funds rate has been the main instrument of monetary policy. Even in periods when the Fed funds rate was not the immediate instrument of monetary policy, such as 1979–82, the Fed considered changes in interest rates when deciding on policy. Bernanke and Blinder (1992) demonstrate that the Fed is able to determine the Fed funds rate in the short run.[6] Romer and Romer (1994) find that the Fed usually "responds to weakness in the economy quite rapidly," the Fed funds rate typically declines after output reaches its peak, and the decline in the rate is usually the result of deliberate policy action.[7] All of these points suggest that changes in the Fed funds rate should be a good measure of monetary policy.

3. Lamont (1993) discusses debt overhang, a related potential source of asymmetry: in expansions, debt overhang will not bind because the returns from investing are high, but it will bind if the economy is stagnant. Debt overhang is defined as occurring "when existing debt deters new investment because the benefits from new investment will go to the existing creditors, not to the new investors."

4. Diebold et al. (1993) propose a class of Markov switching models in which the transition probabilities vary with underlying economic fundamentals. Lee (1991) and Filardo (1994) include explanatory variables with transition probability depending on economic fundamentals. Lee (1991) uses a real interest rate difference as the fundamental factor. Filardo (1994) considers business-cycle predictors, such as the composite Index of Eleven Leading Indicators, the term premium between the ten-year and the one-year Treasury interest rates, the Standard and Poor's Composite Stock Index, and the Federal funds rate. He shows that the inclusion of these variables in the time-varying probabilities helps predict turning points in the business cycle.

5. This approach is Bayesian in spirit, in the sense that the analyst imposes some priors about some parameters.

6. On this point, see also Cook and Hahn (1989).

7. They also find that the converse is true, namely, that increases in the Fed funds rate after the cyclical trough are the result of deliberate policy action.

Of course, interest rates are partly endogenous. We therefore consider several alternative measures of monetary policy, based on innovations to VAR systems. The main conclusions are not sensitive to how we measure monetary policy.

Our empirical approach is open-ended and could lead to a variety of possible results: evidence that monetary policy has little effect on real output during expansions, during recessions, or at any time—or evidence that monetary policy has similarly strong effects in both expansions and recessions. In fact, we find that changes in the Fed funds rate have a statistically significant and economically important effect on real output growth during both expansions and recessions.

The effect of monetary policy does not appear to be the same in expansions and recessions, however. We find that interest rate changes have a stronger effect on output growth during recessions than during expansions. In a statistical sense, we reject the null hypothesis of symmetry at the .0001 level in many of the specifications. In an economic sense, the differences are large; in a typical specification, the effect of interest rate changes on the growth rate of output is two to three times larger in recessions than expansions.

We also make a start on answering the question of whether changes in interest rates have an incremental effect on output growth or whether they only bite when they are sufficiently large to push the economy from one state to another. We find incremental effects on output growth in both expansions and recessions. We also find that changes in interest rates have a substantial effect on the probability of state switches. For example, we find that successive reductions in the Fed funds rate increase the probability of going from a recession to an expansion from .10 to about .26.

Section II of the article explains the Markov switching model and examines the effect of interest rates on output growth. To address the potential endogeneity of interest rate changes, in section III we test whether monetary policy shocks, as measured by innovations from a VAR, have asymmetric effects on output growth. Section IV focuses on whether changes in interest rates affect the probability of moving between expansions and recessions. Section V concludes.

II. INTEREST RATES AND OUTPUT GROWTH

The Markov Switching Model

As the deliberations of the NBER committee illustrate, considerable judgment can be involved in determining business cycle dating.[8] The Markov switching model explicitly takes into account the probabilistic nature of these judgments by treating the state of the economy (expansion/recession) as an unobserved latent variable.[9] For example, the Hamilton (1989) model is

$$(1)\quad \begin{aligned} y_t-\alpha_0-\alpha_1 S_t &= \phi_1(y_{t-1}-\alpha_0-\alpha_1 S_{t-1}) \\ &\quad +\cdots+\phi_r(y_{t-r}-\alpha_0-\alpha_1 S_{t-r})+\sigma\varepsilon_t, \end{aligned}$$

where S_t is the state variable, y_t is the growth rate of output, and ε_t is distributed $N(0,1)$. The Markov switching model assigns a probability that any given observation comes from the expansion state. This means that the model has a weighted least squares interpretation, where the probabilities are used as the weights.

The Markovian nature of the model comes from the discrete-time, discrete-state Markov process assumed for the variable representing the state of the economy. This stochastic process is characterized by a transition probability matrix which can be written as

$$(2)\qquad P=\begin{bmatrix} p_{00} & p_{01} \\ p_{10} & p_{11} \end{bmatrix}$$

where

$$(3)\quad p_{ij}=\Pr[S_t=j|S_{t-1}=i] \quad \text{with} \quad \sum_{j=0}^{1} p_{ij}=1 \quad \text{for all } i.$$

8. Boldin (1993) provides a thorough survey of alternative techniques for dating business cycles, namely the NBER dating method, gross domestic product rules of thumb, the Commerce Department's business cycle indicators, the Stock and Watson index method, and the Markov switching method. For the period 1990–1992, the various methods are consistent with the official NBER peak, but there is wide variance in the trough date. For the Markov switching method, the author uses monthly unemployment rates, instead of the industrial production growth rates used in our article.

9. Outside the United States (e.g., in Canada), there is frequently no widely recognized counterpart to the NBER business cycle dating. For researchers in these countries, a potential advantage of the Markov switching model is that it allows the data to generate a state variable for expansions and recessions.

TABLE 1
Linear Autoregressive and Markov Switching Specifications (Period of Estimation: 1947:01 to 1993:05 [Monthly] 1947:1 to 1993:1 [Quarterly])

	Monthly		Quarterly	
	Linear Autoregressive	**Markov Switching**	**Linear Autoregressive**	**Markov Switching**
α_1	—	2.6511 (0.2336)	—	7.4561 (0.6281)
α_0	0.2871 (0.0837)	−2.1504 (0.2515)	0.8636 (0.1869)	−6.2853 (0.6273)
σ	1.0046 (0.0286)	0.8628 (0.0282)	2.1567 (0.1119)	1.5446 (0.0795)
ϕ_1	0.3508 (0.0418)	0.2861 (0.0531)	0.3782 (0.0712)	0.5329 (0.0671)
ϕ_2	0.0715 (0.0437)	0.1338 (0.0480)	−0.0547 (0.076)	−0.0634 (0.080)
ϕ_3	0.0653 (0.0432)	0.1565 (0.0536)	0.0797 (0.0766)	0.1215 (0.0789)
ϕ_4	0.0036 (0.0400)	0.0818 (0.0514)	−0.2513 (0.0735)	−0.3740 (0.0733)
p_{11}	—	0.9818 (0.0068)	—	0.9650 (0.0145)
p_{00}	—	0.7702 (0.0695)	—	0.3317 (0.2043)
Log likelihood	2263.51	2288.20	600.58	630.91

Note: Figures in parentheses are standard errors.

In words, this says that p_{10} is the probability of going from state 1 to state 0 (i.e., from expansion to recession). Initially, we will assume that these transition probabilities are constant over time and take the following logit form:

$$(4)\quad p_{11} = P(S_t = 1|S_{t-1} = 1) = \exp(\theta_{0p})/[1 + \exp(\theta_{0p})]$$

$$(5)\quad p_{00} = P(S_t = 0|S_{t-1} = 0) = \exp(\theta_{0q})/[1 + \exp(\theta_{0q})].$$

Later, we will relax the assumption of constant transition probabilities to examine how changes in interest rates affect the probability of a recession.[10]

Table 1 compares the Markov switching model with a linear AR(4) specification of output growth, based on industrial production growth for the United States from 1947 to 1993. The parameters θ_{0p} and θ_{0q} determine the transition probabilities through the logistic distribution function in (4) and (5). The parameters ϕ_1, ϕ_2, ϕ_3, and ϕ_4 capture the autoregressive component of output growth.

As a by-product of both algorithms, we also obtain a sequence of joint conditional probabilities $P(S_t = i, \ldots, S_{t-r} = j|\Phi_t)$, which are the probabilities that the series is in state i or j ($i, j = 0, 1$) at times t, $t-1$, until $t-r$, respectively, conditional on the information available at time t. By summing these joint probabilities, as shown in (6) below, one can obtain the so-called filter probabilities, which are the probabilities of being in state 0 or 1 at time t, given the information available at time t. They are given by

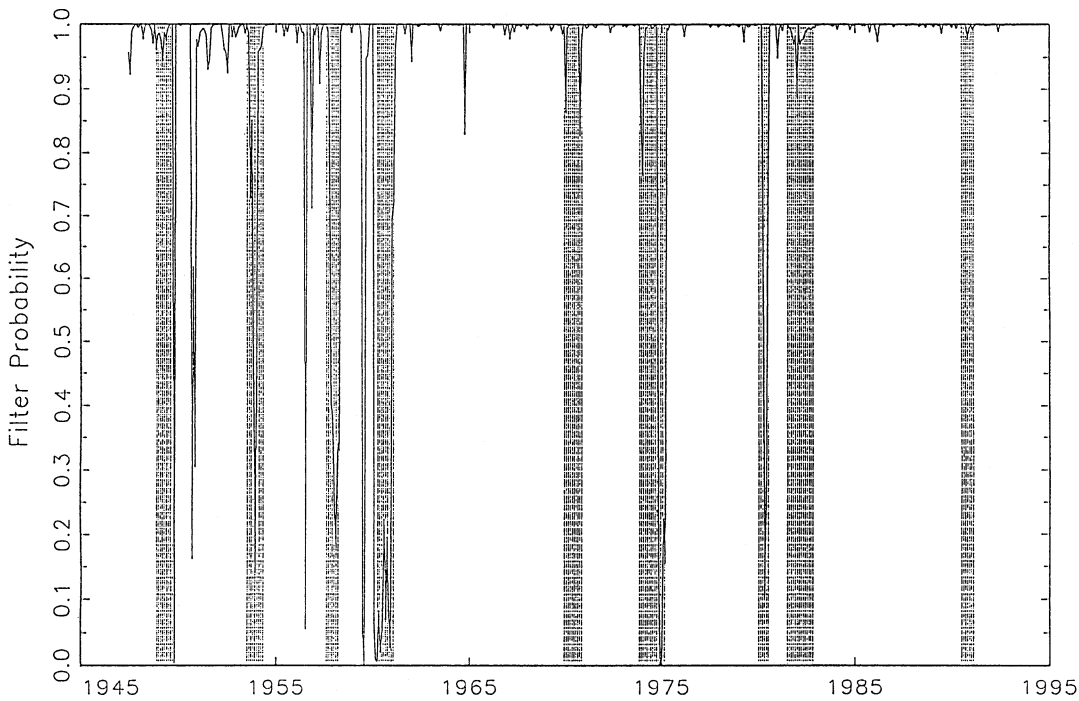
$$(6)\quad p(S_t = j|\Phi_t) = \sum_{i=0}^{1} \cdots \sum_{k=0}^{1} p(S_t = j, S_{t-1} = i, \ldots, S_{t-r} = k|\Phi_t) \qquad j, i, \ldots, k = 0, 1.$$

The filter probabilities provide information about the regime in which the series is most

10. The maximization algorithm for the specifications (1)–(5) is described in detail in Hamilton (1989).

FIGURE 1

Probability of the Expansion State Based on the Markov Switching Model



Note: Shaded areas indicate NBER recessions.

likely to have been at every point in the sample. They are therefore very useful for dating switches.

In practice, Hamilton (1989) finds that estimates of the Markov switching model on U.S. data tend to yield business cycle dating which is quite similar to the NBER dating. We obtain a similar result for monthly growth in industrial production, as illustrated in Figure 1, which graphs the probability that a given month is in the expansion state, based on the Markov switching model described above. Shaded areas mark NBER recessions.

In our sample, the data strongly reject the linear model in favor of the Markov switching model. The likelihood ratio statistic for the monthly data in Table 1 is 49.4 compared with .05 and .01 critical values of 10.34 and 13.81, respectively.[11] The likelihood ratio statistic for the same specifications estimated on quarterly data (also presented in Table 1) is 60.7, again implying strong rejection of the linear model. In contrast, Garcia (1998) and Hansen (1992, 1996) show that the gross national product data in Hamilton (1989) fail to reject the null hypothesis of no switching. Our stronger finding is due to the use of data on industrial production.

Conditioning on the State at the Time of the Shocks

Do changes in interest rates have the same sort of effects regardless of the current state of the economy? To address this question, we extend (1) to allow interest rates to influence the growth rate of output:

$$(7)\quad \begin{aligned} y_t - \alpha_0 - \alpha_1 S_t &= \phi_1(y_{t-1} - \alpha_0 - \alpha_1 S_{t-1}) \\ &\quad + \cdots + \phi_r(y_{t-r} - \alpha_0 - \alpha_1 S_{t-r}) \\ &\quad + \beta_{1q} X_{t-1} + \cdots + \beta_{rq} X_{t-r} \\ &\quad + \beta_{1p} S_{t-1} X_{t-1} \\ &\quad + \cdots + \beta_{rp} S_{t-r} X_{t-r} + \sigma\varepsilon_t \end{aligned}$$

11. The asymptotic distributions of the likelihood ratio, Lagrange multiplier, and Wald tests are nonstandard because the transition probabilities are not identified under the null hypothesis of no switching (see Garcia [1998], Hansen [1992, 1996]). The critical values in the text are based on Garcia (1998).

TABLE 2
State-Dependent Effects of an Increase in the Fed Funds Rate (Conditioning on the State at the Time of the Increase) (Period of Estimation: 1955:2 to 1993:1 [Quarterly])

	Markov Switching Model		
	Hamilton (1989)	Hamilton (1991)	Using NBER Dates
$\alpha_0 + \alpha_1$	0.9503 (0.3943)	3.5398 (0.6114)	1.2560 (0.1883)
α_0	−5.5549 (0.8278)	−1.7960 (0.2725)	−2.0888 (0.3926)
p_{11}	0.9719 (0.0160)	0.9698 (0.0151)	
p_{00}	0.2109 (0.1861)	0.7969 (0.0918)	
β_{1q}	1.4076 (0.4440)	−0.5115 (0.3875)	−0.3821 (0.1676)
β_{2q}	−1.5726 (0.4571)	−1.9258 (0.4299)	−0.3566 (0.1682)
β_{3q}	−0.9165 (0.4676)	−0.5978 (0.4039)	−0.2865 (0.1768)
β_{4q}	−0.7556 (0.4812)	−0.6119 (0.4402)	−0.1484 (0.1953)
$\beta_{1q} + \beta_{1p}$	−0.3249 (0.1062)	−0.3915 (0.0962)	−0.0392 (0.196)
$\beta_{2q} + \beta_{2p}$	−0.3836 (0.1125)	−0.5398 (0.1030)	−0.1664 (0.1751)
$\beta_{3q} + \beta_{3p}$	−0.1513 (0.1081)	−0.3183 (0.1083)	0.1979 (0.1736)
$\beta_{4q} + \beta_{4p}$	−0.1678 (0.1157)	−0.1447 (0.1088)	0.0139 (0.1544)
Log likelihood	536.77	530.79	531.95

where X_{t-r} is the interest rate in period $t-r$.[12]

The first column of Table 2 presents estimates of the effect of changes in the Fed funds rate on the quarterly growth rate of industrial production for 1955:02–1993:01.[13] (We discuss columns two and three of Table 2 in the next subsection.) It may be helpful to provide some interpretation of the various coefficient estimates. In the first column, the quarterly growth rate in an expansion (evaluated at $X_{t-1} = \cdots = X_{t-r} = 0$) is equal to $\alpha_0 + \alpha_1$, which is estimated as about 1.0%. In a recession, it is α_0, which is estimated as about −5.6%. These estimates clearly correspond to expansions as periods when output grows and recessions as periods of output decline.

12. See Boldin (1994) for another approach.

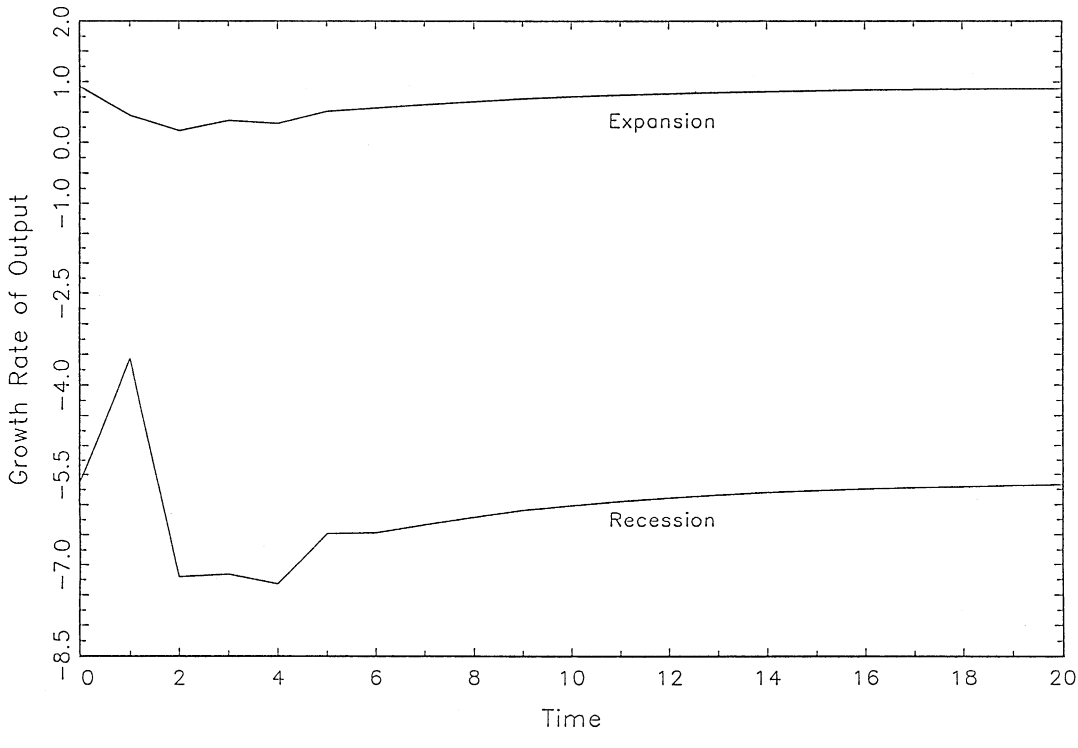
13. This estimation period was based on data availability; our data sources did not provide the Fed funds rate before 1955.

The coefficients labeled β_{iq} can be interpreted as the effect on current output growth of a one-percentage-point increase in the Fed funds rate at $t - i$ if the economy was in a recession at the time of the increase. The coefficients $\beta_{iq}+\beta_{ip}$ have a comparable interpretation for the periods when the economy was in an expansion.

The coefficients show that an increase in the Fed funds rate lowers output. This is true both if the economy was in a recession and if the economy was in an expansion at the time interest rates were raised. The effects are statistically strong. The null hypothesis that all of the β_{iq} are zero is rejected at the .0001 level. The p-value for the expansion coefficients ($\beta_{iq} + \beta_{ip}$) is .0005.

Our focus is on asymmetry between recessions and expansions. The null hypothesis of symmetry can be expressed as $\beta_{iq} = \beta_{iq} + \beta_{ip}$ for $i = 1, 2, 3, 4$. The data show strong evi-

FIGURE 2
State-Dependent Effects of an Increase in the Fed Funds Rate (Conditioning on the State at the Time of the Increase)



dence of asymmetry: the *p*-value for the null hypothesis is less than .0001.

The coefficients suggest that changes in interest rates have a stronger effect when the economy is in a recession. This is illustrated in Figure 2, which shows the effect of a one-standard-deviation increase in the Fed funds rate at $t = 0$ on the growth rate. In a recession, the average growth rate is lower than in an expansion, so at $t = 0$ (before the increase in the Fed funds rate affects output growth) there is a difference in growth rate between the two states. The figure traces out the effect of higher interest rates on output growth, based on our coefficient estimates. The most notable feature of the figure is the sharper drop in the growth rate in a recession than in an expansion.[14] However, an increase in the Fed funds rate also lowers output growth in an economically significant way in an expansion; output growth drops from about 1% to approximately 0.

It may be helpful to compare our results with the recent literature that uses VARs to measure the effects of monetary policy. A recent paper that both adds to and integrates this literature is Bernanke and Mihov (1998). The authors consider five different approaches to measuring the effects of monetary policy, all based directly on estimates of the central bank's operating procedures. The approaches differ in the assumptions they make about which variables the central bank targets and which variables respond only to policy shocks. The FFR model assumes that the Fed targets the Fed funds rate; specifically, the Fed offsets shocks to total reserves demand and borrowing demand, which implies that the pol-

14. The figure also shows a brief rise in growth rate relative to the average growth rate in a recession. Although some conventional VAR studies find a similar initial increase (e.g., Sims [1992, Figure 10]), we do not emphasize this result because it does not seem to be robust; see, for example, the estimate of β_{1q} in columns two and three of Table 2.

icy shock is proportional to the innovation in the Fed funds rate. The BR model assumes that the Fed targets borrowed reserves, which implies that the policy shock is proportional to the borrowed reserves innovation. The NBR model assumes that nonborrowed reserves respond only to policy shocks, which implies that the monetary policy shock equals the innovation in nonborrowed reserves. The NBR-TR model assumes that shocks to total reserves are purely demand shocks that the Fed must accommodate; this implies that the policy shock is proportional to a linear combination of innovations in total reserves and nonborrowed reserves. Finally, the JI model assumes that the demand for total reserves is inelastic in the short run. This leads to a just-identified model that can accommodate hybrid operating procedures.

Using the JI model, Bernanke and Mihov (1998) find that contractionary monetary policy shocks have little effect in the first quarter. The effect of a shock gradually depresses output, with the maximum effect occurring about one year after the shock. The effects then trail off very gradually. The FFR model generates an impulse response function very similar to the one just described for the JI model. The BR model has an initial pattern similar to the JI and FFR models, but the effect on output trails off more quickly after about eight quarters. The NBR model leads to an impulse response function that shows a maximal effect of the monetary policy shock on output somewhat earlier (less than one year after the shock). The NBR-TR model generates an impulse response function similar to that of the BR model. As this summary suggests, a common feature of the impulse response function is that the response of output to a contractionary monetary policy shock is U-shaped.

It would take too much space to describe all of the many other papers in this literature, so we focus on three additional studies. Gordon and Leeper (1994) was a pioneering effort to use information about the central bank's procedures and the operation of the relevant markets to identify monetary policy shocks. The authors find that output begins to fall relatively quickly in response to a contractionary shock, with the maximum effect occurring a little less than one year after the shock and a continuing impact on output for about three years afterward. Christiano et al. (1997) consider two schemes for identifying monetary policy shocks, one based on their own work (CEE shocks) and one based on the work of Sims and Zha (1995) (SZ shocks). The impulse response function for a CEE shock shows the effect on output developing gradually with the greatest effect on output occurring about seven or eight quarters after the shock and then gradually diminishing. For an SZ shock, the effect on output develops very gradually, with the greatest decline in output occurring 12 or 13 quarters after the shock and then gradually tailing off. Leeper et al. (1996) use a 13-variable model with nonrecursive identification. They find that output gradually falls in response to a contractionary monetary policy shock, with the maximum impact about five to seven quarters after the shock, after which the effect of the shock gradually tails off.

The results in Figure 2 are comparable to those found by other studies. As Figure 2 shows, in both an expansion and a recession, the effect of a shock builds gradually over several quarters, reaching its maximum impact about a year (or perhaps a little less) after the shock. After that, in both expansions and recessions, the impact on output gradually trails off. In both expansions and recessions, the effect is economically important. The big difference is in the magnitude of the effect: in an expansion, output growth drops by somewhat less than 1% (from the time of the shock to the time of maximum impact), but in a recession, the effect is substantially larger.

Robustness to Recession Classification

Because the Markov switching model can yield a different dating for recessions than the conventional NBER dating, a useful question is whether the results in the first column of Table 2 are robust to different specifications of the state variable.[15] We use two techniques to check this point. First, we use a modification of the Markov switching specification proposed by Hamilton (1991) that moves the

15. For example, the filter probabilities from the specification in the first column of Table 2 put relatively heavy weight on periods of sharp output decline in the 1950s and 1970s, because the filter probability for a recession is close to 0 for most of the sample period except for the late 1950s and 1973–74 (when it is close to 1) and the early 1960s, 1980, 1982, and 1990 (when it moves away from 0, but in some cases only slightly).

average output decline during a recession (as captured by α_0) close to that for traditional NBER dating. Second, we directly use the NBER dates, rather than treating S_t as an unobserved latent variable.

Estimates based on the Hamilton (1991) technique are presented in the second column of Table 2.[16] The absolute value of α_0 is smaller than in Table 2, reflecting the fact that we are now classifying milder declines in output as recessions.[17] The estimates of β_{iq} and $\beta_{iq} + \beta_{ip}$ show that an increase in interest rates reduces output growth in both recessions and expansions. The effects, however, are much larger during recessions than during expansions; in fact, $\beta_{iq} < \beta_{iq}+\beta_{ip}$ for all i.

Estimates based on the assumption that S_t is observable and corresponds to the NBER dates are presented in the third column of Table 2. Again, there is evidence that an increase in interest rates reduces output in both expansions and recessions. As in the first and second columns, the magnitude of the effect is larger in recessions than expansions. In fact, the effect during expansions shows up only weakly in the third column.

We have also checked the robustness of our results to the choice of sample period and interest rate.[18] In both cases, the results are similar to those in Table 2. An increase in interest rates lowers the output growth rate in both expansions and recessions. As in Table 2, this is a statistically strong result. Also as in Table 2, the drop in output growth is substantially larger if the economy is in a recession at the time interest rates rise.

Conditioning on the Current State

There is another way of looking at asymmetries between recessions and expansions, based on whether there are different effects depending on the *current* state of the economy, rather than the state of the economy at the time the policy action was taken. The following specification addresses the question: if interest rates rise in period $t - s$, does the effect in period t depend on whether the economy is in a recession or an expansion in period t?

$$(8)\quad \begin{aligned} y_t - \alpha_0 - \alpha_1 S_t &= \phi_1(y_{t-1} - \alpha_0 - \alpha_1 S_{t-1}) \\ &\quad + \cdots + \phi_r(y_{t-r} - \alpha_0 - \alpha_1 S_{t-r}) \\ &\quad + \beta_{1q}X_{t-1} + \cdots + \beta_{rq}X_{t-r} \\ &\quad + \beta_{1p}S_tX_{t-1} + \cdots + \beta_{rp}S_tX_{t-r} + \sigma\varepsilon_t \end{aligned}$$

Results for this specification are reported in Table 3. As in the previous tables in this section, there is strong evidence that increases in interest rates lead to a reduction in output in both recessions and expansions. As before, the effects are statistically strong. The p-value for the hypothesis that all $\beta_{iq} = 0$ is less than .0001; for the $\beta_{iq}+\beta_{ip} = 0$, the p-value is .0003.

The data again provide strong evidence of asymmetry. The null hypothesis that $\beta_{iq} = \beta_{iq} + \beta_{ip}$ is rejected with a p-value of less

TABLE 3
State-Dependent Effects of an Increase in the Fed Funds Rate (Conditioning on the Current State) (Period of Estimation: 1955:2 to 1993:1 [Quarterly])

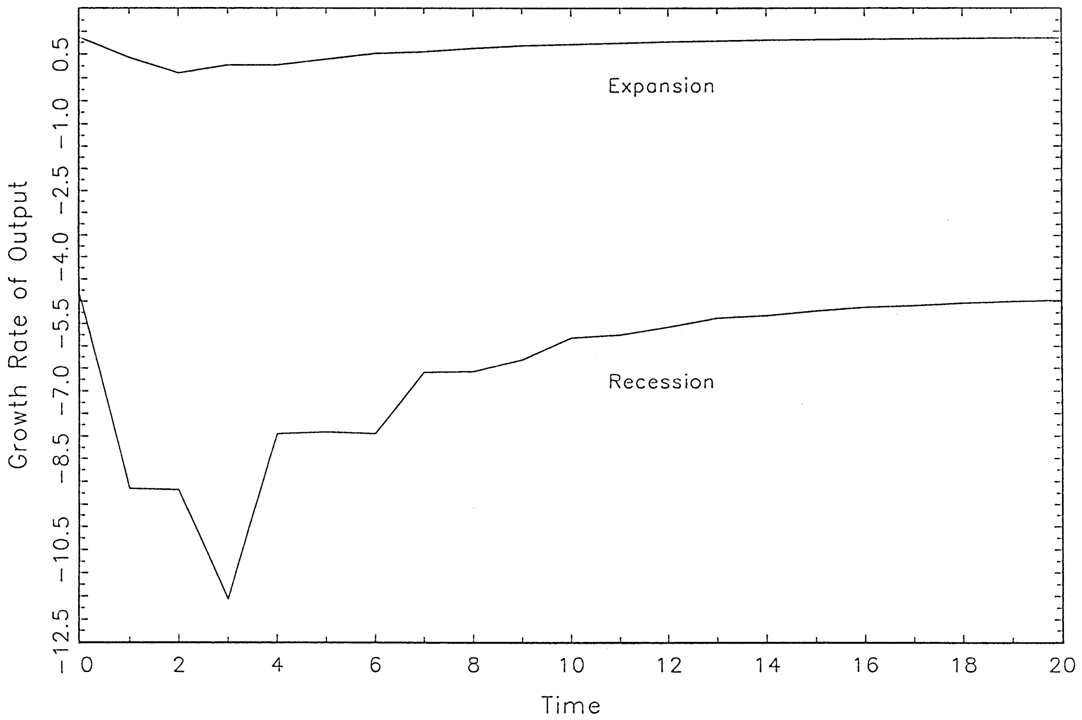
	Coefficient Estimates	**Standard Error**
$\alpha_0 + \alpha_1$	0.9017	0.4442
α_0	−4.5652	0.6783
p_{11}	0.9613	0.0191
p_{00}	0.5021	0.2125
σ	1.3042	0.0823
ϕ_1	0.2695	0.0812
ϕ_2	0.1926	0.0856
ϕ_3	0.3132	0.0822
ϕ_4	−0.0974	0.1047
β_{1q}	−2.9544	0.4436
β_{2q}	−2.1756	0.4266
β_{3q}	−3.2404	0.6654
β_{4q}	0.6086	0.5201
$\beta_{1q} + \beta_{1p}$	−0.2993	0.1178
$\beta_{2q} + \beta_{2p}$	−0.4406	0.1207
$\beta_{3q} + \beta_{3p}$	−0.2113	0.1016
$\beta_{4q} + \beta_{4p}$	−0.1066	0.1088
Log likelihood = 530.34		

16. In this approach, we penalize any deviation from the average growth rate in recessions over the sampling period, as dated by the NBER. This average for the estimation period is equal to −1.74%. The estimate obtained for α_0 is therefore very close to this number.

17. θ_{0q} is also considerably larger, implying a greater probability of remaining in a recession.

18. We estimated the model over the subperiod 1965–1993. In addition, we extended the sample period to 1947–1993 by replacing the Fed funds rate with the T-bill rate. We also reestimated the specification in Table 2 for the 1955–1993 period using the T-bill rate.

FIGURE 3
State-Dependent Effects of an Increase in the Fed Funds Rate
(Conditioning on the Current State)



than .0001.[19] The coefficients suggest a much stronger effect when the economy is in a recession. The sharp difference in the effects of policy tightening is illustrated in Figure 3, where the fall in output growth is much more dramatic when the economy is in a recession than when it is in an expansion.

Higher-Frequency Dynamics

As Table 4 shows, many of the patterns that emerge in monthly data are similar to those we have seen before. Figure 4 shows that the filter probabilities are quite similar when we replace (1) with (7) in the specification of the Markov switching model, specifically when we allow interest rates to affect output growth. As in previous tables, policy tightening leads to lower output growth both in recessions and expansions. When we test the symmetry hypothesis, it is strongly rejected; the p-value is less than .0001. As in the quarterly data, this is because the magnitude of the coefficients tends to be smaller in the expansion state.

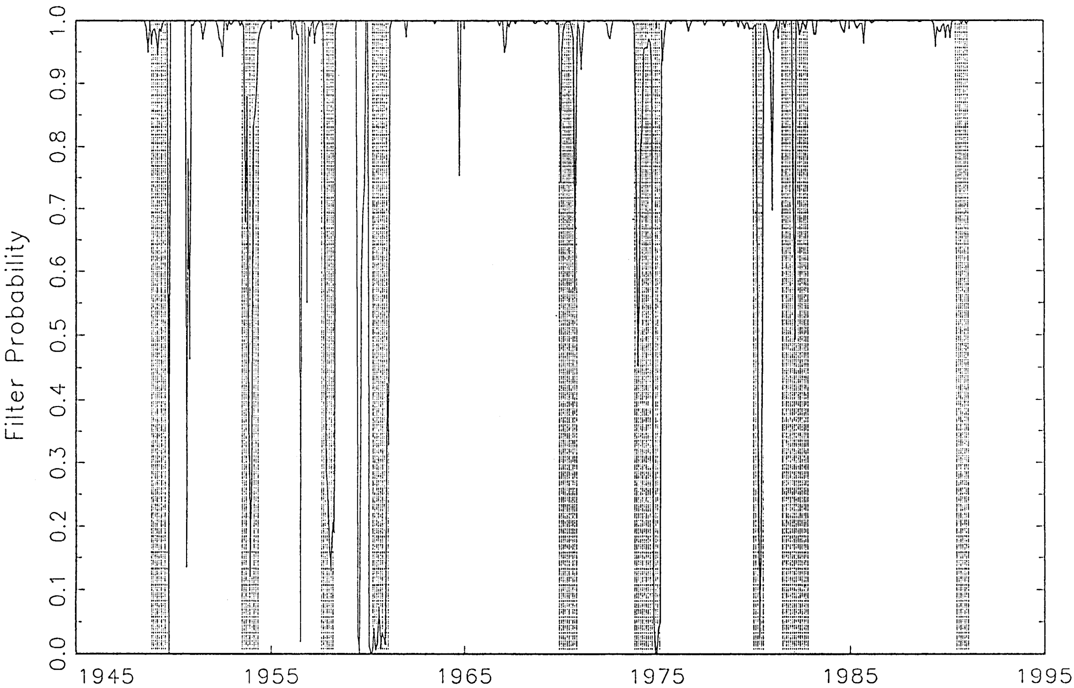
In addition, the monthly data reveal a feature of short-term dynamics that is not visible in the quarterly data. In the expansion state, the coefficients for the first two months are both economically and statistically small. As in the quarterly data, the coefficients in the recession state are initially positive, but they turn negative after two months. This suggests that it may take about two months before higher interest rates begin to bite.

III. VAR-BASED MEASURES OF MONETARY POLICY SHOCKS

There are many reasons for believing that changes in the Fed funds rate provide a good measure of the stance of monetary policy, as we noted previously. Macroeconomists are naturally sensitive to the potential identification problem, however. Interest rates are not exogenous; they are affected by shocks to supply and demand in capital markets

19. To examine the robustness of these results, we estimated a specification with the T-bill rate and obtained results similar to those in Table 5. In particular, the hypothesis of symmetry between recessions and expansions is rejected at a marginal significance level of .0001.

FIGURE 4
Probability of the Expansion State Based on the Markov Switching Model (Including Interest Rates in the Specification)



Note: Shaded areas indicate NBER recessions.

and may be partly endogenous due to the monetary policy reaction function. Since Sims (1980), many macroeconomists have used innovations from VARs to address the identification issue. As an alternative measure of monetary policy, we therefore estimate several VARs and use the innovations from these instead of changes in the Fed funds rate.

We consider three different VAR-based measures of monetary policy. In the first, we began by estimating a VAR with industrial production, M1, the price index, and the Fed funds rate using six lags of each variable at monthly frequency. A specification similar to that in Table 2 (namely, equations [7], [2], [4], and [5]) was then estimated with the innovations from the Fed funds rate equation used as the X variable in (7). The results are reported in the first column of Table 5.

The residuals from the Fed funds rate equation do not necessarily represent a pure monetary policy shock, because they may be correlated with the residuals from the other equations. A common way to deal with this is to orthogonalize the residuals, but results can be sensitive to the way in which the orthogonalization is done.[20] Bernanke (1986) and others have suggested using structural VARs. Under identifying assumptions described by Bernanke and Blinder (1992), the Choleski orthogonalized residuals from a VAR (with the Fed funds rate as the last equation) have a clear interpretation as monetary policy shocks.[21] This is what we use as a measure of monetary policy in the specification reported in the second column of Table 5.

A variety of authors have noted that there is a "price puzzle" associated with some VARs. The puzzle is that a contractionary

20. In our data, the largest entry in the correlation matrix of the residuals was .17, so our results may not be very sensitive to the ordering of a Choleski orthogonalization. (See, for example, Sims [1992].)

21. The identifying assumptions are that innovations in the Fed funds rate are attributed solely to the Fed and that current values of output, money, and the price level do not enter the Fed's monetary policy rule. (An alternative identifying assumption would be that the Fed funds rate does not affect output within period.) In all the specifications in Table 5, we estimate the VAR at monthly frequency (and sum the innovations over a given quarter) because these assumptions are more likely to hold at monthly frequency.

TABLE 4
State-Dependent Effects of an Increase in the Fed Funds Rate (Conditioning on the State at the Time of the Increase) (Period of Estimation: 1955:02 to 1993:01 [Monthly])

	Coefficient Estimates	Standard Error
$\alpha_0 + \alpha_1$	0.4385	0.0957
α_0	−1.6237	0.2557
θ_{0p}	0.9796	0.0087
θ_{0q}	0.6751	0.1383
σ	0.7884	0.0301
ϕ_1	0.2615	0.0580
ϕ_2	0.0846	0.0587
ϕ_3	0.1166	0.0620
ϕ_4	0.0512	0.0595
β_{1q}	0.5025	0.4786
β_{2q}	1.7369	0.4049
β_{3q}	−1.0826	0.3609
β_{4q}	−0.0382	0.3473
$\beta_{1q} + \beta_{1p}$	−0.0778	0.0720
$\beta_{2q} + \beta_{2p}$	0.0197	0.0788
$\beta_{3q} + \beta_{3p}$	−0.1539	0.0762
$\beta_{4q} + \beta_{4p}$	−0.1208	0.0706
Log likelihood = 1936.26		

monetary policy shock appears to lead to an increase in the price level. The puzzle disappears when the VAR conditions on supply shocks (i.e., by including commodity prices in the VAR). In our third specification, we therefore condition on commodity prices.

The main results are similar in all three specifications reported in Table 5. A contractionary monetary policy shock decreases output growth in both expansions and recessions. In all the specifications in Table 5, the results are statistically strong.[22] Once higher interest rates begin to bite, the effects are about two to three times greater during recessions than during expansions.

In addition to the results reported in Table 5, we also estimated comparable specifications using the Hamilton (1991) algorithm and the NBER dates (as in Table 2 above) and obtained similar results. Interestingly, the Markov switching model tends to fit the data considerably better than specifications based on the NBER dates.[23]

IV. DO INTEREST RATES AFFECT THE PROBABILITY OF A STATE SWITCH?

In the heyday of activist macroeconomic policy, there was a belief in fine-tuning, which might be defined as the ability to incrementally adjust choice variables through the use of policy instruments. Much of the evidence on the effectiveness of monetary policy (such as that provided by Friedman and Schwartz [1963], the Volcker disinflation, or Romer and Romer [1990]) comes from episodes where there were sharp policy changes, rather than small adjustments. Models with an L-shaped aggregate supply curve, finance constraints, or multiple equilibria all suggest potential nonlinearities. It may be the case that monetary policy has little effect unless it is dramatic. The type of question which motivates this section is: do changes in interest rates have an incremental effect on the growth rate during an expansion or do they only affect the economy if they are sufficiently strong to plunge the economy into a recession?

We begin by addressing a more modest type of question—namely, given that the economy is currently in an expansion, does a rise in interest rates increase the probability of a recession? With an appropriate extension, the Markov switching model is well suited to addressing this question, because it provides an explicit estimate of the probability of going from an expansion to a recession. From equations (3) and (4), we can see that this probability is equal to $p_{10} = 1 - p_{11}$, which depends on the parameter θ_{0p} and which we have so far constrained to be constant over time. In this section, we relax the assumption that the transition probabilities are constant[24]; instead, we allow them to be functions of changes in interest rates, so

22. The hypothesis that all β_{iq} equal zero can be rejected at the .0001 level in all specifications; the same level holds for the expansion coefficients except in the second specification where the marginal significance level is .002.

23. For example, the likelihood ratio statistic for a comparison of the Hamilton (1989) specification and the NBER dates with the X variable as specified in the second column of Table 5 was 24.6. Though this seems large, it is not clear whether it would be significant at conventional levels because there is not yet an asymptotic distribution theory covering the case of a constrained filter.

24. Diebold et al. (1993) discuss the econometrics of variable transition probabilities.

TABLE 5
State-Dependent Effects of an Increase in the Fed Funds Rate (Conditioning on the State at the Time of the Increase) (Period of Estimation: 1955:2 to 1992:4 [Quarterly])

	Measure of Monetary Policy Shock		
		Structural VAR Innovations	
	Nonstructural VAR Innovations	Not Conditioning on Commodity Prices	Conditioning on Commodity Prices
$\alpha_0 + \alpha_1$	1.0095 (0.1737)	0.9913 (0.1697)	1.0090 (0.1662)
α_0	−5.4481 (0.5783)	−6.7004 (0.6789)	−6.9172 (0.8025)
p_{11}	0.9717 (0.0136)	0.9767 (0.0131)	0.9760 (0.0141)
p_{00}	0.2045 (0.1718)	0.2469 (0.1868)	0.2486 (0.2006)
β_{1q}	4.8538 (0.7537)	1.9545 (0.2730)	2.0950 (0.4044)
β_{2q}	−2.1633 (0.8072)	−0.6174 (0.3632)	−0.6626 (0.3852)
β_{3q}	−1.9642 (0.8466)	−0.3988 (0.3727)	−0.5136 (0.3981)
β_{4q}	−0.8314 (0.7167)	−0.0706 (0.2715)	−0.1348 (0.3851)
$\beta_{1q} + \beta_{1p}$	0.0798 (0.1173)	−0.2788 (0.0699)	−0.2893 (0.0848)
$\beta_{2q} + \beta_{2p}$	−0.3221 (0.1225)	−0.2672 (0.0748)	−0.2397 (0.0841)
$\beta_{3q} + \beta_{3p}$	−0.2648 (0.1215)	−0.0969 (0.0775)	−0.0682 (0.0922)
$\beta_{4q} + \beta_{4p}$	−0.0407 (0.1197)	−0.0626 (0.0754)	−0.0442 (0.0902)
Log likelihood	542.14	534.96	536.16

that (4) and (5) are replaced with

$$(9)\quad p_{00} = P(S_t = 1|S_{t-1} = 1) = \exp(\theta_{0p} + \theta_{1p}Z_{t-k} + \theta_{2p}Z_{t-m} + \theta_{3p}Z_{t-s})/[1 + \exp(\theta_{0p} + \theta_{1p}Z_{t-k} + \theta_{2p}Z_{t-m} + \theta_{3p}Z_{t-s})] \quad \text{and}$$

$$(10)\quad p_{00} = P(S_t = 0|S_{t-1} = 0) = \exp(\theta_{0q} + \theta_{1q}Z_{t-k} + \theta_{2q}Z_{t-m} + \theta_{3q}Z_{t-s})/[1 + \exp(\theta_{0q} + \theta_{1q}Z_{t-k} + \theta_{2q}Z_{t-m} + \theta_{3q}Z_{t-s})].$$

To isolate the effect of interest rate changes on transition probabilities from the more standard linear effect, we constrain the linear effect to zero. In other words, we estimate a specification using (1) rather than (7).[25]

Changes in the Fed Funds Rate

We begin by estimating the specification on monthly data using changes in the Fed funds rate for Z. To keep the number of parameters manageable (and to reduce noise in month-to-month interest rate changes), we let Z_{t-k} represent the change in the Fed

25. In principle, changing the specification of the transition probabilities could alter the classification of periods into expansions and recessions. In practice, we obtain business cycle dating similar to that shown in Figure 1 with the specification reported below in Table 6. The maximization algorithm for specifications (1)–(3) and (9)–(10) is described in detail in Filardo (1994), who uses a time-varying transition probability model to study the effect of various business cycle leading indicators on the dating of booms and recessions.

TABLE 6
Variable Transition Probabilities: Changes in the Fed Funds Rate (Lags = −1 to −4 to −7, −7 to −10) (Period of Estimation: 55:11 to 93:05 [Monthly]; 450 Observations)

	Coefficient Estimates	Standard Error
α_1	0.4629	0.1043
α_0	−2.2796	0.2502
θ_{0p}	4.5132	0.4922
θ_{0q}	2.2378	0.7037
σ	0.8000	0.0267
ϕ_1	0.1758	0.0584
ϕ_2	0.1382	0.0493
ϕ_3	0.1958	0.0579
ϕ_4	0.1499	0.0526
θ_{1p}	−0.2927	0.2788
θ_{2p}	−0.4603	0.2385
θ_{3p}	−0.2843	0.2238
θ_{1q}	0.8534	0.4204
θ_{2q}	−0.0813	0.5420
θ_{3q}	1.5703	1.0682
Log likelihood = 1898.06		

funds rate from month −4 to −1, Z_{t-m} the change from month −7 to −4, and Z_{t-s} the change from month −10 to −7. Results for this specification are presented in Table 6. The coefficients θ_{ip} reflect the change in the probability of remaining in an expansion associated with an increase in interest rates. The negative coefficients in Table 6 imply that an increase in interest rates increases the probability of going from an expansion into a recession. Similarly, the primarily positive θ_{iq} coefficients mean that a decrease in interest rates is associated with a higher probability of getting out of a recession.

To give an idea of the magnitude of the effects implied by the θ coefficients, we consider the following experiment. Suppose the Fed were to increase the Fed funds rate by 50 basis points in each of three successive quarters; how would this affect the probability of going from an expansion to a recession?[26] Evaluated at $Z_{t-i} = 0$ for all i in (7), the probability of going from an expansion to a recession is .011 for the specification in Table 6.[27] (Recall that this is the probability of expansion ending *in a given month*; obviously the cumulative probability over several months will be larger.) As Table 7 shows, the experiment we have described is associated with an increase of slightly more than half in a probability of going from an expansion to a recession; the probability increases from .011 to .018.

Table 7 allows us to address a long-standing question in macroeconomics: are cuts in interest rates during a recession like "pushing on a string"? With no change in the Fed funds rate, the probability of going from a recession to an expansion is about .10. Table 7 shows that successive reductions in the Fed funds rate of the sort we have described are associated with an increase of about two to three times in the probability of going from a recession to an expansion; the probability increases from .10 to about .26.

There is frequently uncertainty about the current state of the economy, as witnessed by the debate in 1991–92 over whether the recovery had started or the economy was only partway through a double-dip recession. In such periods, it may be useful to know, without specifying the current state of the economy, what effect do changes in interest rates have on the probability that a recession will occur? Analytically, this question is different because it depends on both p_{00} and p_{11}. The unconditional probability of being in a recession is about .10. Successive increases in the Fed funds rate in the experiment described above increase this probability by a bit more than one-half. Figure 5 illustrates the path through time of the probability of a recession based on the estimated coefficients in Table 6.[28]

Changes in the Paper-Bills Spread

The spread between commercial paper and T-bill rate has featured prominently in recent empirical work on the link between

26. The monthly standard deviation of the Fed funds rate is 64 basis points; the quarterly standard deviation is 146 basis points. A plot of the Fed funds rate over our sample period shows that there are many episodes when the Fed funds rate rises or falls for several successive quarters.

27. The mean change in the Fed funds rate over our sample period is 0.35 basis points (i.e., 0.0035 percentage points).

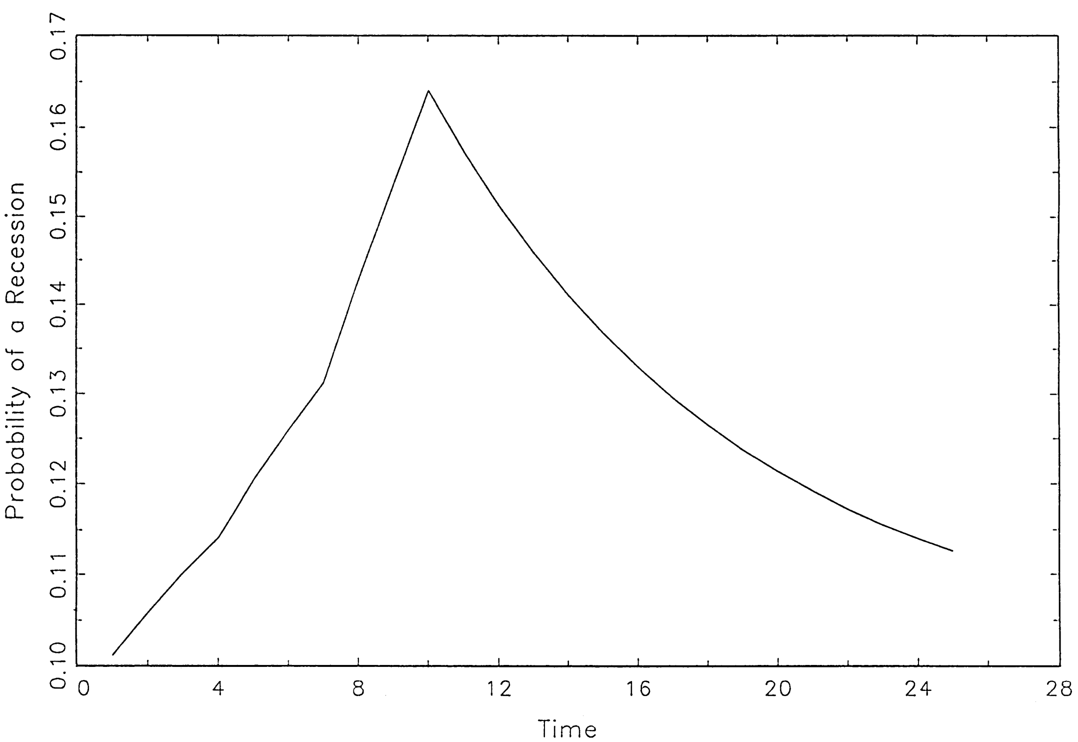
28. We have checked the robustness of our results to the choice of sample period and interest rate. In both cases, the results are qualitatively similar.

TABLE 7
The Effect of Changes in the Fed Funds Rate on the Transition Probabilities

		Evaluated at				
		Minus 50 Basis Points	**Minus 25 Basis Points**	$Z = 0$	**Plus 25 Basis Points**	**Plus 50 Basis Points**
Probability of going	1 quarter	0.0094	0.0101	0.0108	0.0117	0.0125
from an expansion	2 quarters	0.0075	0.0090	0.0108	0.0131	0.0157
to a recession in:	3 quarters	0.0065	0.0084	0.0108	0.0140	0.0181
Probability of going	1 quarter	0.1405	0.1167	0.0964	0.0794	0.0651
from a recession	2 quarters	0.1357	0.1146	0.0964	0.0809	0.0676
to an expansion in:	3 quarters	0.2561	0.1608	0.0964	0.0561	0.0320

Note: This table summarizes the effects of changes in the Fed funds rate of either 25 or 50 basis points over three consecutive quarters, based on our coefficients estimates for θ_{ip} and θ_{iq} ($i = 1, 2, 3$). The monthly standard deviation of the Fed funds rate is 64 basis points over our sample period; the quarterly standard deviation is 146 basis points.

FIGURE 5
The Effect of Changes in Fed Funds Rates on the Probability of a Recession



real and financial variables.[29] Some of this research suggests that the spread is a useful predictor of aggregate output. In addition, it has been suggested that the spread is a measure of tight credit conditions, since when agency costs rise (or finance constraints bind), the gross expected return on investment rises relative to the safe interest rate.[30]

29. See, for example, Friedman and Kuttner (1992) and Stock and Watson (1989).

30. See, for example, Bernanke (1983), Bernanke and Gertler (1989), and Gertler et al. (1991).

Table 8 presents the specification in which we allow the transition probabilities to depend on the spread. The estimates of θ_{ip} imply that an increase in the spread increases the probability of moving from an expansion to a recession. Without any change in the spread, the probability of going from an expansion to a recession is .010. If the spread increases by 25 basis points over three successive quarters, the probability increases to about .037, as shown in Table 9.[31] The effects are even more dramatic if the economy starts in a recession. Without any change in the spread, the probability of going from a recession to an expansion is .12. If the spread decreases by 25 basis points over three successive quarters, the probability increases to .65.[32]

TABLE 8
Variable Transition Probabilities: Changes in the Spread (Period of Estimation: 1955:11 to 1993:11 to 1993:5 [Monthly])

	Coefficient Estimates	Standard Error
α_1	0.4755	0.1121
α_0	−2.2200	0.2286
θ_{0p}	4.5634	0.4902
θ_{0q}	2.0359	0.6362
σ	0.7877	0.0271
ϕ_1	0.1319	0.0519
ϕ_2	0.1478	0.0515
ϕ_3	0.2306	0.0553
ϕ_4	0.1591	0.0513
θ_{1p}	−0.4283	0.7931
θ_{2p}	−1.5947	0.6994
θ_{3p}	−3.2186	1.1099
θ_{1q}	6.0066	2.2413
θ_{2q}	−0.4045	1.0112
θ_{3q}	4.9662	2.2170
Log likelihood = 1904.34		

V. CONCLUSION

A growing body of empirical work has examined potential asymmetries between expansions and recessions.[33] Our article differs from much of this previous work in a crucial way. Most of the work to date is univariate in the sense that it focuses on the time-series properties of a single macroeconomic variable, such as output. It can answer questions like whether there are statistically significant differences in the growth rate of output between expansions and recessions or whether shocks are more persistent during a recession than an expansion. Many of the most interesting questions in macroeconomics, however, are essentially multivariate, because they concern the effect of policy or other shocks on output.

This study examines whether policy shocks have an asymmetric effect on output growth. We find strong evidence that monetary policy has larger effects during a recession than during an expansion. This is true both when we use changes in the Fed funds rate as a measure of monetary policy and when we use monetary policy innovations from a structural VAR. We check whether the results are robust to changes in the dating of business cycles, the choice of sample period, the frequency of the data, and the specification of the econometric model. Variations in these dimensions reinforce the main result: there is an asymmetry in the effects of monetary policy, with stronger effects during recessions than during expansions.

In addition to asymmetry, the Markov switching model allows us to look at whether economic shocks have an incremental effect on output or only affect the economy by increasing the probability of a state switch. The results when we look at the spread between commercial paper and T-bill rates are particularly interesting. The effect of a change in the spread on the probability of going from an expansion to a recession (or vice versa) is substantial. For example, an increase in the spread of 50 basis points decreases the probability of going from a recession to an expansion from .12 to less than .01.

31. The monthly standard deviation of the change in the spread over this period is 26 basis points. The quarterly standard deviation is 50 basis points.

32. The asymptotic t-statistics for θ_{1q} and θ_{3q}, the coefficients that primarily determine this result, are 2.7 and 2.2, respectively. The results are robust to a change in the sample period.

33. See, for example, Neftci (1984), Beaudry and Koop (1993), Cover (1992), Filardo (1994), Hamilton (1989), Huh (1993), and McQueen and Thorley (1993).

APPENDIX

The following is a brief description of the data sources. Output is industrial production (total index). The Fed

TABLE 9
The Effect of Changes in the Spread on the Transition Probabilities

		Evaluated at				
		Minus 50 Basis Points	**Minus 25 Basis Points**	$Z = 0$	**Plus 25 Basis Points**	**Plus 50 Basis Points**
Probability of going	1 quarter	0.0083	0.0093	0.0103	0.0115	0.0128
from an expansion	2 quarters	0.0038	0.0062	0.0103	0.0170	0.0279
to a recession in:	3 quarters	0.0008	0.0028	0.0103	0.0372	0.1254
Probability of going	1 quarter	0.7246	0.3695	0.1155	0.0283	0.0064
from a recession	2 quarters	0.6825	0.3463	0.1155	0.0312	0.0079
to an expansion in:	3 quarters	0.9626	0.6471	0.1155	0.0092	0.0007

Note: This table summarizes the effects of changes in the spread of either 25 or 50 basis points over three consecutive quarters, based on our coefficient estimate for θ_{ip} and θ_{iq} $(i = 1, 2, 3)$. The monthly standard deviation of the Fed funds rate is 26 basis points over our sample period; the quarterly standard deviation is 50 basis points.

funds and T-bill rates are the monthly average of daily rates. The money supply is M1 (monthly average figures) starting in 1959; the earlier M1 data were provided by R. H. Rasche. The derivation of Rasche's M1 series is described in Rasche (1987). The commercial paper rate is the six-month rate (monthly average). With the exception of the Rasche M1 data, the preceding series are all produced by the Board of Governors of the Federal Reserve System. The price index is the Consumer Price Index (all items) produced by the Bureau of Labour Statistics. Commodity prices are the CRB Spot Market Index—All Commodities produced by the Commodities Research Bureau.

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