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WHEN IS MONETARY POLICY EFFECTIVE?

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ABSTRACT

In this paper, we investigate a number of issues that have not been completely addressed in previous studies regarding the possible asymmetric effects of monetary policy. Overall, we interpret our results as weak evidence in favor of sticky-wage and sticky-price theories and strong evidence against credit-rationing theories. First, we find that models that allow for asymmetries with respect to contractionary/expansionary monetary policy fit the data better than models that allow for asymmetries associated with the state of the business cycle. Second, we find that contractionary monetary policy shocks have a much larger effect on output than expansionary policy shocks, although this result is somewhat sensitive to the econometric specification. Finally, we find that monetary policy shocks that occur during economic expansions appear to have about the same effect as shocks that occur during recessions; this result is robust to various econometric specifications.

When is Monetary Policy Effective?

John Ammer and Allan D. Brunner[1]

I. Introduction

Economists have long been interested in the effects of monetary policy on economic activity. In this paper, we examine whether monetary policy shocks have asymmetric effects on output, as measured by gross domestic product (GDP). There are a number of economic theories that suggest that the effects of monetary policy are state-dependent. For example, some theories of wage or price stickiness -- see Tsiddon (1991), Caballero and Engel (1992), and Ball and Mankiw (1994) -- imply that expansionary policy shocks should be largely ineffective, while contractionary policy shocks should have a significant impact on economic activity. According to these theories, this asymmetry occurs because the aggregate supply curve is kinked -- relatively flat below the point on the supply curve that corresponds to expected output and price levels and essentially vertical above the point.

By contrast, some theories of credit rationing imply that monetary policy shocks (contractionary or expansionary) should be more effective during recessionary periods of economic activity, when large numbers of households and firms are likely to be credit-constrained. According to these theories -- see Gertler (1988), Bernanke (1983), and Gilchrist, Bernanke, and Gertler (1994) for recent surveys of this literature -- the availability of credit and the ability of households and firms to qualify for credit are much more sensitive to interest rate shocks when balance sheets are weak and income streams are relatively low. For example, if a borrower already has enough collateral to qualify for a bank loan, a lower interest rate will have only the usual textbook effects, such as a movement along a

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demand curve for bank credit. However, if the borrower is marginally constrained by asset values, a lower interest rate (which tends to raise asset values) may have an additional positive impact on the borrower's decisions to borrow and spend.

There are several empirical studies that have examined the asymmetric effects of monetary policy. Using linear models, Cover (1992) found that contractionary monetary policy shocks have a much larger effect on output than expansionary policy shocks. Although Thoma (1994) found a similar asymmetric effect of monetary policy, his results are based on regressions of output on a monetary aggregate. Since movements in money are likely due to non-monetary policy shocks as well as monetary policy shocks, it is unclear whether the asymmetries identified by Thoma can be attributed to monetary policy per se. Moreover, both of these studies could be mis-identifying the source of asymmetry, since contractionary monetary policy is often associated with expansionary economic activity.

In addition, Tufte (1992), Boldin (1994), Thoma (1994), and Garcia and Schaller (1994) found evidence that the effects of monetary policy vary with the business cycle, with policy more effective during recessions than during economic expansions. Still, each of these studies regresses an output measure on monetary aggregates or short-term interest rates rather than focusing on the role of monetary policy shocks. In addition, as with the previously-cited studies, there are no formal tests of these models against alternative hypotheses, such as whether asymmetric effects are better associated with contractionary/expansionary monetary policy rather than with the state of the business cycle.

In this paper, we investigate a number of issues that have not been completely addressed in previous studies. First, in contrast to most of the literature, we examine the effects of monetary policy shocks rather than the effects of changes in a monetary policy instrument, such as an interest rate or a measure of money. This is an important distinction to make if changes in the Fed's policy instrument are due to systematic responses to changes in other variables as well as monetary policy shocks.

Indeed, we find that about 90 percent of the variation in the federal funds rate -- our assumed policy instrument -- is attributable to factors other than monetary policy surprises. As a result, it would be misleading to use only single-equation regressions of output on the federal funds rate to make inferences about the effects of monetary policy.

Second, in contrast to the studies noted above, we examine econometric models that allow for both types of asymmetric effects of monetary policy -- with respect to periods of either expansionary/contractionary policy or expansionary/recessionary periods of economic activity. Finally, we estimate several types of linear and non-linear models to ensure that our results are robust to a variety of econometric specifications.

Overall, we interpret our results as weak evidence in favor of sticky-wage and sticky-price theories and strong evidence against credit-rationing theories. First, we find that models that allow for asymmetries with respect to contractionary/expansionary monetary policy fit the data better than models that allow for asymmetries associated with the state of the business cycle. Second, we find that contractionary monetary policy shocks generally have a much larger effect on output than expansionary policy shocks, although this result is somewhat sensitive to the econometric specification. In particular, contractionary policy shocks are well-correlated with future recessions. This makes it somewhat difficult to determine whether our shocks are truly exogenous or whether they are a proxy for a variable that we omitted from the Fed's reaction function and that negatively affects economic activity. Finally, we find that monetary policy shocks that occur during economic expansions appear to have about the same effect as shocks that occur during recessions; this result is robust to various econometric specifications.

Our results also have wider implications. For example, they have important implications for those studies that have documented an unstable linear relationship between aggregate output and monetary policy -- see especially Christiano and Ljungqvist (1988), Stock and Watson (1989), Friedman and Kuttner (1992), and Thoma (1994). That is, our findings suggest that, if monetary policy is particularly potent during monetary contractions, then it should be expected that the coefficients of a simple linear regression of output on interest rates should be unstable over time, with coefficients that are larger and more statistically significant from zero during periods of contractionary monetary policy.

Our findings also have implications for those studies that have documented nonlinearities in output -- see Neftci (1984), Brock and Sayers (1988), Brunner (1992, 1995), Sichel (1993), Potter (1991), and Beaudry and Koop (1994). These studies found, in a univariate context, that the effects of a shock to output are state-dependent (nonlinear and asymmetric). Our results suggest that some of this asymmetry can be attributed to the differential effects of monetary policy shocks, although the latter effects appear to explain only a small amount of the variation in output growth.

Our results are not entirely consistent, however, with studies that have focused on narrower measures of economic activity. Thoma, Boldin, and Garcia and Schaller, for example, find that policy shocks that occur during recessions have stronger effects on industrial production than shocks that occur during expansions. However, as discussed earlier, it is not clear from those studies whether models with this type of asymmetry fit the data better than models with alternative types of asymmetries. In addition, each of these studies regressed output on monetary policy variables rather than monetary policy shocks. Still, it could be the case that our results are not robust to alternative measures of economic activity.

The remainder of the paper is organized as follows. Section II presents our econometric results using linear models of output growth, and section III discusses results obtained with nonlinear models. Section IV reviews the results of a sensitivity analysis where we examine the robustness of our results to various assumptions made in sections II and III. Finally, section V provides some concluding remarks.

II. Results Using Linear Models

In this paper, we employ a two-step procedure for identifying the effects of monetary policy shocks. First, we regress the federal funds rate -- our assumed monetary policy instrument -- on variables that are likely to be in the Federal Reserve's reaction function. The residuals from this regression are the monetary policy shocks. The second step consists of regressing output growth on the policy shocks. The latter regression can be interpreted as an impulse response function, capturing the lagged effects on output of an exogenous change in interest rates (i.e., an exogenous change in the stance of monetary policy). In the remainder of this section, we describe the data used in the paper, our approach to identifying monetary policy shocks, and our econometric results using simple linear models of output growth.

The Data

In this and following sections, we use data on gross domestic product (GDP), M1, the consumer price index (CPI), three-month Treasury bill rates, and the federal funds rate. The data are from 1959Q1 through 1994Q4, taken from the Federal Reserve's FAME databases. All data, with the exception of GDP, are measured as the month-average level during the third month of the quarter. GDP, M1, and the CPI are expressed as percent changes (first-differences of log-levels times 100) due to the non-stationarity in these variables.

The Fed's Reaction Function

A Federal Reserve reaction function must be specified in order to obtain a set of monetary policy "shocks." There has been much recent discussion of how to correctly identify monetary policy shocks -- see, for example, Bernanke and Blinder (1992), Gordon and Leeper (1993), Christiano, Eichenbaum, and Evans (1994), and Brunner (1994). Still, while there is some agreement that the federal funds rate is the best indicator of the stance of monetary policy, there is little agreement concerning which indicators of economic activity should be included in the Fed's reaction function. Consequently, we will conduct our analysis using three different reaction functions. For most of our analysis, we used the following behavioral relationship:

$$R_t^f = \alpha_0 + \sum_{j=0}^{4} \alpha_{1j}\, \Delta Y_{t-j} + \sum_{j=0}^{4} \alpha_{2j}\, \Delta P_{t-j} + \sum_{j=1}^{4} \alpha_{3j}\, \Delta M1_{t-j} + \sum_{j=1}^{4} \alpha_{4j}\, R_{t-j}^f + \epsilon_t^{MP} \qquad (1)$$

where R^f denotes the federal funds rate, $\Delta M1$ denotes M1 growth, ΔY denotes GDP growth, ΔP denotes CPI inflation, and ε^{MP} represents a monetary policy shock, an exogenous shock to the federal funds rates. This specification is similar to the "benchmark model" studied by Christiano, Eichenbaum, and Evans (1994). Note that positive interest rate shocks correspond to contractionary monetary policy. Also, with this specification, we are assuming that the Fed responds to contemporaneous movements in output and prices, but only to lagged changes in M1. That is, we are assuming that the Fed's money supply rule is weakly exogenous with respect to M1, although it does responds with a lag to money demand shocks. Importantly, for each set of coefficients -- α_{ij}, for a given i and for all j -- we can reject the null hypothesis that the coefficients are jointly statistically different from zero. In section IV, we will test the robustness of our results based on the specification outlined in equation (1) by examining results using two other reaction functions.

Figure 1 shows the one-year moving-average of the monetary policy shocks that are derived from the reaction function in equation (1). It is interesting to note that in many cases, positive interest rate shocks (contractionary monetary policy) tend to lead economic recessions (the shaded bars) by a few quarters. This could indicate that positive monetary policy shocks actually have a strong contractionary effect on economic activity. On the other hand, this feature could also reflect an important omitted variable from equation (1) that both causes the Fed to lower the federal funds rate and that causes recessions. We will return to this feature later.

Linear Models

We begin our analysis by looking at some simple linear models of output growth, models that are analogous to those studied by Tufte (1992), Cover (1992), and Thoma (1994):

$$\Delta Y_t = \mu + \sum_{j=1}^{K} \beta_j \Delta Y_{t-j} + \sum_{j=1}^{L} \gamma_j \epsilon_{t-j}^{MP} + u_t \tag{2}$$

where u represents an aggregate shock that by construction is orthogonal to ε^{MP}. Note that with this specification, we are assuming that output does not respond contemporaneously to monetary policy shocks. The long-run effect of a monetary policy shock on the level of output is $\gamma(1)/[1-\beta(1)]$, where $\gamma(1)$ is the cumulative sum of the coefficients on monetary shocks and $\beta(1)$ is the cumulative sum of coefficients on lagged output growth. Our prior is that $\gamma(1)$ is less than zero -- that positive interest-rate shocks are contractionary. Moreover, we are particularly interested in whether this sum is statistically different from zero and whether it is state-dependent, either varying according to whether ε^{MP} is positive or negative or to whether ε^{MP} occurred during an economic recession or expansion.

We estimated several versions of the model in equation (2), with K and L ranging from 0 to 4. Based on either the Aikaike information criterion (AIC) or the Schwarz criterion (SC), the optimal specification for this model contains one lag of output growth (K=1) and two lags of the interest rate shock (L=2). The parameter estimates for this specification (model 1A) are presented in Table 1a. Since we are also interested in whether the coefficients on the interest rate shocks are state-dependent -- either with respect to expansionary/contractionary periods of economic activity or with respect to the sign of the policy shocks -- we also estimated two variations of model 1A that relax the symmetry conditions in equation (2) as follows:

$$\Delta Y_t = \mu + \sum_{j=1}^{K} \beta_j \, \Delta Y_{t-j} + \sum_{j=1}^{L} \gamma_j^i \, \epsilon_{t-j}^{MP} + u_t \quad i = R, E \tag{3}$$

$$\Delta Y_t = \mu + \sum_{j=1}^{K} \beta_j \, \Delta Y_{t-j} + \sum_{j=1}^{L} \gamma_j^i \, \epsilon_{t-j}^{MP} + u_t \quad i = +, - \tag{4}$$

In equation (3), γ_j^R denotes the j-period lagged response of output growth to an interest rate shock that occurred in period t, given that period t+j corresponds to a recession. Similarly, in equation (4), γ_j^+ denotes the j-period lagged response of output growth to an positive interest rate shock (a contractionary policy shock) that occurred in period t. Respectively, γ_j^E and γ_j^- have the opposite interpretations.

The parameter estimates for these regressions (models 1B and 1C, respectively) are shown in the last two columns of Table 1a. The Akaike information criterion (AIC), shown at the bottom of the table, indicates that model 1C -- corresponding to asymmetric effects with respect to expansionary/contractionary monetary policy -- fits the data about as well as the symmetric model does, while the more conservative Schwarz criterion (SC) prefers the symmetric model. Both criteria indicate that model 1B -- corresponding to a distinction between expansionary and contractionary periods of economic activity -- is inferior to both of the other models.

Table 1b presents the results of likelihood ratio (LR) tests for various restrictions on coefficients in models 1A, 1B, and 1C. There is a pair of numbers listed in the table for each test: The first number corresponds to the cumulative sum of certain coefficients (shown in column 1), and the second number is the significance level for a $\chi^2(1)$ test with a null hypothesis that the sum is equal to zero. As shown in line 1 of the table, the sum of the coefficients on the monetary policy shocks in model 1A ($\gamma_1+\gamma_2$) is statistically different from zero at any conventional significance level. That is, a contractionary monetary policy shock will a permanent negative effect on the level of GDP.

Lines 2 and 4 correspond to tests on the coefficients of model 1B. The cumulative sum of coefficients on shocks that occur during recessions (line 2) and the cumulative sum of coefficients on shocks that occur during expansions (line 3) are both significantly different from zero. Although the former effects are nearly twice as large, the difference between the two sums is not statistically different from zero (line 4). By contrast, the sum of coefficients on positive interest rate shocks (contractionary policy) are substantially larger, statistically different from zero, and statistically different from the effect of negative interest rate shocks (expansionary policy). The results in Tables 1a and 1b provide some support for sticky-price and sticky-wage theories and strong evidence against credit-rationing theories.

As noted earlier, positive (negative) interest rate shocks appear to be leading indicators of recessions (expansions). This could mean that the interest rate shocks in the previous regressions are not capturing the causal effects of monetary policy, but, rather, are merely proxing for other factors that signal a major shift in economic conditions.[2] In order to eliminate this possibility, we allowed the conditional mean in equations (2), (3), and (4) to be state-dependent as well. In particular, we substituted μ^R and μ^E for μ, where μ^R is equal to one in periods that have been identified by the National Bureau of Economic Research (NBER) as recessionary periods and where μ^E is equal to $1-\mu^R$. For example, the model in equation (2) is rewritten:

$$\Delta Y_t = \mu_i + \sum_{j=1}^{K} \beta_j [\, \Delta Y_{t-j} - \mu_{t-j} \,] + \sum_{j=1}^{L} \gamma_j \, \epsilon_{t-j}^{MP} + u_t \qquad \mu_i = R, E \tag{5}$$

Note that the inclusion of these dummy variables is a somewhat of a "worst-case" scenario, since it assumes that economic agents knew with certainty the current state of the economy, whereas the NBER made its assessment only after the recession ended. We address this uncertainty in the next

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[2] The results obtained by Tufte, Cover, and Thoma must be considered with some caution for the same reason.

section of the paper, when we model the state of the economy as an unobservable variable.

The optimal specification for a linear model with dummy variables (model 2A) has zero lags of output growth (K=0) and two lags of interest rate shocks (L=2). Parameter estimates for this model are presented in Table 2a, along with parameter estimates for the corresponding asymmetric models (models 2B and 2C). As predicted, the inclusion of the dummy variables reduced the magnitude of the impact of the monetary policy shocks.

LR tests are presented in Table 2b. Despite the lower coefficient estimates due to the inclusion of dummy variables for expansions and recessions, the results are qualitatively similar to the previous results. As before, the cumulative sum of coefficients on the policy shocks for the symmetric model are statistically different from zero. Again, the sum on shocks that occurred during recessions are not statistically different from the sum on shocks that originated during expansions. However, the sum of coefficients on positive interest rate shocks are quite different in size from those on negative interest rate shocks, although they are only marginally-statistically different from each other.

To summarize the results of this section, we conclude on the basis of using linear models similar to those used by Tufte, Cover, and Thoma, that models of output growth that account for asymmetric effects of monetary policy with respect to whether monetary policy is contractionary or expansionary fit the data better than models that allow for an alternative type of asymmetry and about as well as symmetric models. Moreover, we find that the effects of contractionary monetary policy on the level of GDP are substantially larger than the effects of expansionary monetary policy, although the statistical significance of this difference is somewhat sensitive to econometric specification.

III. Results Using Non-Linear Models

In the previous section, we treated the current state of the economy (as measured by GDP growth) as being known with certainty by using a set of dummy variables for those periods that the NBER determined to be either recessions or expansions. In reality, the NBER makes its determination several periods after a recession or an expansion begins. In addition, the NBER looks at several economic indicators other than GDP to make its determination. As a result, its business cycle dates may not appropriately capture the business cycle features of GDP. Accordingly, in this section, we model this uncertainty about the state of the economy using extended versions of Hamilton's (1989) switching-regime model, similar to the approaches taken by Boldin (1994) and Garcia and Schaller (1994). The extensions to Hamilton's model and our econometric results are presented below.

Extensions to Hamilton's Model

Hamilton's (1989) switching regime model has proved quite successful in characterizing the nonlinear time-series properties of U.S. real output.[3] The model parsimoniously captures business cycle asymmetries with shifts between two unconditional means and with unequal probabilities of switching from one growth-state to another; in other words, the probability of output remaining in the high-growth state is allowed to be greater than the probability of remaining in the low-growth state. Moreover, the dates of recessions and expansions that are implied by the fitted model match closely those determined by the NBER.

In Hamilton's model, output growth is modeled as a univariate process, in which the mean growth rate depends on the value of an unobservable two-state Markov variable (S_t):

$$\Delta y_t = \mu_{S_t} + \sum_{j=1}^{K} \beta_j [\, \Delta y_{t-j} - \mu_{S_{t-j}} \,] + u_t \qquad S_t = R, E \tag{6}$$

The evolution of S_t is governed by time-invariant state-transition probabilities:

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[3] These nonlinearities have also been modeled, using other statistical methods, by Neftci (1984), Brock and Sayers (1988), Brunner (1992, 1995), Sichel (1993), Potter (1991), and Beaudry and Koop (1993).

$$Pr(S_t = E \mid S_{t-1} = E) = p_t = p$$
$$Pr(S_t = R \mid S_{t-1} = R) = q_t = q \tag{7}$$

Hamilton found that this nonlinear model fit U.S. GNP better than a linear univariate model, and his ex-post probability estimates of recessions and expansions well-approximated the NBER dates of U.S. business cycles.

Because Hamilton's model is univariate, it gives no hint as to what set of economic factors drives the business cycle. To address this, we extend Hamilton's original model in two ways, both which allow monetary policy shocks to augment the role of the unobservable state variable in propagating cycles in GDP. First, we allow monetary policy shocks to directly affect the growth rate of output; that is, we modify the model in equation (7) as follows:

$$\Delta y_t = \mu_{S_t} + \sum_{j=1}^{K} \beta_j [\, \Delta y_{t-j} - \mu_{S_{t-j}} \,] + \sum_{j=1}^{L} \gamma_j \epsilon^{MP}_{t-j} + u_t \qquad S_i = R, E \tag{8}$$

In addition, following Diebold, Lee, and Weinbach (1994) and Filardo (1994), we allow these shocks to also affect the state-transition probabilities by modifying the relationships in equation (7) as follows:

$$p_t = \frac{\log(\, \delta_0 + \sum_{j=1}^{M} \delta_j \epsilon^{MP}_{t-j} \,)}{1 + \log(\, \delta_0 + \sum_{j=1}^{M} \delta_j \epsilon^{MP}_{t-j} \,)} \tag{9}$$

$$q_t = \frac{\log(\, \psi_0 + \sum_{j=1}^{M} \psi_j \epsilon^{MP}_{t-j} \,)}{1 + \log(\, \psi_0 + \sum_{j=1}^{M} \psi_j \epsilon^{MP}_{t-j} \,)} \tag{10}$$

As in the previous section, we are interested in whether the coefficients are state-dependent. Accordingly, we also estimated asymmetric versions of these models, relaxing the symmetry conditions in equations (8), (9) and (10). First, we allowed for asymmetries with respect to the state of the business cycle. In particular, we estimated models where equation (8) is replaced with:

$$\Delta y_t = \mu_{S_t} + \sum_{j=1}^{K} \beta_j [\Delta y_{t-j} - \mu_{S_{t-j}}] + \sum_{j=1}^{L} \gamma_j^{S_{t-j}} \epsilon_{t-j}^{MP} + u_t \qquad S_i = R, E \tag{11}$$

In addition, we allowed for asymmetries with respect to positive and negative interest rate shocks, by replacing equations (8), (9) and (10), respectively, with:

$$\Delta y_t = \mu_{S_t} + \sum_{j=1}^{K} \beta_j [\Delta y_{t-j} - \mu_{S_{t-j}}] + \sum_{j=1}^{L} \gamma_j^i \epsilon_{t-j}^{MP} + u_t \qquad S_i = R, E \textit{ and } i = +, - \tag{12}$$

$$p_t = \frac{\log(\delta_0 + \sum_{j=1}^{M} \delta_j^i \epsilon_{t-j}^{MP})}{1 + \log(\delta_0 + \sum_{j=1}^{M} \delta_j^i \epsilon_{t-j}^{MP})} \qquad i = +, - \tag{13}$$

$$q_t = \frac{\log(\psi_0 + \sum_{j=1}^{M} \psi_j^i \epsilon_{t-j}^{MP})}{1 + \log(\psi_0 + \sum_{j=1}^{M} \psi_j^i \epsilon_{t-j}^{MP})} \qquad i = +, - \tag{14}$$

Empirical Results

Table 3 shows the "optimal" specification for three symmetric versions of the extended Hamilton model. In addition to basic features of the models, several model selection criteria for each model are shown at the bottom of the table. First, as shown in the first column of the table (model 3A), the optimal specification for Hamilton's original model with time-invariant probabilities -- equations (6) and (7) -- includes one lag of output growth (K=1). On the basis of any conventional confidence level, we can easily reject the null hypothesis of no switches-in-regime -- an AR(1) model in this case -- against the alternative of a one-lag Hamilton model.[4] In addition, both the AIC and the SC prefer the Hamilton model over a linear alternative.

The second column of the table (model 4A) corresponds to the optimal specification for Hamilton's model augmented with monetary policy shocks in the conditional mean -- equations (7) and (8). This models uses one lag of output growth and two lags of the interest rate shocks (K=1 and L=2). Again, we can easily reject the null of no switches-in-regime; in this case, the null model is model 1A in Table 1a. Also, we can easily reject Hamilton's original model (model 3A) in favor of a switching model with monetary policy effects on the conditional mean.

Finally, the last column (model 5A) shows the optimal specification for Hamilton's model with time-varying state-transition probabilities, consisting of equations (6), (9) and (10). As with the other non-linear models, it fits the data better than a linear alternative. Although a LR test and the AIC prefer the time-varying probability model over the basic Hamilton model, the more-conservative SC does not. Similarly, of the three models presented in Table 3, the AIC prefers model 5A, while model 4A is preferred by the SC.[5]

Although our model selection criteria do not point to a commonly-preferred model, we will proceed by looking at asymmetric versions of model 4A -- Hamilton's model augmented with monetary policy effects in the conditional mean -- which is chosen by the more-conservative SC. Table 4a presents the parameter estimates for the symmetric and the asymmetric versions of model 4A. The parameters in the first column of the table indicate that the two states correspond to a low-growth state that averages about minus 6 percent and a high-growth state of about 3-1/4 percent. Note that

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[4] Since some parameters in the Hamilton model are not identified under the null, the LR statistic does not have a standard $\chi^2(1)$ distribution. Garcia (1992) reports that the appropriate critical value for a 95 confidence region is 10.3.

[5] We also estimated models with both monetary policy effects in the conditional mean and with time-varying probabilities. We could not reject the restrictions implied by either model 4A or 5A in favor of a hybrid model.

this average growth rate in the high-growth is about the same as for the models with dummy variables for NBER-determined recessions and expansions, but that the average rate of growth in the slow-growth state is much lower; that is, the definition of a "recession" in the Hamilton model is much greater than that "defined" by the NBER. The slow-growth state is not very persistent; if GDP growth is in the low-growth state, there is only a 23 percent probability of remaining in that state. Conversely, if GDP growth is in the high-growth state, there is 97 percent probability of remaining in that state. Finally, the cumulative sum on the monetary policy shocks are quite similar to previously-estimated models.

The last two columns of the table list the parameter estimates for asymmetric versions of this model -- both with respect to expansionary/recessionary periods of economic activity (model 4B) and with respect to expansion/contractionary monetary policy (model 4C). Again, the qualitative aspects of these results are similar to previously-estimated models.

LR tests for parameter restrictions are presented in Table 4b. Although we have now incorporated uncertainty with respect to the current state of the economy, the results are quite similar to those already presented. As before, the cumulative sum of coefficients on the policy shocks for the symmetric model are statistically different from zero. Again, the sum on shocks that occurred during recessions are not statistically different from the sum on shocks that originated during expansions. However, the sum of coefficients on positive interest rate shocks are quite different in size from those on negative interest rate shocks, although they are only marginally-statistically different from each other.

IV. Sensitivity Analysis

In the two previous sections, we found that monetary policy shocks have about the same effect on output during recessions as in expansions, but that contractionary policy shocks have a much larger effect than expansionary policy shocks. These results, of course, are predicated on the way monetary policy shocks were calculated. In this section, we examine the sensitivity of these results to various other methods for computing monetary policy shocks.

As discussed earlier, we assumed that the Federal Reserve reacts to contemporaneous changes in output and prices but not to contemporaneous changes in money -- see equation (1). While these assumptions are in accord with stylized facts, there are reasons to consider alternative sets of assumptions. First, most broad measures of economic activity and prices for a particular period are not available until subsequent periods. Although there are narrower measures available, it seems prudent to test the robustness of the previously-obtained results to these assumptions. Second, there are probably several indicators of economic activity or of price developments that are not included in the Fed's reaction function in equation (1). As a consequence, we also consider an alternative measure of policy shocks that was proposed and analyzed by Bernanke (1993), which attempts to account for any omitted variables.

Accordingly, we first examine the effects of monetary policy shocks when equation (1) is replaced with:

$$R_t^f = \alpha_0 + \sum_{j=1}^{4} \alpha_{1j}\, \Delta Y_{t-j} + \sum_{j=1}^{4} \alpha_{2j}\, \Delta P_{t-j} + \sum_{j=1}^{4} \alpha_{3j}\, \Delta M1_{t-j} + \sum_{j=1}^{4} \alpha_{4j}\, R_{t-j}^f + \epsilon_t^{MP} \qquad (1')$$

This reaction function is similar to the "policy-first" specifications studied by Christiano, Eichenbaum, and Evans (1994) and Brunner (1994). We found that there are very few qualitative differences between the monetary policy shocks derived using equation (1) and those derived using equation (1'). The effects of the latter shocks on economic activity are summarized in Table 5. The results are essentially the same as those reported in Table 4b. First, when symmetric effects are imposed -- line 1 of the table -- the cumulative effect of a monetary policy shock on output is statistically different from zero and about the same magnitude as reported in Table 4b. Second, when the effects of a policy shock are allowed to differ depending on the state of the business cycle -- lines (2) through (4) -- it can be seen that the respective impacts are about the same and the difference is not distinguishable from zero. Finally, as before, it is contractionary monetary policy shocks that appear to have the strongest influence on economic activity, as shown in lines (5) through (7). However, the difference between the effects of positive and negative interest-rate shocks is only marginally different from zero.

Our second robustness check uses the spread between the federal-funds rate and the three-month-Treasury-bill rate (TBR) as the dependent variable in the Fed's reaction function:

$$\begin{aligned} R_t^f - TBR_t &= \alpha_0 + \sum_{j=0}^{4} \alpha_{1j}\, \Delta Y_{t-j} + \sum_{j=0}^{4} \alpha_{2j}\, \Delta P_{t-j} \\ &+ \sum_{j=1}^{4} \alpha_{3j}\, \Delta M1_{t-j} + \sum_{j=1}^{4} \alpha_{4j}\, (R_{t-j}^f - TBR_{t-j}) + \epsilon_t^{MP} \end{aligned} \qquad (1'')$$

As discussed by Bernanke (1993), the inclusion of the Treasury-bill rate is an attempt to capture all relevant contemporaneous and lagged information that is contained in the bill rate as a result of market forces but not fully captured by the limited set of macroeconomic variables that are included in the Fed's reaction function in equation (1).

The impact of the monetary policy shocks implied by equation (1") on economic activity are summarized in Table 6. Although the cumulative effect of these shocks is almost three times as large as for either of the two previous sets of monetary policy shocks, the qualitative nature of their effects on economic activity is nearly the same.

V. Conclusions

In this paper, we investigated a number of issues that have not been completely addressed in previous studies regarding the possible asymmetric effects of monetary policy. First, in contrast to most of the literature, we examined the effects of monetary policy shocks rather than the effects of changes in a monetary policy instrument, such as an interest rate or a measure of money. This is an important distinction to make if changes in the Fed's policy instrument is the result of systematic response to changes in other variables as well as monetary policy shocks. Indeed, we found that about 90 percent of the variation in the federal funds rate -- our assumed policy instrument -- is attributable to factors other than monetary policy surprises. As a result, it would be misleading to use only single-equation regressions of output on the federal funds rate to make inferences about the effects of monetary policy.

Second, in contrast to those studies cited earlier, we examined econometric models that allow for both types of asymmetric effects of monetary policy -- with respect to periods of either expansionary/contractionary policy or expansionary/recessionary periods of economic activity. Finally, we estimated several types of linear and non-linear models to ensure that our results were robust to a variety of econometric specifications.

Overall, we interpret these results as weak evidence in favor of sticky-wage and sticky-price theories and strong evidence against credit-rationing theories. First, we find that models that allow for asymmetries with respect to contractionary/expansionary monetary policy fit the data better than models that allow for asymmetries associated with the state of the business cycle. Second, we find that contractionary monetary policy shocks have a much larger effect on output than expansionary policy shocks, although this result is somewhat sensitive to the econometric specification. In particular, contractionary policy shocks are well-correlated with future recessions. This makes it somewhat difficult to determine whether our shocks are truly exogenous or whether they are a proxy for a variable that we omitted from the Fed's reaction function and that adversely affects economic activity. Finally, we find that monetary policy shocks that occur during economic expansions appear to have about the same effect as shocks that occur during recessions; this result is robust to various econometric specifications.

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Table 1a. Parameter Estimates for Linear Models
of the Effects of Interest-Rate Shocks (ε^{MP})

Parameter	Model 1A	Model 1B	Model 1C
μ	2.85 (.38)	2.79 (.38)	3.81 (.58)
β_1	.29 (.07)	.32 (.08)	.24 (.08)
γ_1	-.19 (.12)		
γ_2	-.92 (.26)		
γ_1^R		-.53 (.48)	
γ_2^R		-1.24 (.45)	
γ_1^E		-.03 (.30)	
γ_2^E		-.83 (.30)	
γ_1^+			-.72 (.43)
γ_2^+			-1.30 (.44)
γ_1^-			.30 (.47)
γ_2^-			-.41 (.45)
σ	4.86 (.27)	4.84 (.26)	4.80 (.26)
-LLF	447.0	446.5	445.1
AIC	452.0	453.5	452.1
SC	459.5	467.0	462.6

Note: Numbers in parentheses are standard errors.

Table 1b. LR Tests for Asymmetric Effects of Interest-Rate Shocks (ε^{MP}) Using Linear Models

	Measured Effect	Model 1A	Model 1B	Model 1C
1)	$\gamma_1 + \gamma_2$	-1.11 [<.01]		
2)	$\gamma_1^R + \gamma_2^R$		-1.77 [.02]	
3)	$\gamma_1^E + \gamma_2^E$		-.86 [.05]	
4)	$(\gamma_1^R + \gamma_2^R)$ $- (\gamma_1^E + \gamma_2^E)$		-.91 [.30]	
5)	$\gamma_1^+ + \gamma_2^+$			-2.02 [<.01]
6)	$\gamma_1^- + \gamma_2^-$			-.10 [.87]
7)	$(\gamma_1^+ + \gamma_2^+)$ $- (\gamma_1^- + \gamma_2^-)$			-1.92 [.05]

Note: Numbers in brackets are significance levels for $\chi^2(1)$ tests that the measured effect is significantly different from zero.

Table 2a. Parameter Estimates for Linear Models
of the Effects of Interest-Rate Shocks (ε^{MP})
With Dummy Variables for Recessions/Expansions

Parameter	Model 2A	Model 2B	Model 2C
μ^R	-1.77 (.58)	-1.76 (.54)	-1.13 (.71)
μ^E	3.82 (.86)	3.83 (.81)	4.23 (.95)
γ_1	-.30 (.22)		
γ_2	-.55 (.22)		
γ_1^R		-.18 (.40)	
γ_2^R		-.55 (.39)	
γ_1^E		-.34 (.26)	
γ_2^E		-.53 (.26)	
γ_1^+			-.63 (.36)
γ_2^+			-.79 (.37)
γ_1^-			.02 (.42)
γ_2^-			-.25 (.39)
σ	4.17 (.24)	4.17 (.23)	4.14 (.23)
-LLF	424.1	424.1	423.1
AIC	429.1	431.1	430.1
SC	436.7	441.6	440.6

Note: Numbers in parentheses are standard errors.

Table 2b. LR Tests for Asymmetric Effects of Interest-Rate Shocks (ε^{MP}) Using Linear Models With Dummy Variables for Recessions/Expansions

	Measured Effect	Model 2A	Model 2B	Model 2C
1)	$\gamma_1 + \gamma_2$	-.85 [.01]		
2)	$\gamma_1^R + \gamma_2^R$		-.73 [.23]	
3)	$\gamma_1^E + \gamma_2^E$		-.87 [.02]	
4)	$(\gamma_1^R + \gamma_2^R) - (\gamma_1^E + \gamma_2^E)$		.14 [.85]	
5)	$\gamma_1^+ + \gamma_2^+$			-1.42 [.01]
6)	$\gamma_1^- + \gamma_2^-$			-.23 [.67]
7)	$(\gamma_1^+ + \gamma_2^+) - (\gamma_1^- + \gamma_2^-)$			-1.19 [.15]

Note: Numbers in brackets are significance levels for $\chi^2(1)$ tests that the measured effect is significantly different from zero.

Table 3. Summary Statistics for "Optimal" Specification of Various Non-Linear Models of the Effects of Interest-Rate Shocks (ε^{MP})

Statistic	Model 3A	Model 4A	Model 5A
Specification	(1,0,0)	(1,2,0)	(1,0,2)
Number of Parameters	6	8	10
-LLF	396.1	390.2	387.3
LR Test for No Switches-in-Regime	<.01	<.01	<.01
LR Test Against Model 3a	--	<.01	<.01
AIC	402.1	398.2	397.2
SC	411.1	410.2	412.3

Note: The specification of non-linear models is summarized by (K,L,M), where K is the number of lags of GDP in the mean, L is the number of lags of interest rate shocks in the mean, and M is the number of lags of interest rate shocks in the time-varying transitional probabilities for the Markov variable.

Table 4a. Parameter Estimates for Non-Linear Models
of the Effects of Interest-Rate Shocks (ε^{MP})
With Unobservable Markov Variable for Recessions/Expansions

Parameter	Model 4A	Model 4B	Model 4C
q	.23 (.27)	.23 (.23)	.19 (.22)
p	.97 (.02)	.97 (.02)	.97 (.02)
μ^R	-5.98 (.87)	-5.94 (1.11)	-5.88 (1.20)
μ^E	3.24 (.35)	3.19 (.37)	4.05 (.66)
β_1	.26 (.31)	.27 (.09)	.27 (.11)
γ_1	-.10 (.31)		
γ_2	-.86 (.26)		
γ_1^R		-.38 (.53)	
γ_2^R		-1.31 (.51)	
γ_1^E		-.04 (.38)	
γ_2^E		-.76 (.32)	
γ_1^+			-.37 (.37)
γ_2^+			-1.30 (.37)
γ_1^-			.33 (.42)
γ_2^-			-.29 (.43)
σ	2.93 (.36)	2.91 (.34)	2.94 (.17)
-LLF	390.2	389.6	388.5
AIC	398.2	399.6	398.5
SC	410.2	414.6	413.5

Note: Numbers in parentheses are standard errors.

Table 4b. LR Tests for Asymmetric Effects of Interest-Rate Shocks (ε^{MP}) Using Non-Linear Models With Unobservable Markov Variable for Recessions/Expansions

	Measured Effect	Model 4A	Model 4B	Model 4C
1)	$\gamma_1 + \gamma_2$	-.96 [.01]		
2)	$\gamma_1^R + \gamma_2^R$		-1.69 [.04]	
3)	$\gamma_1^E + \gamma_2^E$		-.80 [.03]	
4)	$(\gamma_1^R + \gamma_2^R) - (\gamma_1^E + \gamma_2^E)$		-.89 [.30]	
5)	$\gamma_1^+ + \gamma_2^+$			-1.67 [<.01]
6)	$\gamma_1^- + \gamma_2^-$			-.04 [.94]
7)	$(\gamma_1^+ + \gamma_2^+) - (\gamma_1^- + \gamma_2^-)$			-1.71 [.06]

Note: Numbers in brackets are significance levels for $\chi^2(1)$ tests that the measured effect is significantly different from zero.

Table 5. LR Tests for Asymmetric Effects of Interest-Rate Shocks (ε^{MP}) Using Non-Linear Models With Unobservable Markov Variable for Recessions/Expansions
(federal-funds rate is weakly exogenous to all variables)

	Measured Effect	Model 6A	Model 6B	Model 6C
1)	$\gamma_1 + \gamma_2$	-.96 [<.01]		
2)	$\gamma_1^R + \gamma_2^R$		-1.24 [.01]	
3)	$\gamma_1^E + \gamma_2^E$		-.87 [.04]	
4)	$(\gamma_1^R + \gamma_2^R) - (\gamma_1^E + \gamma_2^E)$		-.37 [.59]	
5)	$\gamma_1^+ + \gamma_2^+$			-1.55 [<.01]
6)	$\gamma_1^- + \gamma_2^-$			-.30 [.54]
7)	$(\gamma_1^+ + \gamma_2^+) - (\gamma_1^- + \gamma_2^-)$			-1.25 [.09]

Note: Numbers in brackets are significance levels for $\chi^2(1)$ tests that the measured effect is significantly different from zero.

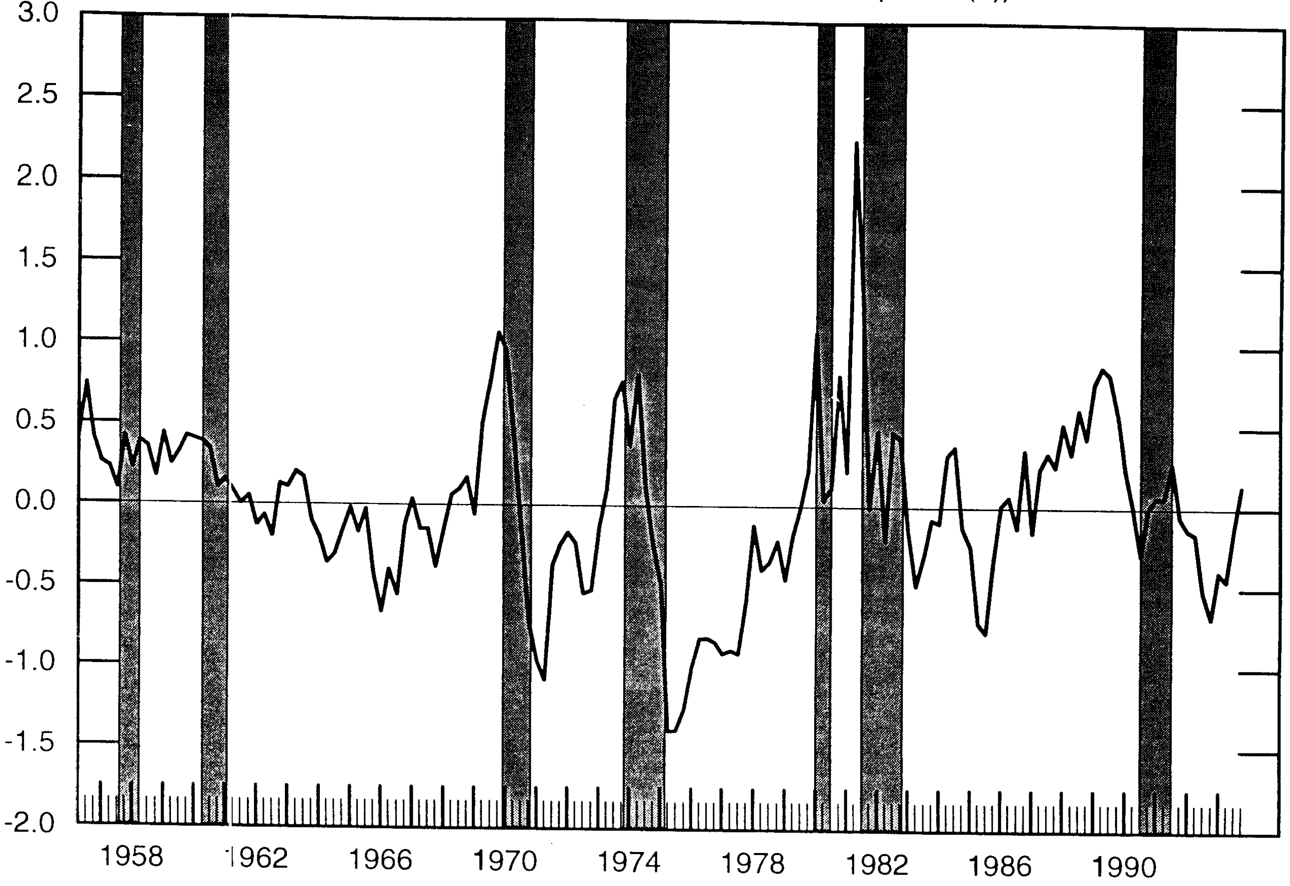
Table 6. LR Tests for Asymmetric Effects of Interest-Rate-Spread Shocks (ε^{MP}) Using Non-Linear Models With Unobservable Markov Variable for Recessions/Expansions (federal-funds rate minus 3-month-Treasury-bill rate)

	Measured Effect	Model 7A	Model 7B	Model 7C
1)	$\gamma_1 + \gamma_2$	-2.89 [<.01]		
2)	$\gamma_1^R + \gamma_2^R$		-3.34 [.15]	
3)	$\gamma_1^E + \gamma_2^E$		-2.85 [.01]	
4)	$(\gamma_1^R + \gamma_2^R) - (\gamma_1^E + \gamma_2^E)$		-.49 [.84]	
5)	$\gamma_1^+ + \gamma_2^+$			-3.89 [<.01]
6)	$\gamma_1^- + \gamma_2^-$			-.99 [.46]
7)	$(\gamma_1^+ + \gamma_2^+) - (\gamma_1^- + \gamma_2^-)$			-2.90 [.17]

Note: Numbers in brackets are significance levels for $\chi^2(1)$ tests that the measured effect is significantly different from zero.

Figure 1. Monetary Policy (Interest Rate) Shocks

(one-year moving-average, based on equation(1))



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