DOES THE FEDERAL RESERVE LEXICOGRAPHICALLY ORDER ITS POLICY OBJECTIVES?

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INTRODUCTION

The Federal Reserve does not clearly express its monetary policy goals and priorities. For this reason, researchers often employ monetary policy reaction functions to measure the Fed's response to changes in macroeconomic conditions [Barth, Sickles, and Weist, 1982]. A reaction function empirically relates the central bank's policy instrument (usually the federal funds rate) to the objectives of monetary policy (for example, inflation and unemployment). Assuming stability of the underlying macroeconomy, the estimated coefficients from a reaction function reveal information about the Fed's macroeconomic policy priorities [Chappell, Havrilesky, and McGregor, 1993].

Authors of nearly all reaction function studies assume that the central bank's reaction function is linear. Therefore, they implicitly assume that the Fed's response to a change in inflation or unemployment is the same regardless of whether inflation or unemployment is unusually high or low. We argue that a linear reaction function does not accurately capture the Fed's response to macroeconomic conditions. Our argument is largely motivated by the results of Romer and Romer [1989] who identify six episodes during the postwar period when the Fed engaged in contractionary monetary policy in an effort to reduce inflationary pressures in the economy. Their results imply that the Fed may respond exclusively and with greater intensity to a particular policy objective when that policy objective moves beyond acceptable bounds. Thus, although the Fed may respond modestly (or not at all) to its policy objectives for extended periods of time, this pattern of behavior may be interrupted by periods when the Fed responds more aggressively to a single objective.

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The behavior described above is known as lexicographic ordering. In particular, if inflation is above some threshold level, the Fed may abandon all concern for unemployment and concentrate solely on reducing inflation; or, if unemployment is above some threshold value, the Fed may abandon all concern for inflation and concentrate exclusively on reducing unemployment. If the Fed does lexicographically order its policy objectives, then reaction function coefficients estimated in previous studies are actually averages of coefficients obtained from periods of relatively modest responses to policy objectives and periods of relatively intense responses to policy objectives.

In this paper, we test for threshold effects and lexicographic ordering by modeling the Fed's reaction function as a threshold regression model [Tong, 1983]. Following Hakes [1990], we divide the post-Accord period into subperiods based on the chairmanship of the Fed.[1] We find that during the Martin, Burns and Miller chairmanships, the threshold variable in the Fed's reaction function is unemployment. In general, during these subperiods, we find that when unemployment is rising, the Fed engages in an expansionary policy to reduce unemployment regardless of the level of inflation. However, during the Greenspan subperiod, our estimates suggest that the threshold variable in the Fed's reaction function is inflation. During this subperiod we find that when inflation is greater than or equal to three percent, the Fed engages in a contractionary policy to reduce inflation regardless of the unemployment situation. We fail to find a nonlinear reaction function for the Volcker subperiod. Therefore, except for the Volcker subperiod, we find evidence that the Fed lexicographically orders its policy objectives.

METHODOLOGY AND EMPIRICAL RESULTS

We test for threshold effects and lexicographic ordering of policy objectives in the following Federal Reserve reaction function:

$$\Delta FF_t = \alpha + \underset{(+)}{\beta_1 \pi_{t-1}} + \underset{(-)}{\beta_2 \Delta u_{t-1}} + \eta_t \tag{1}$$

where ΔFF is the change in the federal funds rate, π is the rate of inflation, and Δu is the change in the unemployment rate. Equation 1 suggests that the Fed adjusts its policy instrument (the federal funds rate) in response to the most recent movements in its macroeconomic policy objectives (inflation and unemployment).[2] The expected signs are shown below each coefficient under the assumption that the Fed responds countercyclically to movements in its policy objectives.

Our choice of the differenced federal funds rate as the policy indicator is based on early work by Abrams, Froyen, and Waud [1980] and on more recent work by Bernanke and Blinder [1992] and Bernanke and Mihov [1995]. Abrams, et al. [1980], argue that the federal funds rate is the best measure of monetary policy regardless of the actual operating procedures employed by the Fed. Their argument is supported by Bernanke and Blinder [1992] and Bernanke and Mihov [1995]. These recent papers provide evidence that the supply of non-borrowed reserves is infinitely elastic during the post-Accord period which implies that the Fed targets the federal funds rate in the short-run. Indeed, nearly all reaction function studies employ the federal funds rate as the policy indicator [Hakes and Gamber, 1992; Chappell, Havrilesky, and McGregor, 1993].

TABLE 1
Benchmark Results

Sample Period	π_{t-1}	$\Delta\mu_{t-1}$
Full Sample (1955.01-1994.12)	0.08 (0.09)	-0.84[b] (0.12)
Martin (1955.01-1970.01)	0.12 (0.09)	-0.22[b] (0.09)
Burns and Miller (1970.02-1979.07)	0.10 (0.13)	-1.1[b] (0.19)
Volcker (1979.08-1987.08)	0.26 (0.30)	-1.77[b] (0.48)
Greenspan (1987.09-1994.12)	-0.06 (0.15)	-0.33[a] (0.15)

Standard errors are in parentheses.
a. significant at the 5 percent level.
b. significant at the 1 percent level.

With regard to the specification of the Fed's policy objectives, we employ the lagged inflation rate and the lagged first difference of the unemployment rate. We choose inflation and unemployment for the following reasons. Although the Employment Act of 1946 effectively specifies three policy objectives—growth, employment, and inflation—growth and employment are nearly collinear. Thus, many studies employ proxies for either growth or employment, but not both [Hakes and Rose, 1992-93]. Since the Humphrey-Hawkins Act imposes a specific unemployment target on the Fed, we choose the unemployment rate as the measure of real economic activity. The data for the policy objectives are generated from monthly, seasonally adjusted, values of the producer price index and the prime age male unemployment rate. The transformations on the data are the minimum necessary to induce stationarity. That is, the growth rate of the producer price index and the first difference of the unemployment rate are stationary.[3]

Before we test for nonlinearities in the Fed's reaction function, we estimate a linear benchmark reaction function for the post-Accord sample period of 1955(1) through 1994(12) and, following Hakes [1990], for subperiods which correspond to the various chairmanships of the Fed.[4] The results of these estimates are reported in Table 1. The estimates suggest that the primary concern of the Fed is unemployment, although that emphasis appears to be reduced in recent years. None of the estimates show a significant response to inflation.

Our thesis is that these estimates do not accurately capture the Fed's response to unemployment and inflation because the model constrains the Fed's response to be linear. To test for nonlinearities in the Fed's reaction function, we adopt the model and econometric technique of Tong [1983] and Tsay [1989] to model the Fed's reaction function as a threshold regression. Our work follows closely the work of Shen and Hakes [1995] and, for this reason, only a brief description of the technique is provided below.

The Fed's reaction function can be modeled as a nonlinear threshold regression by estimating Equation 1 with OLS for different inflation and/or unemployment regimes. For example, Equation 1 can be estimated for values of inflation above some threshold value and for values of inflation below this same threshold value. Alternatively, Equation 1 could be estimated for values of the change in unemployment above some unemployment threshold value and for values below the unemployment threshold value. Thus, the model is linear within each inflation or unemployment regime but potentially nonlinear across regimes.

The modeling process requires the following steps. First, we test the model to see if it is indeed nonlinear with respect to either of the independent variables. If the model is nonlinear, we then determine the threshold value(s) applicable to the threshold variable. Finally, we partition the data based on the threshold value(s) and estimate the models with OLS on the resulting subsets of data.

To accomplish the task outlined above, we employ Tsay's [1989] arranged autoregression. First, to test the model for the presence of nonlinearities, we arrange the observations according to the value of the independent variable that we hypothesize to be the threshold variable—for example, from the smallest inflation value to the largest inflation value or from the smallest unemployment value to the largest. Second, we calculate an F-statistic proposed by Tsay [1989] by estimating a series of sequential regressions. We begin by estimating the model utilizing the first 20 observations in the arranged data set.[5] We then add one additional observation per regression until all observations are included. At each step in this sequential estimation, we compute the one-step-ahead forecast error denoted ϵ. We then standardize this sequence of forecast errors by dividing each error by the standard deviation of the sequence. We denote these standardized predictive residuals by μ. This sequence of μ's is then regressed on the arranged independent variables beginning with the 21st observation. The estimated residuals from this regression are denoted by ν. The F-statistic for the null hypothesis of no threshold effect is:

$$F = \frac{\left(\sum \mu^2 - \sum \nu^2\right)/d.f.}{\sum \mu^2/d.f.}$$

where d.f. denotes degrees of freedom. The degrees of freedom in the numerator are the number of estimated parameters plus one. The degrees of freedom in the denominator are the number of forecast errors generated. We generate an F-statistic for each independent variable in the reaction function.

TABLE 2
F-statistics for Nonlinearity Tests

Sample Period	π_{t-1}	μ_{t-1}
Full Sample (1955.01-1994.12)	1.1	4.4[b]
Martin (1955.01-1970.01)	1.2	2.7[a]
Burns and Miller (1970.2-1979.07)	2.6[a]	2.6[a]
Volcker (1979.08-1987.08	1.1	1.2
Greenspan (1987.09-1994.12)	4.2[b]	2.4

a. significant at the 5 percent level for the test of the null hypothesis that the reaction fucntion is linear with respect to the independent variable listed above.
b. significant at the 1 percent level for the test of the null hypothesis as described in note a.

The F-statistics for the full sample period and for subperiods defined according to who was chairman of the Fed are provided in Table 2. We reject the null hypothesis that the reaction function is linear with respect to unemployment for the full sample period and for the Martin subperiod and the Burns and Miller subperiod. We reject the null hypothesis that the reaction function is linear with respect to inflation for the Burns and Miller subperiod and the Greenspan subperiod. We fail to reject the null for either independent variable for the Volcker subperiod.

The next step in the estimation procedure is to identify the threshold value(s) for the threshold variables—those variables that we have previously found to exhibit a nonlinear relationship with the dependent variable. Again, we arrange the data in ascending order based on the threshold variable. We sequentially estimate Equation 1 beginning with the first 20 observations, adding one observation per estimate until all observations are included. The sequence of t-ratios for the coefficient on the threshold variable are then plotted against the values of the threshold variable. When the t-ratios reach a peak or change direction, we have crossed a threshold and entered a new inflation or unemployment regime. The t-ratios determine the threshold values in the following manner. When the sequential estimations, each of which is associated with a proposed threshold value, pass the true threshold value, the estimated parameters will become a weighted average of two different data-generating pro-

TABLE 3
Threshold Results

Sample Period	Threshold Variable	Threshold Value	Below Threshold π_{t-1}	Below Threshold μ_{t-1}	Above Threshold π_{t-1}	Above Threshold μ_{t-1}
Full Sample (1955.01-1994.12)	Δu	0	0.36[b]	-0.19	-0.03	-1.9[b]
			(0.05)	(0.29)	(0.07)	(0.39)
			[n=182]		[n=278]	
			$\bar{R}^2 = 0.17$			$\bar{R}^2$=0.12
Martin (1955.01-1970.01)	Δu	0	0.16[b]	-0.12	0.27	-0.76[a]
			(0.07)	(0.24)	(0.18)	(0.27)
			[n=127]		[n=32]	
			$\bar{R}^2 = 0.01$			$\bar{R}^2$=0.16
Burns and Miller (1970.02-1979.07)	Δu	0	0.25[b]	-0.09	-0.04	-1.7[b]
			(0.07)	(0.10)	(0.06)	(0.45)
			[n=49]		[n=43]	
			$\bar{R}^2 = 0.19$			$\bar{R}^2$=0.21
Volcker	none					
Greenspan (1987.09-1994.12)	π	0.25	0.05	-0.26	0.91[b]	0.02
			(0.04)	(0.30)	(0.33)	(0.30)
			[n=28]		[n=34]	
			$\bar{R}^2 = 0.05$		$\bar{R}^2$=0.17	

a. significant at the 5 percent level for the test of the null hypothesis that the reaction fucntion is linear with respect to the independent variable listed above.
b. significant at the 1 percent level for the test of the null hypothesis as described in note a.

cesses and, thus, the estimated parameters will become less significant [Shen and Hakes, 1995, 362].

Figures 1 through 4 show the sequential t-ratios for the four subperiods for which we have identified nonlinearities or threshold effects. Note that although the Burns and Miller subperiod exhibits nonlinearities with regard to both inflation and unemployment (see Table 2), the threshold for inflation leaves only four observations on one side of the threshold and, thus, it cannot be estimated.[6] For this reason, we only report results for the Burns and Miller subperiod partitioned by an unemployment threshold.

Columns two and three of Table 3 show the threshold variable and the threshold value for the full sample period and for each of the subperiods. For the full sample period, Figure 1 suggests a threshold of zero for the change in unemployment because the t-ratio for the coefficient on the change in unemployment declines for values of the change in unemployment greater than or equal to zero. For the Martin subperiod, Figure 2 shows a consistent decline in the t-ratio for values of the change in unemployment of 0.2 or greater, which suggests a threshold value of 0.2.[7] For the Burns

FIGURE 1
Full Sample, 1955.01-1994.12
Threshold Δu

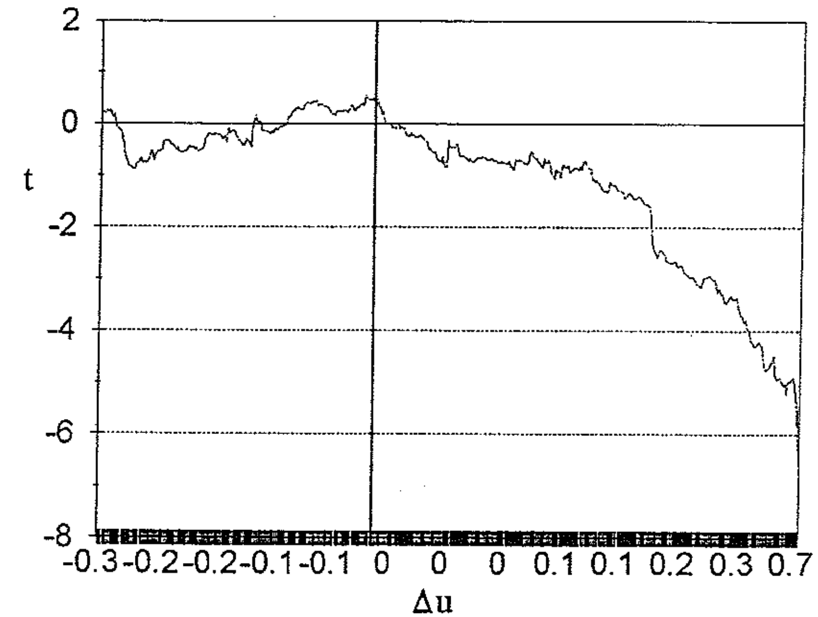


FIGURE 2
Martin Sample, 1955.01-1970.01
Threshold Δu

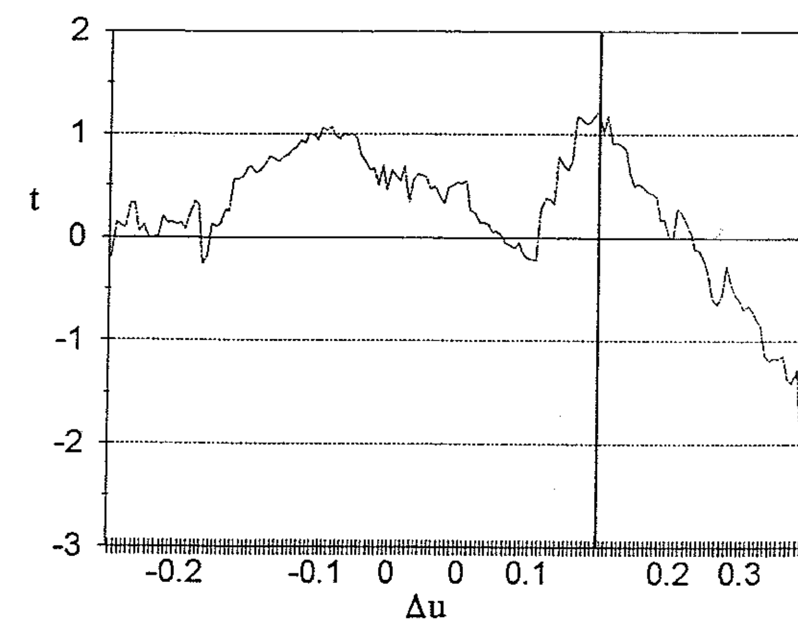


FIGURE 3
Burns and Miller Sample, 1970.02-1979.07
Threshold Δu

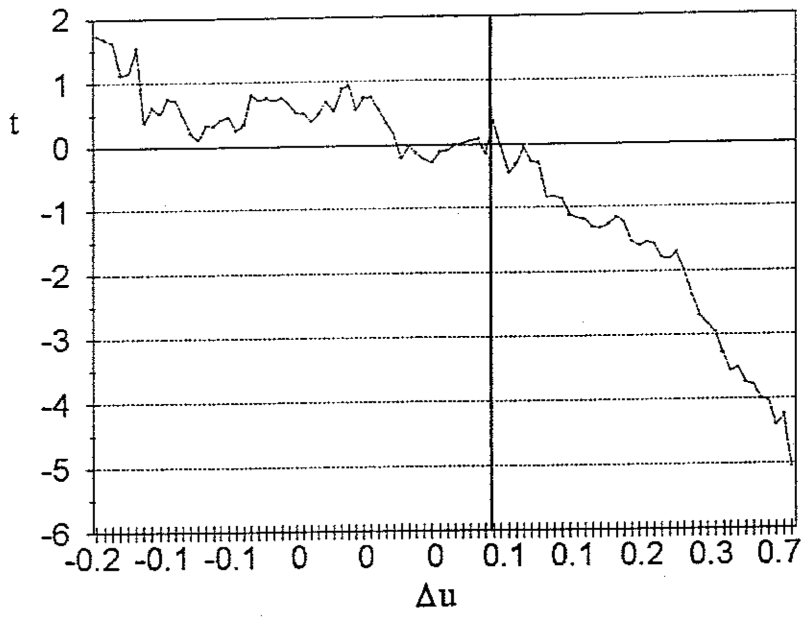
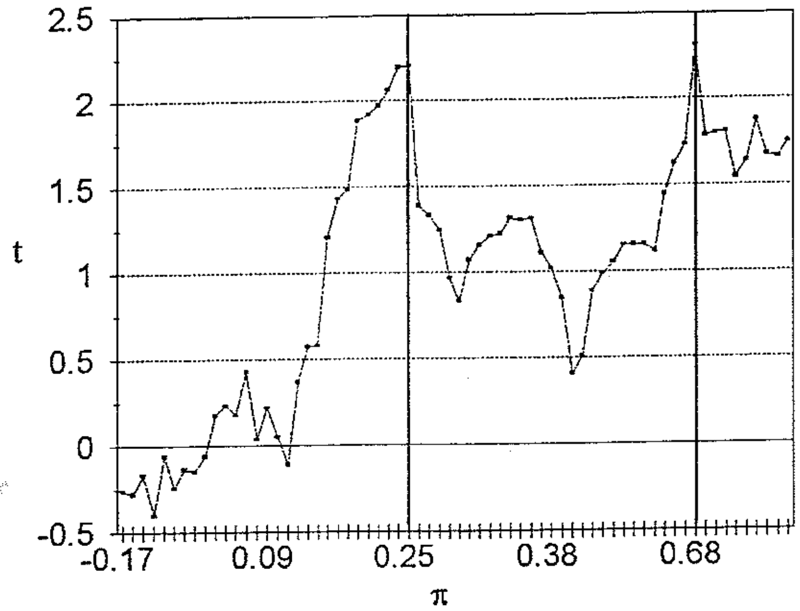


FIGURE 4
Greenspan Sample, 1987.09-1994.12
Threshold π



and Miller subperiod, Figure 3 shows a consistent decline in the t-ratio for values of the change in unemployment greater than or equal to 0.1, which suggests a threshold of 0.1. Finally, for the Greenspan subperiod, Figure 4 demonstrates two distinct thresholds for the monthly inflation rate—0.25 and 0.68.[8]

The final step in estimating the model is to estimate the OLS regressions on the subsets of ordered data which have now been partitioned by the threshold values. For the full sample period we identify the change in unemployment as the threshold variable and zero as the threshold value. Thus, we estimate two reaction functions on the ordered data. The first reaction function employs all of the observations for which the change in the unemployment rate is less than zero. The second employs all of the observations for which the change in the unemployment rate is greater than or equal to zero.[9] We repeat this estimation procedure for all of the subperiods.

The threshold estimates are presented in the last four columns of Table 3. For the full sample period, estimates of the reaction function for periods when the unemployment rate is falling show that the Fed responds countercyclically to movements in inflation but does not respond countercyclically to unemployment conditions. However, when the model is estimated for periods when the change in unemployment is greater than or equal to zero, the Fed shows no concern for inflation and responds countercyclically to unemployment. We find similar results for the Martin subperiod and the Burns and Miller subperiod, although the threshold value for unemployment differs slightly.

When we move to the Volcker and Greenspan subperiods, the results change markedly. While the Volcker subperiod fails to exhibit any threshold effects, the threshold variable for the Greenspan subperiod has shifted from the unemployment rate to the inflation rate. During the Greenspan era, the threshold value for the inflation rate is 0.25 measured on a monthly basis, equal to a 3 percent inflation rate measured on an annual basis. Estimates of the model suggest that, under Greenspan, when inflation is greater than or equal to 3 percent, the Fed demonstrates by far the greatest countercyclical response to inflation that we find for any post-Accord subperiod. Moreover, we find no evidence that the Fed responds countercyclically to changes in unemployment under Greenspan, even during periods when inflation is below the 3 percent threshold.

Addressing our results in total, we make the following observations. If we compare the benchmark results to the threshold results (Tables 1 and 3), we see that: (1) the Fed responds with greater intensity to a policy objective when that policy objective moves beyond some boundary, (2) the Fed tends to respond to the objective of lesser concern only when the primary or threshold objective is within acceptable bounds—a behavior which can be described as lexicographic ordering, and (3) the linear benchmark results give the false impression that the Fed responds only to unemployment while the nonlinear threshold results more accurately show the conditions under which the Fed responds to inflation. For example, the threshold results show that during the Martin subperiod and the Burns and Miller subperiod, the Fed only responds to inflation when the change in unemployment is below certain bounds. However, during the Greenspan era, the Fed only responds to inflation when inflation is above certain bounds. Finally, if we view Table 3 as a demonstration of the Fed's policy progression over time, we see that the Fed has moved away from a concern for changes in unemployment and toward a concern for inflation.

SUMMARY AND CONCLUSION

We model the Federal Reserve's reaction function as an arranged regression in order to reveal threshold effects in the independent variables. We find that during the Martin subperiod and the Burns and Miller subperiod, the Fed's threshold variable is unemployment. During these subperiods, the Fed only responds to inflation when unemployment is below the threshold. During the Greenspan era, we find that the Fed's threshold variable is inflation. Under Greenspan, however, even when inflation is under the threshold, we find no evidence that the Fed responds to changes in unemployment. We find no evidence of threshold effects during the Volcker chairmanship.

The discovery of threshold effects in the Fed's reaction function suggests that the Fed has, at times, lexicographically ordered its policy objectives. Further, the existence of threshold effects implies that the Fed's reaction function is not linear. As a result, a linear reaction function underestimates the response of the Fed to a policy objective when the policy objective exceeds the threshold and overestimates the response of the Fed when the policy objective is beneath the threshold.

Finally, the results reported in our paper are particularly relevant because, at present, the charge of the Fed is under legislative review. Historically, the response of the Federal Reserve to the macroeconomy has been guided by the Employment Act of 1946 which loosely requires the federal government to promote growth, full employment, and stable prices. More recently, the Fed has been charged by the Humphrey-Hawkins Act of 1978 with a specific unemployment target of four percent. At present, however, the Fed supports legislation that repeals the Humphrey-Hawkins Act and replaces it with the Economic Growth and Price Stability Act. This act would effectively charge the Federal Reserve with the single policy objective of price stability. Our results suggest that at inflation rates greater than or equal to 3 percent, the Fed currently abandons other stabilization objectives and concentrates solely on reducing inflation. Thus, the Fed may be asking Congress to validate a policy that it is already implementing.

NOTES

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1. The Federal Reserve-Treasury Accord is the event that is often considered to establish the Federal Reserve's independence from the Treasury. Although this agreement occurred during 1951, 1953 is usually cited as the first year when the Fed was, in practice, independent of the Treasury. Our paper employs data from 1955(1) through 1994(12).

2. Hakes [1988a] and [1990] finds similar results across reaction functions in which the policy objectives have been forecast from a VAR model (forward looking) and reaction functions in which the policy objectives are simple lagged values. This is because the most significant variable in the VAR is the most recent lagged value of the policy objective. Therefore, we employ lagged values of the policy objectives.
3. The inflation rate appears to be stationary over our sample. This is consistent with Gamber [1996]. Although the outcome of the augmented Dickey-Fuller tests appears sensitive to our choice of starting date and nuisance parameters there is clear evidence of overdifferencing when the log of the price level is differenced twice. Further, a unit root in the inflation rate is troublesome from the perspective of a reasonable Fed reaction function. That is, it is unlikely that the Fed would allow the inflation rate to exceed reasonable bounds as is evident in the post-war data.
4. Hakes [1990] demonstrates that there may be structural break points in the Fed's reaction function based on the chairman of the Fed. Since the Miller subperiod is too short (17 months) to estimate independently and since there is a structural break at the beginning of the Volcker subperiod [Hakes, 1988b], we have grouped Miller's subperiod with Burns.
5. The starting sample size of 20 observations was arbitrarily chosen. However, our goal was to start with a large enough sample so that the initial estimates were not sensitive to additional observations. For example, we could start with 5 observations and work our way through the sample but we would likely find shifting thresholds as each new observation is added to the sample until enough observations were added to gain some stability in the estimates.
6. Of the four observations above the inflation threshold, three are from months associated with the first oil price shock in 1974 when the Fed clearly accommodated the unusual increases in inflation.
7. Figure 2 may be interpreted as suggesting two thresholds—one at -0.1 and one at 0.2. However, the change in unemployment below the threshold of -0.1 does not vary (all values are equal to -0.2). Since we cannot estimate the model for this potential unemployment regime, we report results only for the single threshold value of 0.2. Further, we employ all of the observations when we estimate the model based on a single threshold value of 0.2. That is, we include all of the observations below the threshold of 0.2 in the "below the threshold" regime. Our results were not sensitive to the inclusion or exclusion of the values of the change in unemployment below -0.1.
8. Only ten observations are above the 0.68 threshold, two of which are September and October 1990. Oil prices rose dramatically during these two months, following the invasion of Kuwait. To accommodate these adverse supply shocks, the Fed *cut* the federal funds rate by 9 and 30 basis points during those months. Thus, we do not produce estimates for this subsample because of the small sample size and the two outliers.
9. The observations associated with the threshold value itself are grouped with the "above the threshold" data since the threshold is determined as the first point associated with the new regime as we move through the ordered data.

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