Monetary Policy Under Federal Reserve Chairmen Volcker and Greenspan: An Exercise in Description*

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Abstract

This paper investigates how closely U.S. monetary policy over the last seventeen years can be described by systematic reactions to a limited set of key macroeconomic variables. We take the Federal Reserve's principal policy instrument, or operating target, to be the federal funds rate. A novel feature of our empirical analysis is that we investigate whether the FOMC has responded to its members' own short-term forecasts of the key variables as opposed to recent outcomes for them—in other words, whether policy can best be described as proactive or reactive. Furthermore, we study whether or not monetary policy changes tended to be gradual in response to changes in the state of the macroeconomy; whether real or nominal variables mattered more in setting policy; and, pertaining to real economic activity, whether the level of activity (relative to full employment) or the growth rate of activity is more relevant.

In our analysis, we use only information available to the FOMC at the time decisions were taken, carefully eliminating data contamination by subsequent data revisions and definitional changes. We find that policy can be described surprisingly accurately by focusing on just two variables, inflation and a real activity indicator. However, the reaction functions that best characterize policy under Chairmen Volcker and Greenspan differ markedly. We explain these differences in detail.

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1 Introduction

The Federal Reserve Act, as amended in 1977, requires the Federal Reserve to foster simultaneously "maximum employment, stable prices, and moderate long-term interest rates," although the horizon being addressed by this language is subject to differing interpretations. Against this backdrop, Federal Reserve policy is broadly understood as responding to macroeconomic developments regarding inflation and real economic activity. The 1990 Economic Report of the President summarizes this view as follows:

> The Federal Reserve generally increases interest rates when inflationary pressures appear to be rising and lowers interest rates when inflationary pressures are abating and recession appears to be more of a threat. (Council of Economic Advisers, February 1990)

The degree to which the response of policy to inflation and economic activity can be characterized as systematic or discretionary has been debated extensively in the academic literature as well as in policy circles. In the context of the early discussions on fine tuning versus k-percent money growth rules, a monetary policy that responded to transitory economic fluctuations would have been termed discretionary. In recent years, however, a number of authors have suggested that activist monetary policy rules, which prescribe that the Federal Reserve vary its instrument systematically in response to economic developments, differ from purely discretionary policy and should be given greater weight in policy discussions.[1] To the extent the central bank is known to adhere to such rules, it is argued, policy performance would be improved by providing the hypothesized credibility benefits associated with more rigid rules while affording greater flexibility in mitigating macroeconomic shocks.[2] These rules typically imply a systematic response of the monetary instrument to one or two clearly identified and easily measured macroeconomic concepts

[1] See, for example, the rules examined by McCallum (1988), Taylor (1993), and Henderson and McKibbin (1993). Taylor, in particular, forcefully argues in favor of using such rules to guide policy, even if policymakers are reasonably expected to deviate from them when faced with unforeseen contingencies. Of course a policy along these lines could as easily be called discretionary. We attempt to stay clear of the semasiology of this issue.

[2] The performance of such simple rules was evaluated in various macroeconomic models in the volume edited by Bryant, Hooper and Mann (1993).

such as real GDP growth, the rate of inflation, the output gap, the rate of unemployment or the deviation of nominal GDP from a fixed path.[3]

This paper investigates to what extent Federal Reserve policy over the last seventeen years has been systematic in responding to a limited set of such macroeconomic variables. We take the Federal Reserve's monetary policy instrument, or operating target, to be the level of the federal funds rate that the Federal Open Market Committee (FOMC) intends for the Manager of the System Open Market Account to pursue. We then try to identify the main macroeconomic variables that the FOMC appears to have responded to in deciding at what level to set the federal funds rate.

The paper is an exercise in description, not prescription. That is, we do not try to uncover the properties of the optimal reaction function but instead attempt to estimate simple reaction functions to see how closely they can describe Federal Reserve policy over this interval. Indeed, investigating the optimality of any specific rule would require an explicit model of the macroeconomy and would need be conditioned on one's beliefs about the accuracy with which such a model depicts reality.[4] Rather, our aim is to identify the one or two summary measures of the inflation and employment situation that can most closely characterize the systematic reaction of monetary policy to macroeconomic conditions over the past seventeen years.

Four main issues are examined in detail. First, whether the FOMC has responded to its members' own short-term forecasts of the macroeconomy as opposed to recent macroeconomic outcomes; in other words, whether policy can best be described as proactive or reactive. The Federal Reserve Board staff's macroeconomic forecasts, which appear in a document called the "Greenbook" that is distributed to the FOMC before each FOMC meeting, naturally engender the presumption that forecasts may play some role in the deci-

[3]The exact choices can often be associated with policies described as nominal income targeting or inflation targeting.

[4]Optimal policy reaction functions would involve complex relationships and require policy to respond to many variables and with many lags. And as the underlying structure of the economy evolved, their parameterizations would change accordingly. Along these lines, deviations of the Federal Reserve's operating target from a simple rule might well reflect exactly the appropriate degree of "discretion" required for policy to be optimal.

sion making. Moreover, the various lags in the monetary policy process traditionally have been used to justify a forward-looking monetary policy, and "preemptive" actions, which received special attention in 1994, of course require forecasts.

Among academics, Hall and Mankiw (1994) suggested that the central bank should base its policy decisions on the consensus of the Blue Chip forecasts of the U.S. economy. Bernanke and Woodford (1996), however, argued that using private forecasts to guide policy may present some theoretical problems. Targeting central-bank forecasts of inflation was advocated by Svensson (1996). However, forecasts are subject to considerable error, and at least one experienced observer, Axilrod (1990), chastened by the inflationary episode of the 1970s, cautioned against relying too much on them.[5] Others, including Meltzer (1987) and Brunner and Meltzer (1993), completely dismissed the use of forecasts for policy purposes, asserting that forecasts are too inaccurate to serve at all as a useful guide in policy design.

The second issue we investigate is whether or not monetary policy changes tended to be gradual in response to changes in the state of the macroeconomy. This is a relevant consideration if the Federal Reserve were to attempt to mitigate the interest rate volatility which would result from an immediate and complete policy response to changes in economic conditions.[6] Alternatively, such a gradual policy response may be justified by uncertainty about the impact of policy on inflation and economic activity.

Third, we investigate the relative weight accorded to inflation versus real economic conditions in setting policy. If the Federal Reserve indeed places substantial emphasis on a cyclical stabilization objective, in addition to its inflation objective, the preferred policy reaction function would be expected to incorporate a policy response to real variables as well as to inflation. Even if the policymaker intends to focus only on stabilizing inflation, however, the level of resource utilization, as measured by deviations of output from its potential or unemployment from its natural rate, could still be a useful indicator of future inflationary pressures and may enter the reaction function for this reason.

[5]Stephen Axilrod served as Staff Director for Monetary and Financial Policy at the Board of Governors over much of the Volcker era.

[6]See Goodfriend (1991) for a discussion of interest rate smoothing considerations.

Lastly, pertaining to real economic activity, we investigate whether the level of activity (relative to full employment) or the growth rate of activity appears to have been more relevant for policy decisions.

To address the issues raised above this paper estimates the Federal Reserve's reaction function over the last seventeen years using a semi-annual data set of forecasts and outcomes on inflation, unemployment and output growth.

In our analysis, we use only information available to the FOMC at the time decisions were taken, carefully eliminating data contamination by subsequent data revisions and definitional changes. Doing so ensures that the systematic reaction we uncover is explicitly operational and is not subject to McCallum's (1993) justified critique regarding policy rules based on unrealistic information assumptions. We construct measures of forecasts from the projections of key macroeconomic indicators made by the Federal Reserve Board Governors and Reserve Bank Presidents and publicly released each February and July as part of the Board's semi-annual Monetary Policy report to the Congress (the Humphrey-Hawkins report). These projections appear to be the only publicly available source of quantitative information regarding FOMC members' beliefs about the state of the economy over the next several quarters.[7] We assess the extent to which these measures of forecasts, combined with perceived outcomes, can explain the level of the federal funds rate set immediately after the February and July FOMC meeting.

Our work is hardly the first attempt to estimate Federal Reserve reaction functions using the federal funds rate as the policy instrument, which started with Havrilesky, Sapp, and Schweitzer (1975). By contrast, no previous researcher to our knowledge has used Humphrey-Hawkins forecasts to estimate such reaction functions. McNees (1986, 1992) and Tootell (forthcoming) estimated reaction functions using the Greenbook forecasts. Romer and Romer (1996) used differences between Greenbook forecasts and private forecasts to explain changes in the intended federal funds rate. McNees (1995) studied the accuracy of

[7] In this regard, they are more relevant for FOMC decisions than other forecasts, including the Federal Reserve Board staff forecasts presented in the Greenbook.

Humphrey-Hawkins forecasts, and Levy (1987) argued informally that the change in the federal funds rate over the preceding year appears related to the ex-post forecast error of the FOMC forecasts in the February Humphrey-Hawkins report. Related to our work are also the recent studies by Bernanke and Mihov (1996) and Clarida and Gertler (1996) who constructed forecasts of inflation and output for Germany using vector autoregressions and examined reaction functions based on these ex-post estimated forecasts.

We find that simple reaction functions that respond to inflation and real economic activity fit the path of the federal funds rate over the past seventeen years surprisingly well, and broadly share desirable features of policy rules that have emerged from model-based research. However, the details of the functions best describing policy differ markedly between the eras of Chairmen Volcker and Greenspan. The most striking difference is that while policy during the Volcker era can be adequately described as reacting to recent outcomes of inflation and real GDP growth, policy during the Chairman Greenspan era is best characterized as dominantly proactive, responding mainly to the FOMC's forecasts regarding inflation and unemployment. Also, the FOMC's policy in the Volcker era, at least over semiannual intervals, exhibits an immediate and complete adjustment of its federal funds rate instrument to changes in the macroeconomic variables, while the FOMC in the Greenspan era has evinced partial adjustment. Both, however, share the key characteristics of strong reaction to inflationary pressures and concern for the real side of the economy, consistent with the stated goals of the Federal Reserve.

The paper is organized in six sections. Following this introduction, in section 2 we provide a detailed description of the data we employ in our analysis. In section 3 we describe the specification of the simple reaction functions we estimate and in section 4 provide the estimation results. We then offer an interpretation of our findings in section 5 and a brief conclusion in section 6.

2 Data

2.1 FOMC forecasts

Since 1979, the Humphrey-Hawkins report has presented the range of forecasts of the individual Federal Reserve Governors and Reserve Bank Presidents.[8] Starting in February 1983, each range was supplemented by its "central tendency," which was constructed by dropping the high and low tails of each range. We take the midpoints of these central tendencies from February 1983 on, and the midpoints of the ranges for previous years, to represent our point estimates of FOMC expectations. For this reason, in estimating reaction functions, we can only use variables for which the FOMC has provided forecasts. The four measures forecast by Governors and Presidents are the growth rate of real output, the growth rate of nominal output, the rate of inflation, and the rate of unemployment. For real and nominal output and for prices, the forecasts are for annual growth rates on a fourth-quarter-to-fourth-quarter basis. For unemployment, the forecasts are for the average level in the fourth quarter.[9]

Concrete examples of the timing of the release of the forecasts of the Governors and Presidents are shown in Figure 1. Forecasts for 1996 were first reported in July 1995 (not shown). In February 1996, revised forecasts were reported for that year, as shown in the top panel. Then, in July, the final updated forecasts for 1996 accompanied the first forecasts for 1997, as shown in the bottom panel.

Since the FOMC's forecasts apply to quarterly data, it is convenient to describe our dataset in terms of a quarterly frequency although we have only two observations per year. Denoting time (measured in quarters) with t, we associate the February Humphrey-Hawkins report with the first quarter of the year and the July Humphrey-Hawkins with the third quarter. We construct a dataset containing two sets of forecasts for each year covering

[8] In February 1980 the projections were those of Board members only; in July 1980, of voting FOMC members only.

[9] The particular measures have been redefined over the years. For real and nominal output, Gross National Product was used through July 1991, thereafter replaced by Gross Domestic Product. For inflation, the implicit deflator of the GNP was used through July 1988, thereafter replaced by the CPI.

four-quarter intervals that always end three quarters in the future. For any variable x, we let $x_{t+i|t}$ denote the estimated outcome (for $i \leq 0$) or forecast (for $i > 0$) of the value of the variable x at $t+i$ as of time t.[10] Thus, letting u denote the rate of unemployment, $u_{t+3|t}$ would represent the three quarter ahead forecast of the rate of unemployment formed during quarter t, and $u_{t-1|t}$ the estimate, as of quarter t, of what the outcome for the rate of unemployment was in the previous quarter.

As shown on the time chart in Figure 2, using the rate of unemployment as an example, the forecasts reported to the Congress in February have exactly the desired timing. That is, when t is the first quarter, the three-quarter-ahead forecast of unemployment, $u_{t+3|t}$, corresponds to the Humphrey-Hawkins forecast for the rate of unemployment in the fourth quarter of the same year. That is, when t represents the first quarter of a year we have

$$u_{t+3|t} \equiv u^{HH}_{t+3|t},$$

where we employ the superscript HH to denote the Humphrey-Hawkins forecasts. Note that in Figure 2 the arrow points to the quarter on the time line for which the unemployment rate is predicted (t+3), while the dotted line points to the quarter in which the forecast is made (t). Similarly, for inflation and real GDP growth, when t represents the first quarter of a year the three-quarter-ahead forecast corresponds to the rate of growth of prices or of GDP from the fourth quarter of the previous year to the fourth quarter of the current year, exactly matching the horizon of the Humphrey-Hawkins forecast. Letting π represent the rate of inflation over four quarters and q represent real GDP growth over four quarters, when t is the first quarter of a year we have

$$\pi_{t+3|t} \equiv \pi^{HH}_{t+3|t},$$

and

$$q_{t+3|t} \equiv q^{HH}_{t+3|t},$$

[10] Importantly, because of the lags with which information about the past becomes available, we need to keep track not only of revisions of forecasts but also of revisions regarding outcomes when trying to understand the environment in which FOMC decisions were taken. We describe the data we use for outcomes later on.

For the July Humphrey Hawkins reports, however, we need to estimate the forecast of the unemployment rate for next year's second quarter, and the corresponding forecasts of four-quarter growth rates for prices and output that end in the second quarter of next year, by combining available information. The timing of the two Humphrey-Hawkins forecasts and the constructed forecast for three quarters ahead is shown again with respect to the time line in Figure 2. In this case the dashed arrow refers to the three-quarter ahead observation for which an unemployment forecast is needed. We approximate the unemployment forecast in the second quarter of the following year by simply averaging the forecasted levels for the current year's fourth quarter and next year's fourth quarter that are contained in the report. That is, when t represents the third quarter of the year we set

$$u_{t+3|t} = \frac{1}{2}(u^{HH}_{t+1|t} + u^{HH}_{t+5|t}).$$

Other than the rare occurrence of a shock known to have only transitory effects, for a four-quarter interval that starts two quarters later, it is doubtful that the Governors and Presidents have strong views about the likelihood of different changes in the unemployment rate over the two halves of that period. Thus, we assume that the changes forecasted in July for the unemployment rate in each half of next year are the same.

The desired second-quarter-to-second-quarter forecasts of growth rates of real output or prices are obtained by constructing two forecasted half-year annualized growth rates and then averaging them. In other words, using inflation as an example, when t represents the third quarter of the year we set

$$\pi_{t+3|t} = \frac{1}{2}(\pi^{S}_{t+1|t} + \pi^{S}_{t+3|t})$$

where S stands for semi-annual, so that $\pi^{S}_{t+1|t}$ is the inflation forecast for the second half of the current year, and $\pi^{S}_{t+3|t}$ is the forecast for the first half of the following year.

The inflation forecasted for the second half of the current year, $\pi^{S}_{t+1|t}$, can be inferred from the reported inflation forecast for the whole current year from a base of last year's fourth quarter, $\pi^{HH}_{t+1|t}$, and the estimated inflation over the first half of the current year from a fourth quarter of last year base, $\pi^S_{t-1|t}$. That is, expressing all terms as annualized growth rates, when t is a third quarter

$$\pi^S_{t+1|t} = 2\pi^{HH}_{t+1|t} - \pi^S_{t-1|t}.$$

For $\pi^S_{t+3|t}$, inflation over the first half of the next year, we simply set it equal to the forecast for all of next year contained in the July Humphrey-Hawkins report. That is, we set

$$\pi^S_{t+3|t} = \pi^{HH}_{t+5|t}.$$

We apply the same procedures in constructing the data series we use to represent the forecasted GDP growth, q. Much as before, we assume that GDP growth in each half of the following year equals the forecasted rate for the year as a whole contained in the July Humphrey-Hawkins report.

2.2 Outcomes observed immediately before the policy decision

In our examination of simple policy rules, we want to allow for a direct comparison of rules based on the forecasts described above, to rules based on outcomes of these variables. To that end, we construct parallel variables reflecting the latest historical information available to the FOMC at the time of the meetings preceding the two Humphrey-Hawkins reports in every year.

Thus, for the unemployment rate, we create the variable $u_{t-1|t}$ which for the February observation reflects the average level in the fourth quarter of the prior year and for the July observation reflects the average level in the second quarter of the current year. Similarly, for real growth and inflation, we create the variables $q_{t-1|t}$ and $\pi_{t-1|t}$. These reflect the four-quarter growth rate of output or prices ending in the fourth quarter of the prior year for the February observation, and ending in the second quarter of the current year for the July observation.

To ensure that our definition of outcomes is not contaminated by delays in the initial release and subsequent updates of the data, we rely only on data which would have been available to the FOMC by early February or early July. This implies that the data we use correspond either to preliminary estimates, first reported quarterly data, or estimates based on partial data.[11] To match the timing of this information as closely as possible, for the years 1980 through 1991 inclusive, we use Board-staff estimates of outcomes ending in the prior quarter contained in the Greenbook, distributed to FOMC prior to the early February or early July FOMC meetings. Even so, because Greenbook data are confidential for five years, for February observations in 1992 and 1993 we have replaced Greenbook values with the estimates that extended through the fourth quarter of the prior year contained in the Humphrey-Hawkins reports themselves. Because these figures do not appear in the February report in the most recent three years, for the February observations in 1994 through 1996 we use the mid-February Blue-Chip consensus estimates. Similarly, for the July observations in the last five years—1992 through 1996—we have replaced comparable Greenbook estimates with the mid-July Blue-Chip consensus estimates.

2.3 The policy instrument

For the federal funds rate, which we consider as the FOMC's policy instrument, we use the Committee's intended level as of the close of financial markets on the final day of the February and July FOMC meetings. Prior to August 1989, the FOMC did not specify a precise point estimate for its intended federal funds rate. During all of the period before August 1989, however, the Manager of the System Open Market Account recorded, on a weekly basis, a relatively narrow range of expected federal funds trading. We take the midpoint of this range to be our point estimate of the FOMC's "intended" federal funds rate during that period.

[11]For instance, since unemployment and CPI inflation are released monthly, about three weeks after the end of the month, our second-quarter "outcomes" for July for these variables must sometimes be based on partial data for the whole quarter.

3 Specifying a simple reaction function

The reaction functions we estimate for the federal funds rate all share the following underlying structure. Much as reflected in the quote in page 1, they posit that the systematic component of monetary policy can be described as a notional target for the federal funds rate, $\hat{f}$, which increases with inflation, π, and real activity, x, as measured by real output growth, q, or the rate of unemployment, u. Restricting attention to a linear specification, we posit that[12]

$$\hat{f} = a_0 + a_\pi \pi + a_x x$$

This specification encompasses, in spirit, both the rule specified by Taylor (1993), and by Henderson and McKibbin (1993), provided the output gap, y, is used as the measure of economic activity, and provided contemporaneous measures of inflation and output are employed. Specifically Henderson and McKibbin examined rules of the form

$$\hat{f} = r^* + \pi^* + \sigma(\pi - \pi^*) + \sigma y$$

where π^* denotes the policymaker's inflation target and r^* the long run average or "equilibrium" real rate of interest. They provided comparisons of simulation results for different values of $\sigma > 1$. The choice $\sigma = 2$, which appeared to provide favorable results, would suggest $a_\pi = a_y = 2$ in our notation.[13] Taylor proposed the closely related specification

$$\hat{f} = r^* + \pi + \sigma(\pi - \pi^*) + \sigma y$$

and specified the value 0.5 for σ which would correspond to $a_\pi = 1.5$ and $a_y = 0.5$ in our notation. He assumed an inflation target, π^*, and an equilibrium real rate, r^* each of 2, and noted that the resulting policy prescription fits actual performance remarkably well

[12] As a first step, we restrict attention to linear reaction functions, not because we think they necessarily describe Federal Reserve behavior accurately but because they are the simplest and involve the fewest parameters. A future step might entail investigation of non-linear reaction functions such as those characterizing "opportunistic disinflation" examined by Orphanides and Wilcox (1996), and Orphanides, Small, Wilcox and Wieland (1996).

[13] Levin (1996) provides a detailed comparison of this parameterization of the Henderson amd McKibbin rule and the Taylor rule we describe below.

over the 1987-1992 period. Although we do not have information about the FOMC's beliefs regarding the output gap, and, consequently, cannot directly estimate exact counterparts of the rules proposed by Taylor and by Henderson and McKibbin, as we show later on, an indirect comparison is possible, using the unemployment rate as a measure of the level of economic activity, and then applying Okun's law.

In summary, a systematic response of the FOMC to a slowdown in economic activity would imply reducing the notional federal funds rate target, which means $a_q > 0$ when we employ the real growth of output as our measure of activity, and $a_u < 0$ when we use the rate of unemployment. Further, we would expect that the notional federal funds rate target responds more than one-to-one to changes in inflation so as to induce a movement in the same direction in the real interest rate, suggesting $a_\pi > 1$.

In estimating our specification we need to take an explicit stand regarding the timing of the information about inflation and real activity that the FOMC takes into account. To that end, we set

$$\hat{f}_t = a_0 + a_\pi \pi_{\tau|t} + a_x x_{\tau|t}$$

where τ captures this timing. The explanatory variables $\pi_{\tau|t}$ and $x_{\tau|t}$, the latter of which stands for either $q_{\tau|t}$ or $u_{\tau|t}$, are meant to encompass the information variables to which the FOMC may be reacting. Figure 3 again employs a time line to put the timing of the explanatory variables into perspective, using the unemployment outcomes and forecasts as an example. Again, the arrows point to the quarter to which the forecast or outcome applies, while the dotted line points to the date on which the forecast and the estimate of the outcome are made.

In the regression we allow for the possibility that the FOMC responds to both outcomes and forecasts by defining summary information variables that are weighted averages of outcomes and forecasts:

$$\pi_{\tau|t} \equiv (1-\phi)\pi_{t-1|t} + \phi\pi_{t+3|t},$$

and

$$q_{\tau|t} \equiv (1-\phi)q_{t-1|t} + \phi q_{t+3|t},$$

or

$$u_{\tau|t} \equiv (1-\phi)u_{t-1|t} + \phi u_{t+3|t},$$

where ϕ effectively represents the weight that the FOMC assigns to forecasts relative to outcomes. Thus, if ϕ is set equal to 1, the information variable collapses to a forecast alone. By contrast, if ϕ is set equal to 0, the information variable comprises only an outcome. In principle, ϕ can assume any value between 0 and 1, and the value of ϕ best describing the data can be estimated.[14]

Finally, we allow for the possibility that the FOMC only partially adjusts the intended federal funds rate, f, towards its notional target, $\hat{f}$, instead of implementing the target in every period. To the extent that the FOMC responds to forecasts, a partial adjustment to the prescribed long-run value could represent an element of caution in its policy response in light of the remaining uncertainty about the future. Partial adjustment can be introduced by allowing the FOMC decision just prior to the Humphrey-Hawkins report to be influenced by the level of the intended federal funds decided at the FOMC meeting before the previous Humphrey-Hawkins report. With our timing convention, this can be written as

$$f_t = (1-\rho)\hat{f}_t + \rho f_{t-2}$$

where ρ provides a measure of the degree of partial adjustment so that $\rho = 0$ reflects an immediate adjustment of the intended federal funds rate to its notional target.

4 Empirical Results

We use our data set to estimate least squares regressions explaining the intended level of the nominal federal funds rate following the February and July FOMC meetings. Our data set starts in February 1980, just after the new operating procedures for monetary policy

[14]Notice that for simplicity, we constrain the values of ϕ applying to inflation and the real variable to be equal. We recognize that this need not be the case in more general specifications.

were introduced in October 1979. It extends through July 1996, with two semi-annual observations for each of the seventeen years. Thus, we have a total of 34 observations. We always enter an inflation rate information variable, and we use for the real activity information variable either four-quarter real output growth (odd numbered tables) or the unemployment rate as an index of resource utilization (even numbered tables). Appearing as the inflation and the real right-hand side variables are: the outcomes, setting ϕ at 0 in columns 1 and 2 of each table; the forecasts, setting ϕ at 1 in columns 3 and 4; and the weighted average of outcomes and forecasts, allowing the regression equation to determine the value of ϕ in columns 5 and 6. The partial adjustment parameter, ρ, is set to 0 in the odd-numbered columns, but estimated in the even-numbered columns. All regression equations that encompass the early 1980s also include a dummy variable for the credit controls episode affecting the July 1980 data point.

The results in Tables 1 and 2 cover the entire sample period. In all the results on the two tables, the coefficients of the inflation terms, the a_πs, are greater than both 0 and 1 at a high level of significance. As for the real variable, both Table 1 (columns 4 and 6) and Table 2 (column 4) appear at first blush to embody satisfactory results, with all coefficients of sensible sign and magnitude, and almost always statistically significant.

The sample period, however, contains a natural breakpoint that corresponds to the replacement of Chairman Paul Volcker by Alan Greenspan in 1987.[15] This splits the sample period into two almost equal parts, the first with 16 observations, and the second with 18 observations. Dividing the data set in this way reveals in Tables 3 through 6 that the best fitting reaction functions for each sub-sample differ substantially.[16] As a consequence, the regression equation in each of the sub-periods has a lower standard error of estimate than any of the equations estimated over the whole period in Tables 1 and 2.

Each of the Tables 3 through 6 has an associated three panel chart, Figures 4 through

[15]Paul Volcker replaced G. William Miller as chairman on August 6, 1979 and served until August 11, 1987, when Alan Greenspan replaced him.

[16]For the Volcker-era sub-period, we again use a dummy variable for the credit control episode affecting the July 1980 observation.

7. The top panel plots the actual federal funds rate together with the predicted funds rate from the best fitting equation on each associated table, while the middle and bottom panels show both outcomes and forecasts for the real variable and inflation, respectively. These figures facilitate "ocular regressions," enabling one to relate the movements of the funds rate visually to the variations in the relevant explanatory variables in each sub-period. Recall that in each panel the points for a given date refer to different four-quarter intervals: The dotted outcomes line refers to 4-quarter growth ending one quarter before the date on the horizontal axis, while the dashed forecasts line refers to 4-quarter growth ending three quarters after the date on the horizontal axis.

For the Volcker era, the best fitting equation is shown in column 1 of Table 3, which contains outcomes alone for inflation and real output growth, with no lagged dependent variable. The following points concerning this equation are notable. First, the coefficient on the inflation term, 1.54, is significantly greater than 1. Second, comparing columns 1 in Tables 3 and 4, using output growth in the regression equation yields a much better fit to the data than using the unemployment rate, with the coefficient on the outcome for economic growth a significant 0.32. Third, the results for the outcomes in column 1 of Table 3 evince much more explanatory power than those for the forecasts in column 3. Indeed, the equation in column 1 with the two outcomes alone has a little lower standard error of estimate than the equation in column 5 with weighted averages of outcomes and forecasts variables. In other words, in the Volcker era, adding forecasts for inflation and output growth to an equation with their outcomes is not worth the loss of one degree of freedom that results from estimating ϕ. The coefficient ϕ is not significantly different from zero, suggesting that the FOMC put virtually no weight on forecasts. And fourth, column 2 demonstrates the lack of significance for a ρ coefficient on the lagged dependent variable; policy actions evidently did not incorporate a partial adjustment process in the Volcker era.

The top panel of Figure 4 charts the predictions of the specification using outcomes alone for real growth and inflation in column 1 of Table 3–shown by the dotted line–against the actual intended federal funds rate over the Volcker-era sub-period–plotted by the solid line. The middle and bottom panels of Figure 4 graph the outcomes and forecasts of the output growth rate and the inflation rate over the Volcker-era sub-period. Notice that the outcomes for the output growth rate vary considerably more than its forecasts.

By contrast, for the Greenspan-era sub-period, the regression results reported in column 4 of Table 6, which incorporate forecasts alone for inflation and the unemployment rate, along with a lagged dependent variable, contain the lowest standard error of estimate. Some points regarding this equation are notable. First, the long-run coefficient on the inflation forecast in column 4, 2.23, of course remains significantly greater than 1. Second, the equation has a standard error of estimate of only 0.32 percentage point, considerably lower than that in any of the columns in Table 5, which instead uses the real growth rate, and the long-run coefficient on the unemployment rate forecast, -2.22, is highly significant. Third, in terms of fit, the equation in column 6 of the same table, which embodies an estimated ϕ coefficient that affords forecasts a 0.94 weight and outcomes a 0.06 weight, is a close runner-up to the equation in column 4; however, the estimate of ϕ is not quite significantly different from 1, which is consistent with little role for outcomes. Fourth, the results reported in columns 3 and 5 of Table 6, which do not allow for a lagged dependent variable, display a somewhat higher standard error of estimate than those of columns 4 or 6 using a lagged dependent variable with a significant ρ coefficient; interestingly, not permitting a partial adjustment process in column 5 yields a lower estimate of ϕ, 0.78, which signifies a greater weight on outcomes, than do the results for ϕ when a lagged dependent variable is used in columns 4 or 6.

The top panel of Figure 7 shows the good predictive performance in the Greenspan sub-period of the specification in column 4 of Table 6 using the forecasts of inflation and the unemployment rate, along with the lagged dependent variable. Outcomes and forecasts for the unemployment rate and the inflation rate appear in the middle and lower panel.

Figure 8 illustrates one of our fundamental points in a striking way. In this chart, we identify the reaction function in each of two sub-samples with the estimated specification that fits best in the respective sub-period, as described above. This specification is then also simulated over the other sub-period. Thus, the Volcker-era reaction function incorporating outcomes alone for inflation and output growth with no lagged dependent variable is simulated over a post-sample period represented by the second sub-interval, February 1988 to July 1996. As may be seen from the dotted line, the predicted values from this Volcker-era reaction function tend to run above the actual federal funds rate in the second sub-period. The only exception is a brief episode in July 1988 and February 1989.[17]

This dotted line simulated over the second sub-period should be interpreted as applying only quarter-by-quarter, assuming that the Volcker-era FOMC suddenly were confronted with the macroeconomic conditions captured by the outcomes prevailing in that quarter. The chart ignores the feedback effects of the counterfactual path for the federal funds rate prescribed by the Volcker-era reaction function on macroeconomic outcomes that would have increasingly asserted themselves as the 1990s progressed. With the counterfactual outcomes had the Volcker-era reaction function really been in effect diverging more and more from those that actually transpired, the prescribed funds rate path in turn would have differed increasingly as time passed from the dotted line.

The Greenspan-era reaction function, which uses forecasts alone for inflation and the unemployment rate with a lagged dependent variable, is, of course, estimated over the second sub-period and simulated backward over a "pre-sample" period from February 1980 to July 1987. During most of the first sub-period, the predicted funds rates from this estimated reaction function, designated by the dashed line, fall noticeably short of the actual funds rates.

A certain conceptual inconsistency in applying the dashed simulation line for the Greenspan-era reaction function to the first sub-sample even on a quarter-by-quarter basis should be recognized. The forecasts made by Governors and Presidents presumably rested on their assumption that the FOMC would be setting the federal funds rate in accord with the Volcker-era reaction function. Had the counterfactual Greenspan-era reaction function in-

[17]Note that for the purpose of comparison in Figure 8 we removed the effect of the credit-control dummy in the Volcker era regression for the July 1980 observation.

stead been in force, then presumably the Governors and Presidents would have taken the alternative path for the federal funds rate into account in formulating their projections, even in a particular isolated quarter. With the alternative Greenspan-era reaction function yielding quite different funds rate settings over much of the period, the differential impact of this counterfactual funds rate path, even on a forecast going only three quarters into the future, might be significant. In addition, of course, if the Greenspan-era reaction function actually had been followed by the FOMC over all of the first sub-period, then as time passed the outcomes and, partly as a result of different initial conditions, the forecasts themselves would have evolved increasingly differently from the historical record, in turn implying a growing divergence from the dashed line, even assuming the implementation of the Greenspan-era reaction function.

5 Interpretation

A useful check on our parameterization can be achieved by linking the parameters of our simple rules to the steady state values to which the federal funds rate, inflation and real activity would settle in the absence of any economic shocks.[18] Naturally, in a steady state, inflation would be expected to attain the FOMC's underlying target, π^*, and real activity would be consistent with sustained growth at potential, q^*, and unemployment would be equal to its natural rate, u^*. Further, the federal funds rate would equal the sum of inflation and the equilibrium real rate r^*. Thus, in steady state, our simple rules imply

$$r^* + \pi^* = a_0 + a_\pi \pi^* + a_x x^*$$

where, once again, x stands for q or u depending on the specification. Solving for a_0 yields

$$a_0 = r^* - (a_\pi - 1)\pi^* - a_x x^*$$

An intuitive interpretation of the expressions for a_0, the constant term in the regressions, is that the nominal federal funds rate would need to be higher, the higher is the Wicksellian

[18]This assumes, of course, that the estimated rule would have the necessary stability properties which would ensure convergence of the economy to a steady state.

natural real funds rate, the lower is the central bank's long-run inflation rate target, and the lower is the rate of growth of potential output or, recognizing that the coefficient on u^* in the expression for a_0, that is, $-a_u$, is positive, the higher is the natural rate of unemployment. Our regression equations implicitly treat each of these components of the estimated regression intercept, a_0, as itself a constant over the sample period.

Taking r^*, π^*, and q^* or u^* all to be constant over each sample period is an admittedly strong simplifying assumption. However, because r^* and q^* or u^* represent the FOMC's perception of their estimated values, it is certainly possible for them to be more stable over time than their actual counterparts in the "real world," which may well be subject to appreciable random variation as well as to secular changes. Furthermore, whether or not the implicitly adopted long-run inflation target π^* is constant is also a matter in the hands of the FOMC. On the other hand, the assumption of constancy in all the starred terms seems even stronger after recognizing that a change in q^* or u^* would tend to induce a reinforcing change in r^*.[19] Both the effect on q^* or u^* and the effect on r^* would tend to alter the intercept, a_0, in the same direction.

With this understanding, some interpretative comments may place our regression results and Figure 8 in perspective. Solving the previously derived expressions for a_0 for π^* yields

$$\pi^* = \frac{r^* - a_q q^* - a_0}{a_\pi - 1}$$

for the best fitting reaction function in the Volcker era, and

$$\pi^* = \frac{r^* - a_u u^* - a_0}{a_\pi - 1}$$

for the best fitting one in the Greenspan era. Assuming that, owing to expansionary fiscal policy during the Volcker sub-period, r^* is as high as 3 percent, while q^* equals 2-1/4 percent per year, a value of 1.1 percent per year for the long run inflation target, π^*, when measured by the total CPI, is implied by the regression coefficients. Assuming that during

[19]For example, in many models, a rise in q^*, or a fall in u^* that raised potential output, ceteris paribus, would lower r^* to reestablish a higher long-run equilibrium level of real spending matching the higher level of potential output.

the Greenspan sub-period, r^* has been reduced to 2 percent by fiscal restraint and that u^* has equaled 5-3/4 percent, then the implied value for π^* is 2.6 percent per year. The Boskin Commission (1996) recently estimated the upward bias of inflation measured by the total CPI to have been 1.1 percent per year. Adjusting these π^* estimates by this amount converts them into long-run "true" inflation targets of zero percent for the Volcker era and 1-1/2 percent per year for the Greenspan era.

In light of the inflationary crisis faced by the FOMC when Chairman Volcker assumed the chairmanship, for the FOMC to have adopted a "hard-line" anti-inflationary posture is understandable. As the Staff Director for Monetary and Financial Policy over much of the Volcker-era, Axilrod (1990) noted, "The obvious problem—it was an easy period in that sense—was to control inflation. One way to do it was to impose an M1 rule on yourself, pay little attention to GNP forecasts, and just let the economy adjust. ... [The FOMC] used M1 successfully as that bludgeon to receive a rapid reduction in inflation..." (pp. 578-579.)

By the time of Chairman Greenspan's arrival, the inflation rate already had been reduced to more moderate proportions, and a less Draconian long-term objective evidently was pursued. The lower position of the dashed predicted line relative to the dotted line in Figure 8 over many of the years covered could stem at least in part from this difference. Worth mentioning in this regard, however, is that the FOMC, ceteris paribus, evidently has reacted more aggressively in the long run to increases in inflation in the second sub-period. In the Greenspan era, the FOMC's estimated ultimate response to each percentage point rise in the inflation rate has been to raise the nominal funds rate by 2.23 percentage points compared with 1.54 percentage points in the Volcker era. This estimated long-run response to a change in inflation in the Greenspan era also is larger than the 1.5 figure set a priori by Taylor in his proposed reaction function and closer to the Henderson and McKibbin suggested value of 2. Moreover, the FOMC's estimated response in the Greenspan era to a change in the unemployment rate, at -2.22, is more than twice the value of 1 that would result from applying Okun's Law, with a coefficient of 2 times the unemployment gap equalling the output gap, to the 0.5 coefficient on the output gap assumed a priori by

Taylor but it is about half as large as the value of 4 which would correspond to Henderson and McKibbin's suggested response to the output gap with a coefficient of 2. In light of the evidence assembled by Brayton, Levin, Tryon and Williams (1996) and Levin (1996), which suggests that larger coefficients than Taylor assumed and closer to Henderson and McKibbin's suggested values are consistent with a reaction function which would stabilize the economy more effectively, these findings are quite intriguing.

To be sure, the size of these responses in the short-run in the Greenspan era has been muted by the partial adjustment, or ρ, term of 0.38, which is significantly greater than zero. Hence, the FOMC in the Greenspan era has evinced a somewhat cautious short-run response to varying forecasts of macroeconomic conditions. Federal Reserve Board Vice Chairman Blinder (1995) argued that such a partial adjustment mechanism, as an implication of Brainard (1967), is an appropriate policy adaptation to uncertainty about the future impact of current policy action.

The value for the ρ term in the Volcker era by contrast is estimated to have been insignificantly different from zero. As Axilrod (1996) discussed, "[T]he Great Inflation [of the 1970s] ... came about because of an interaction of a culture of extreme policy caution and a number of unanticipated changes in the economic environment. That is, in the culture of the time the policy instrument, say, the funds rate, was adjusted very carefully–slowly and in small increments. ... In that context, you can think about the policy approach of 1979-82 as an effort to break the culture of excessive policy caution." (pp. 232-233.) The FOMC in the Volcker era evidently was willing to forego gradual adjustment of the policy instrument in response to changing outcomes.

Figure 8 suggests that the FOMC in the Volcker era would have tightened its policy stance appreciably during the second half of 1990 and into early 1991–when the U.S. economy was in recession–in response to the upsurge in inflation in the total CPI. However, such an inference would risk too literal a reading of the concept of "outcomes." That the inflationary upsurge in large part was caused by the oil-price hike associated with the Gulf War was well understood at the time, and much of it was expected to unwind after the end of hostilities. The Volcker-era FOMC surely would not have responded to this kind of shortlived outcome in the same way it would have reacted to one perceived to be more permanent. Hence, in interpreting the Volcker-era reaction function, the distinction between outcomes and forecasts can be overblown. The distinction between outcomes and forecasts also should not be overdrawn in evaluating the FOMC's reliance on forecasts in the Greenspan era. After all, the forecasts presumably already incorporate all the relevant information about the future that was embodied in the observed outcomes.

Even recognizing these caveats, the estimated reaction functions in the two sub-samples have very different characters. What accounts for the change in the fundamental structure of the reaction functions going from the Volcker era to the Greenspan era? One should avoid overly personalizing these results by over-emphasizing who was chairman at the time.[20] Although the chairman is certainly in a position to exercise strong leadership, his own views about the coefficients and even structure of the optimal reaction function—which clearly in practice is much more complex than the simple representations we have considered—along with the views of other FOMC members, could be expected to change over time. After all, fundamental macroeconomic problems and relationships facing policymakers typically evolve with the passage of time, presumably also altering the most suitable policy reaction function regardless of the makeup of the FOMC, including its chairman. For further discussion of this point see Lindsey (1986).

The FOMC's varying use of the monetary aggregates as intermediate targets or macroeconomic indicators as the properties of money demand have changed over the period that we examine is a good case in point. The emphasis placed by the FOMC on the monetary aggregates, after gradually increasing during the 1970s, turned dominant during the three-year experiment with M1 intermediate targeting starting in October 1979. In the fall of 1982, the emphasis placed on M1 was drastically reduced, but M2 and M3 were included among several key policy indicators whose behavior affected the setting of the funds rate

[20]To be sure, Chairman Greenspan, who was a professional forecaster before joining the Federal Reserve, might naturally be expected to recommend putting more weight on forecasts than Chairman Volcker, who was not.

from then on. The broader aggregates, especially M2, continued to play this role until 1993, when a persisting downward shift in its demand relative to predictions based on historical relationships with real output, prices and opportunity costs induced the FOMC to much reduce their policy role.

The diminishing emphasis on outcomes for growth of monetary aggregates relative to predetermined growth paths since 1982 may have widened the scope both (1) for the unemployment rate to replace output growth as the real variable used by the FOMC and (2) for the forecasts for these key macroeconomic variables to supercede their outcomes in importance. After all, the outcome for nominal money growth is conventionally related to the outcomes for inflation and real output growth through a money demand function. However, if nominal monetary targeting were the main reason for the form of the Volcker-era reaction function, then outcomes for both inflation and real output growth–whose sum, nominal output growth, performs well as a single scale variable in demand functions explaining nominal money growth–would have coefficients of similar size. The fact that the coefficient on inflation outcomes in the Volcker era, 1.54, is, statistically speaking, significantly larger than the coefficient on real output growth, .32, indicates that monetary targeting by no means captures the whole story during the entire Volcker era, which, of course, extends through 1987.

In any event, in the couple of years on either side of the time that Chairman Greenspan replaced Chairman Volcker, the dashed and dotted lines showing the two funds rate predictions in Chart 8 are not far apart. The similar prescribed settings for the funds rate over this interval, despite the quite dissimilar underlying structures of the two reaction functions, suggests that strong empirical confirmation cannot be provided for our choice of the exact date separating the two sub-periods, which we selected on a priori grounds related to the person of the chairman. Indeed, the data in this sense are unable to rule out a gradual rather than abrupt transition from the first to the second regime.

The evolution of operating procedures away from being oriented toward money targeting also raises a question about our assumption that a single intended level of the federal funds rate can adequately index the FOMC's operating target before August 1989, when the FOMC did not define its operating target literally in terms of the funds rate.[21]

For the period of a nonborrowed reserves operating target tied to an M1 intermediate target, which extended from October 1979 until the fall of 1982, the likely upcoming trading range for the funds rate was much more unpredictable than afterwards, as it depended on the highly unpredictable quantity of M1 demanded relative to the path that the FOMC had specified for the six or seven weeks between FOMC meetings. Even so, the evolving week-to-week pattern of the funds rate was a product of the existing structure of nonborrowed reserve targeting. In this sense, the federal-funds-rate trading range recorded each week by the Manager, whose mid-point we treat as the "intended" funds rate for this interval, was consistent with the adopted operating procedures designed to return M1 to its targeted path over time. If the FOMC were dissatisfied with the resulting federal funds rate yielded by the procedure, then it could have abandoned this operating procedure, as arguably in fact occurred in the fall of 1982. In addition, as just noted above, monetary targeting could induce an implicit relationship between a federal funds rate dependent variable and independent variables represented by outcomes for inflation and real output growth.

A similar type of rationale also can be advanced for the period between the fall of 1982 and August 1989. If the FOMC were dissatisfied with the evolving federal funds trading area given its borrowed reserves operating target or allowance, altering the borrowing figure to bring the funds rate into a more acceptable trading range was always possible. In this sense, the prevailing funds rate could be considered as "intended," even if it was not completely predictable in advance.[22]

[21] Operating procedures have evolved from a nonborrowed reserve operating target tied to an M1 intermediate target from October 1979 to the fall of 1982, to an operating target for borrowed reserves from the discount window until just after the stock market break in October 1987, to an internally specified, fairly narrow range for the funds rate to accompany a borrowed reserves operating allowance until August 1989, to an internally specified point operating objective for the funds rate until February 1994, to a publicly announced point operating objective for the funds rate after then.

[22] During most of the period in the 1980s characterized by a borrowed operating target, the standrard error of functions relating the federal funds rate to the level of discount window borrowing was limited to about 1/2 percentage point on a reserve-maintainance-period average basis, as estimated in Lindsey and Glassman (1987). The first exceptional sub-period occurred around the time of the difficulties of Continental Illinois in 1984, when bank reluctance to be seen tapping the window intensified for a time before returning to normal.

6 Conclusion

Our estimated simple reaction functions for setting the federal funds rate suggest that monetary policy has conformed closely to a stable and systematic response to measures of inflation and real economic activity in each of the eras of Chairmen Volcker and Greenspan. The details of the policy reaction functions best describing policy under Chairmen Volcker and Greenspan, however, differ. The evidence suggests that the FOMC in the Volcker era put virtually exclusive weight on outcomes for output growth and inflation. By contrast, the FOMC in the Greenspan era instead has dominantly weighed forecasts for the unemployment rate and inflation but, unlike the FOMC in the Volcker era, has adjusted the federal funds rate during semi-annual intervals only partially toward the long-run value prescribed by the estimated reaction function. A common feature of the FOMC in both eras has been its willingness to raise the real federal funds rate appreciably in reaction to an increase in inflation and also its responsiveness to the real side of the economy.

The second exceptional sub-period occurred later in the 1980s, especially once the problems of the thrift institutions surfaced, which caused increasing bank reluctance to borrow, this time on a permanent basis.

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Table 1

Policy reaction to inflation and real output growth
Full sample: 1980-1996

	Regression based on					
	outcomes		forecasts		both	
	(1)	(2)	(3)	(4)	(5)	(6)
a_0	−1.13	−3.13	−2.79	−3.47	−3.64	−5.28
	1.02	1.68	1.47	1.88	1.27	1.68
a_π	1.80	2.10	2.13	2.49	2.17	2.49
	0.17	0.27	0.20	0.28	0.18	0.24
a_q	0.50	0.78	0.58	0.24	0.86	0.96
	0.18	0.28	0.30	0.40	0.26	0.33
ρ	0	0.42	0	0.45	0	0.36
		0.11		0.08		0.08
ϕ	0	0	1	1	0.59	0.66
					0.13	0.14
$\bar{R}^2$	0.78	0.85	0.80	0.90	0.85	0.90
SEE	1.79	1.47	1.71	1.20	1.51	1.19
DW	0.85	1.78	1.12	1.69	0.86	1.44

Notes: The regressions shown are least squares estimates of the equation:

$$f_t = \rho f_{t-2} + (1-\rho)(a_0 + a_\pi \pi_{\tau|t} + a_q q_{\tau|t})$$

where $\pi_{\tau|t} \equiv (1-\phi)\pi_{t-1|t} + \phi\pi_{t+3|t}$ and $q_{\tau|t} \equiv (1-\phi)q_{t-1|t} + \phi q_{t+3|t}$. Here, f denotes the intended federal funds rate, π the inflation rate over four quarters, and q real output growth over four quarters. $q_{t-1|t}$ and $\pi_{t-1|t}$ indicate outcomes for the previous quarter while $q_{t+3|t}$ and $\pi_{t+3|t}$ denote forecasts. In columns (1), (3) and (5) $\rho = 0$, is imposed, while in columns (2), (4) and (6) the unrestricted partial adjustment specification is shown. In columns (1) and (2) $\phi = 0$ is imposed and the regression uses outcomes only. In columns (3) and (4) $\phi = 1$ is imposed and the regression uses forecasts only. Columns (5) and (6) reflect an unrestricted ϕ. Standard errors are shown under the parameter estimates. A dummy variable for the July 1980 observation (reflecting credit controls) is included in the regression but is not shown. 34 observations are used corresponding to the February and July FOMC meetings during 1980-1996.

Table 2

Policy reaction to inflation and unemployment
Full sample: 1980-1996

	Regression based on					
	outcomes		forecasts		both	
	(1)	(2)	(3)	(4)	(5)	(6)
a_0	−0.40	1.95	−1.35	2.39	−0.97	2.96
	1.84	3.26	1.87	2.76	1.81	3.23
a_π	1.57	1.91	1.87	2.97	1.86	3.32
	0.17	0.34	0.20	0.43	0.19	0.60
a_u	0.21	−0.35	0.17	−1.07	0.12	−1.38
	0.27	0.53	0.31	0.56	0.28	0.71
ρ	0	0.49	0	0.54	0	0.60
		0.13		0.08		0.08
ϕ	0	0	1	1	0.69	1.23
					0.20	0.17
$\bar{R}^2$	0.73	0.81	0.78	0.92	0.79	0.92
SEE	2.00	1.69	1.80	1.11	1.76	1.09
DW	0.76	1.45	1.07	1.93	0.96	2.08

Notes: The regressions shown are least squares estimates of the equation:

$$f_t = \rho f_{t-2} + (1-\rho)(a_0 + a_\pi \pi_{\tau|t} + a_u u_{\tau|t})$$

where $\pi_{\tau|t} \equiv (1-\phi)\pi_{t-1|t} + \phi\pi_{t+3|t}$ and $u_{\tau|t} \equiv (1-\phi)u_{t-1|t} + \phi u_{t+3|t}$. Here, f denotes the intended federal funds rate, π the inflation rate over four quarters, and u the average rate of unemployment during a quarter. $u_{t-1|t}$ and $\pi_{t-1|t}$ indicate outcomes for the previous quarter while $u_{t+3|t}$ and $\pi_{t+3|t}$ denote forecasts. In columns (1), (3) and (5) $\rho = 0$, is imposed, while in columns (2), (4) and (6) the unrestricted partial adjustment specification is shown. In columns (1) and (2) $\phi = 0$ is imposed and the regression uses outcomes only. In columns (3) and (4) $\phi = 1$ is imposed and the regression uses forecasts only. Columns (5) and (6) reflect an unrestricted ϕ. Standard errors are shown under the parameter estimates. A dummy variable for the July 1980 observation (reflecting credit controls) is included in the regression but is not shown. 34 observations are used corresponding to the February and July FOMC meetings during 1980-1996.

Table 3

Policy reaction to inflation and real output growth
Volcker era: 1980-1987

	Regression based on					
	outcomes		forecasts		both	
	(1)	(2)	(3)	(4)	(5)	(6)
a_0	1.69	1.55	−0.70	−1.87	2.05	2.02
	0.84	1.02	3.57	4.55	1.18	1.91
a_π	1.54	1.56	1.85	2.20	1.49	1.49
	0.12	0.15	0.41	0.55	0.17	0.28
a_q	0.32	0.34	0.48	0.25	0.30	0.30
	0.13	0.14	0.55	0.70	0.13	0.17
ρ	0	0.04	0	0.37	0	0.00
		0.12		0.13		0.17
ϕ	0	0	1	1	−0.12	−0.11
					0.30	0.44
$\bar{R}^2$	0.92	0.91	0.73	0.83	0.91	0.90
SEE	1.12	1.16	2.00	1.59	1.16	1.21
DW	2.54	2.63	1.52	2.10	2.66	2.66

Notes: The regressions shown are least squares estimates of the equation:

$$f_t = \rho f_{t-2} + (1-\rho)(a_0 + a_\pi \pi_{\tau|t} + a_q q_{\tau|t})$$

where $\pi_{\tau|t} \equiv (1-\phi)\pi_{t-1|t} + \phi\pi_{t+3|t}$ and $q_{\tau|t} \equiv (1-\phi)q_{t-1|t} + \phi q_{t+3|t}$. Here, f denotes the intended federal funds rate, π the inflation rate over four quarters, and q real output growth over four quarters. $q_{t-1|t}$ and $\pi_{t-1|t}$ indicate outcomes for the previous quarter while $q_{t+3|t}$ and $\pi_{t+3|t}$ denote forecasts. In columns (1), (3) and (5) $\rho = 0$, is imposed, while in columns (2), (4) and (6) the unrestricted partial adjustment specification is shown. In columns (1) and (2) $\phi = 0$ is imposed and the regression uses outcomes only. In columns (3) and (4) $\phi = 1$ is imposed and the regression uses forecasts only. Columns (5) and (6) reflect an unrestricted ϕ. Standard errors are shown under the parameter estimates. A dummy variable for the July 1980 observation (reflecting credit controls) is included in the regression but is not shown. 16 observations are used corresponding to the February and July FOMC meetings during 1980-1987.

Table 4

Policy reaction to inflation and unemployment
Volcker era: 1980-1987

	Regression based on					
	outcomes		forecasts		both	
	(1)	(2)	(3)	(4)	(5)	(6)
a_0	3.29	3.60	−0.37	3.47	3.39	3.45
	2.27	2.70	3.61	5.56	2.86	3.41
a_π	1.42	1.45	1.50	2.38	1.41	1.54
	0.14	0.18	0.26	0.64	0.19	0.39
a_u	−0.03	−0.09	0.38	−0.73	−0.04	−0.13
	0.28	0.36	0.49	0.96	0.31	0.42
ρ	0	0.05	0	0.45	0	0.11
		0.17		0.15		0.25
ϕ	0	0	1	1	−0.03	0.16
					0.37	0.58
$\bar{R}^2$	0.87	0.86	0.73	0.84	0.86	0.85
SEE	1.39	1.44	2.02	1.55	1.45	1.51
DW	2.17	2.21	1.64	2.18	2.18	2.23

Notes: The regressions shown are least squares estimates of the equation:

$$f_t = \rho f_{t-2} + (1-\rho)(a_0 + a_\pi \pi_{\tau|t} + a_u u_{\tau|t})$$

where $\pi_{\tau|t} \equiv (1-\phi)\pi_{t-1|t} + \phi\pi_{t+3|t}$ and $u_{\tau|t} \equiv (1-\phi)u_{t-1|t} + \phi u_{t+3|t}$. Here, f denotes the intended federal funds rate, π the inflation rate over four quarters, and u the average rate of unemployment during a quarter. $u_{t-1|t}$ and $\pi_{t-1|t}$ indicate outcomes for the previous quarter while $u_{t+3|t}$ and $\pi_{t+3|t}$ denote forecasts. In columns (1), (3) and (5) $\rho = 0$, is imposed, while in columns (2), (4) and (6) the unrestricted partial adjustment specification is shown. In columns (1) and (2) $\phi = 0$ is imposed and the regression uses outcomes only. In columns (3) and (4) $\phi = 1$ is imposed and the regression uses forecasts only. Columns (5) and (6) reflect an unrestricted ϕ. Standard errors are shown under the parameter estimates. A dummy variable for the July 1980 observation (reflecting credit controls) is included in the regression but is not shown. 16 observations are used corresponding to the February and July FOMC meetings during 1980-1987.

Table 5

Policy reaction to inflation and real output growth
Greenspan era: 1988-1996

	Regression based on					
	outcomes		forecasts		both	
	(1)	(2)	(3)	(4)	(5)	(6)
a_0	−1.82	30.41	−0.78	−10.86	0.02	−4.20
	2.34	158.69	2.16	16.24	1.69	4.48
a_π	1.59	4.55	2.62	3.93	2.59	3.47
	0.47	16.09	0.43	2.30	0.36	1.13
a_q	0.72	−15.72	−1.11	1.16	−1.39	−0.88
	0.35	78.76	0.46	3.63	0.35	0.58
ρ	0	1.03	0	0.68	0	0.68
		0.14		0.32		0.21
ϕ	0	0	1	1	1.15	1.58
					0.06	0.41
$\bar{R}^2$	0.36	0.86	0.78	0.82	0.84	0.90
SEE	1.65	0.78	0.97	0.87	0.84	0.65
DW	0.92	2.28	1.12	0.81	1.84	1.95

Notes: The regressions shown are least squares estimates of the equation:

$$f_t = \rho f_{t-2} + (1-\rho)(a_0 + a_\pi \pi_{\tau|t} + a_q q_{\tau|t})$$

where $\pi_{\tau|t} \equiv (1-\phi)\pi_{t-1|t} + \phi\pi_{t+3|t}$ and $q_{\tau|t} \equiv (1-\phi)q_{t-1|t} + \phi q_{t+3|t}$. Here, f denotes the intended federal funds rate, π the inflation rate over four quarters, and q real output growth over four quarters. $q_{t-1|t}$ and $\pi_{t-1|t}$ indicate outcomes for the previous quarter while $q_{t+3|t}$ and $\pi_{t+3|t}$ denote forecasts. In columns (1), (3) and (5) $\rho = 0$, is imposed, while in columns (2), (4) and (6) the unrestricted partial adjustment specification is shown. In columns (1) and (2) $\phi = 0$ is imposed and the regression uses outcomes only. In columns (3) and (4) $\phi = 1$ is imposed and the regression uses forecasts only. Columns (5) and (6) reflect an unrestricted ϕ. Standard errors are shown under the parameter estimates. 18 observations are used corresponding to the February and July FOMC meetings during 1988-1996.

Table 6

Policy reaction to inflation and unemployment
Greenspan era: 1988-1996

	Regression based on					
	outcomes		forecasts		both	
	(1)	(2)	(3)	(4)	(5)	(6)
a_0	16.09	23.63	7.62	11.55	10.30	11.52
	2.11	8.32	2.10	2.12	1.55	1.96
a_π	0.73	0.00	2.33	2.23	2.04	2.16
	0.21	0.81	0.26	0.23	0.20	0.24
a_u	−2.14	−2.96	−1.63	−2.22	−1.92	−2.18
	0.30	0.99	0.25	0.27	0.18	0.26
ρ	0	0.58	0	0.38	0	0.33
		0.23		0.06		0.10
ϕ	0	0	1	1	0.78	0.94
					0.06	0.09
$\bar{R}^2$	0.82	0.87	0.92	0.98	0.96	0.98
SEE	0.89	0.76	0.59	0.32	0.42	0.33
DW	1.23	1.60	1.45	2.20	1.56	2.14

Notes: The regressions shown are least squares estimates of the equation:

$$f_t = \rho f_{t-2} + (1-\rho)(a_0 + a_\pi \pi_{\tau|t} + a_u u_{\tau|t})$$

where $\pi_{\tau|t} \equiv (1-\phi)\pi_{t-1|t} + \phi\pi_{t+3|t}$ and $u_{\tau|t} \equiv (1-\phi)u_{t-1|t} + \phi u_{t+3|t}$. Here, f denotes the intended federal funds rate, π the inflation rate over four quarters, and u the average rate of unemployment during a quarter. $u_{t-1|t}$ and $\pi_{t-1|t}$ indicate outcomes for the previous quarter while $u_{t+3|t}$ and $\pi_{t+3|t}$ denote forecasts. In columns (1), (3) and (5) $\rho = 0$, is imposed, while in columns (2), (4) and (6) the unrestricted partial adjustment specification is shown. In columns (1) and (2) $\phi = 0$ is imposed and the regression uses outcomes only. In columns (3) and (4) $\phi = 1$ is imposed and the regression uses forecasts only. Columns (5) and (6) reflect an unrestricted ϕ. Standard errors are shown under the parameter estimates. 18 observations are used corresponding to the February and July FOMC meetings during 1988-1996.

Figure 1

FOMC Forecasts in the Humphrey-Hawkins Report

February Report 1996

Economic Projections for 1996
Percent

Indicator	Federal Reserve Governors and Reserve Bank Presidents: Range	Federal Reserve Governors and Reserve Bank Presidents: Central Tendency	Administration
Change, fourth quarter to fourth quarter[1]			
Nominal GDP	4–5	4¼–4¾	5.1
Real GDP[2]	1½–2½	2–2¼	2.2
Consumer price index[3]	2½–3	2¾–3	3.1
Average level, fourth quarter			
Civilian unemployment rate	5½–6	5½–5¾	5.7[4]

1. Change from average for fourth quarter of 1995 to average for fourth quarter of 1996.
2. Chain-weighted.
3. All urban consumers.
4. Annual average.

July Report 1996

Economic Projections for 1996 and 1997

	Federal Reserve Governors and Reserve Bank Presidents: Range	Federal Reserve Governors and Reserve Bank Presidents: Central Tendency	Administration
1996			
Percent change, fourth quarter to fourth quarter[1]			
Nominal GDP	4¾ to 5¾	5 to 5½	5.0
Real GDP	2½ to 3	2½ to 2¾	2.6
Consumer price index[2]	3 to 3¼	3 to 3¼	3.2
Average level in the fourth quarter, percent			
Civilian unemployment rate	5¼ to 5¾	About 5½	5.6
1997			
Percent change, fourth quarter to fourth quarter[1]			
Nominal GDP	4 to 5½	4¼ to 5	5.1
Real GDP	1½ to 2½	1¾ to 2¼	2.3
Consumer price index[2]	2½ to 3¼	2¾ to 3	2.8
Average level in the fourth quarter, percent			
Civilian unemployment rate	5½ to 6	5½ to 5¾	5.7

1. Change from average for fourth quarter of previous year to average for fourth quarter of year indicated.
2. All urban consumers.

Figure 2

The Timing of the Forecasts in the Humphrey-Hawkins Report
Unemployment Rates

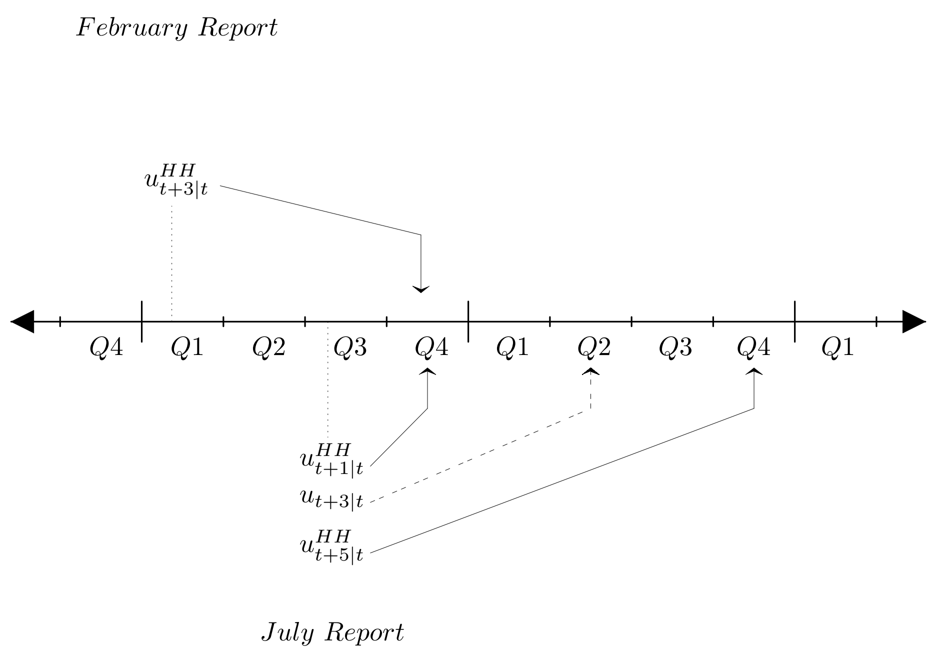


Figure 3

The Timing of the Explanatory Variables
Outcomes and Forecasts of Unemployment

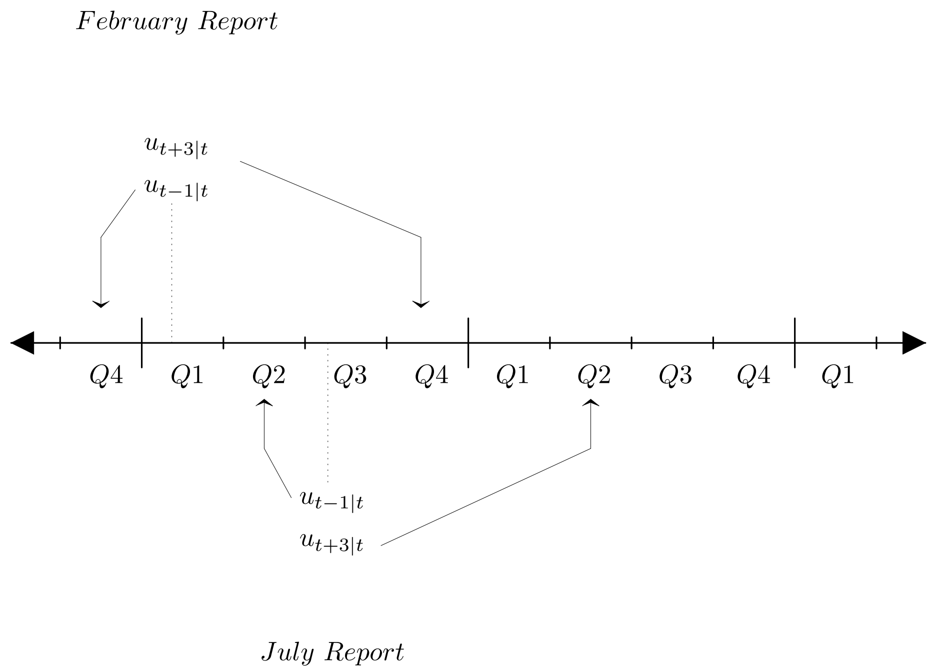
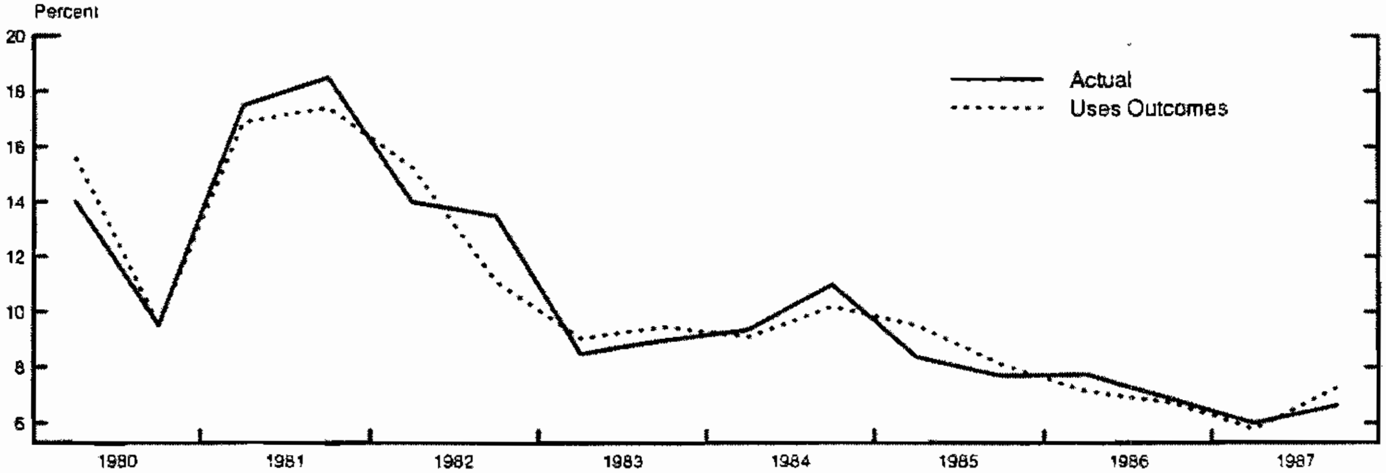


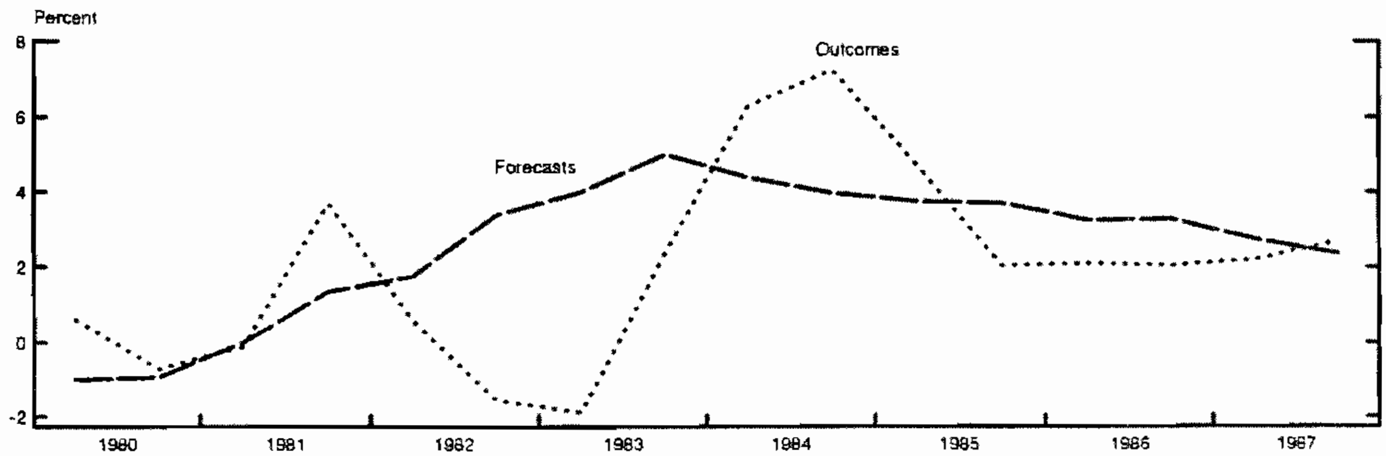
Figure 4

Volcker Era: Fit Based on Real Growth and Inflation

Actual and Fitted Federal Funds Rate



Growth Rate of Output



Inflation Rate

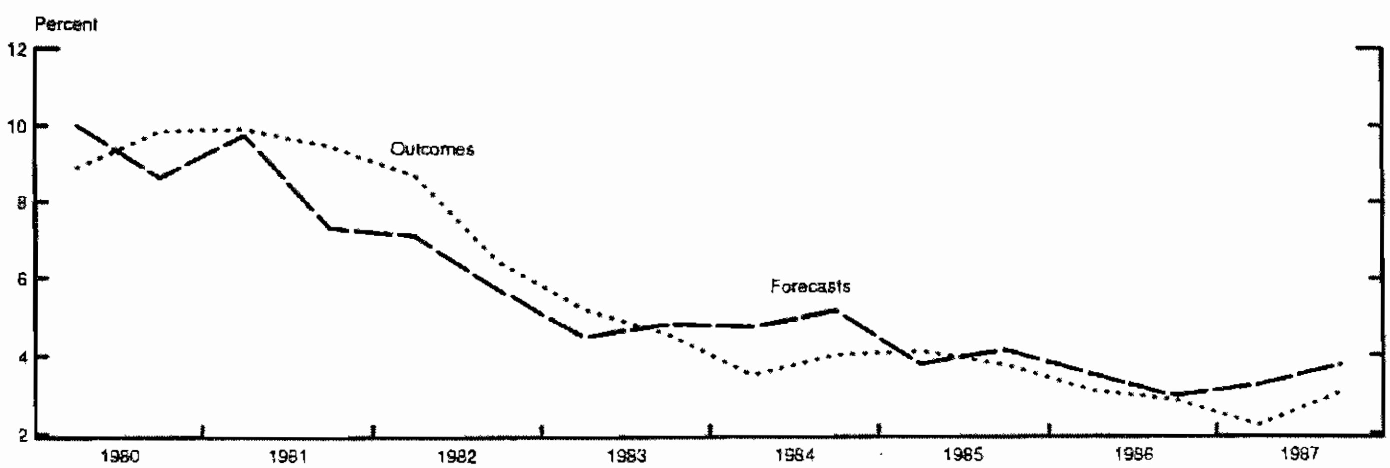
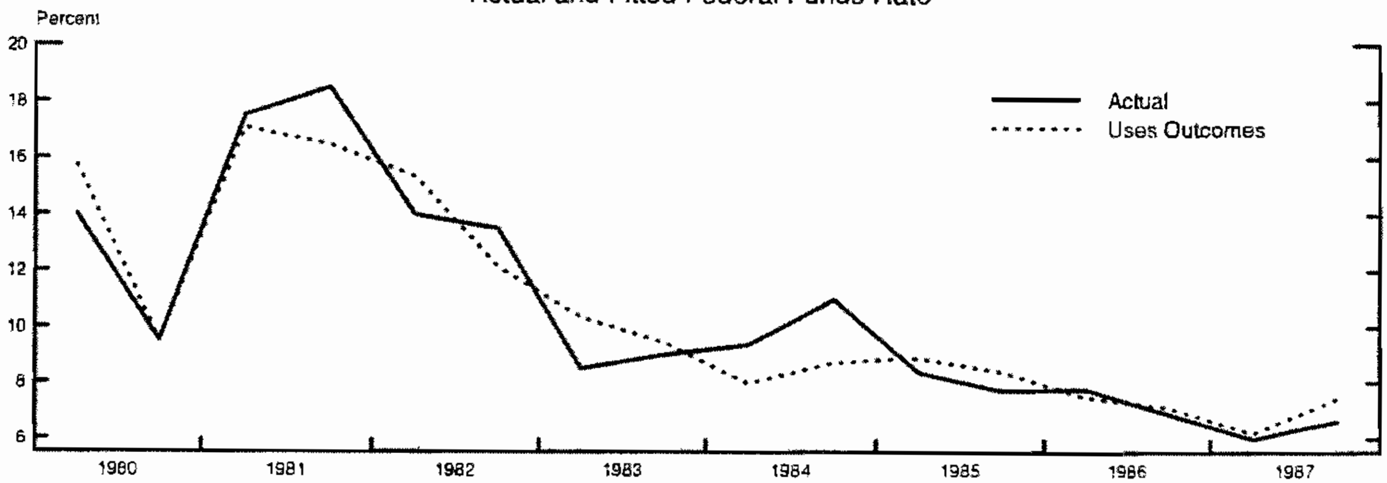


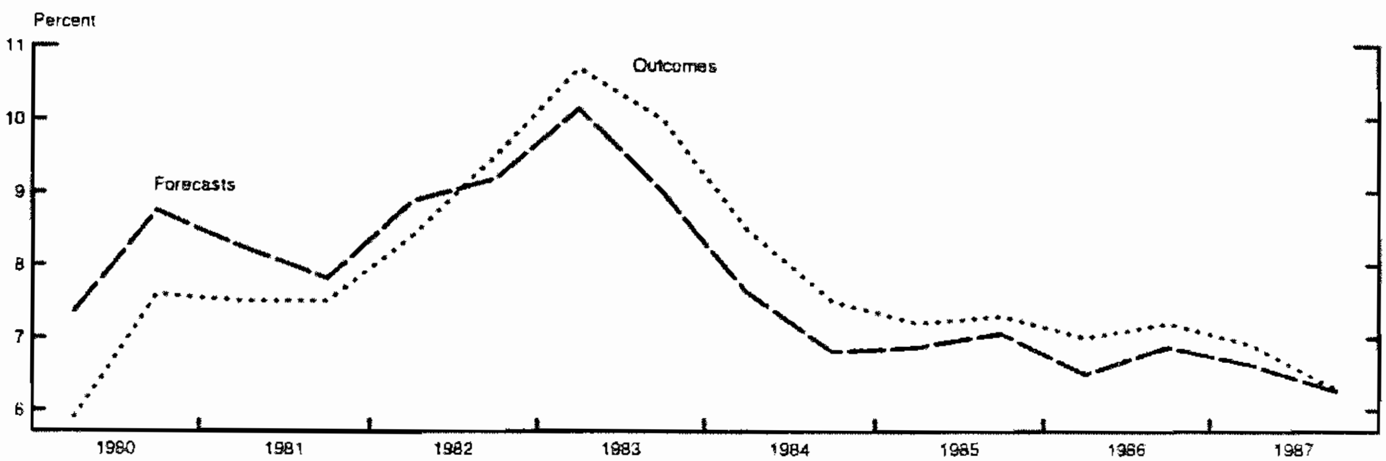
Figure 5

Volcker Era: Fit Based on Unemployment and Inflation

Actual and Fitted Federal Funds Rate



Unemployment Rate



Inflation Rate

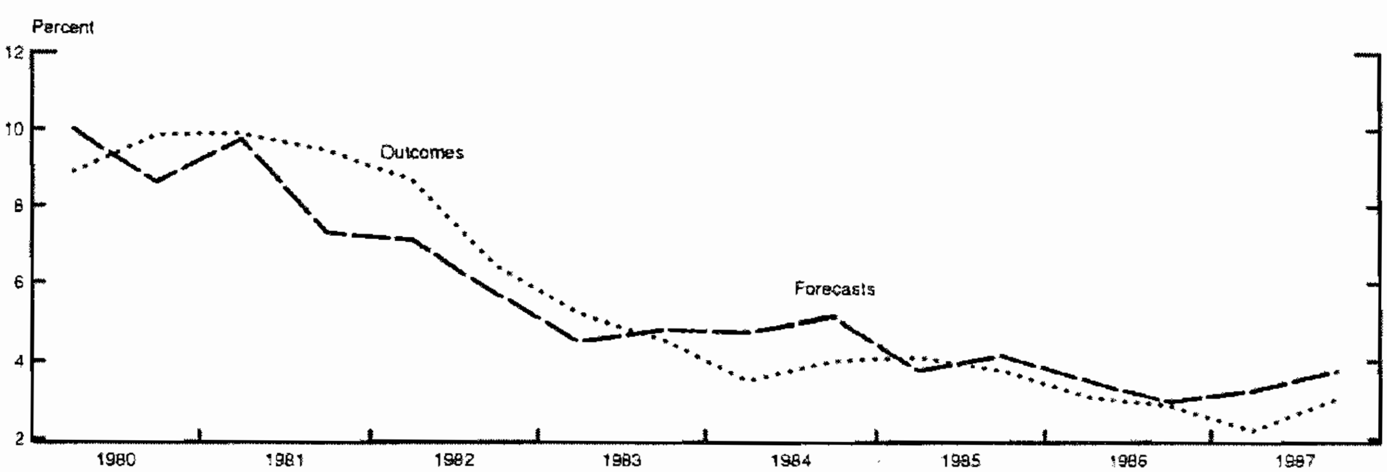


Figure 6

Greenspan Era: Fit Based on Real Growth and Inflation

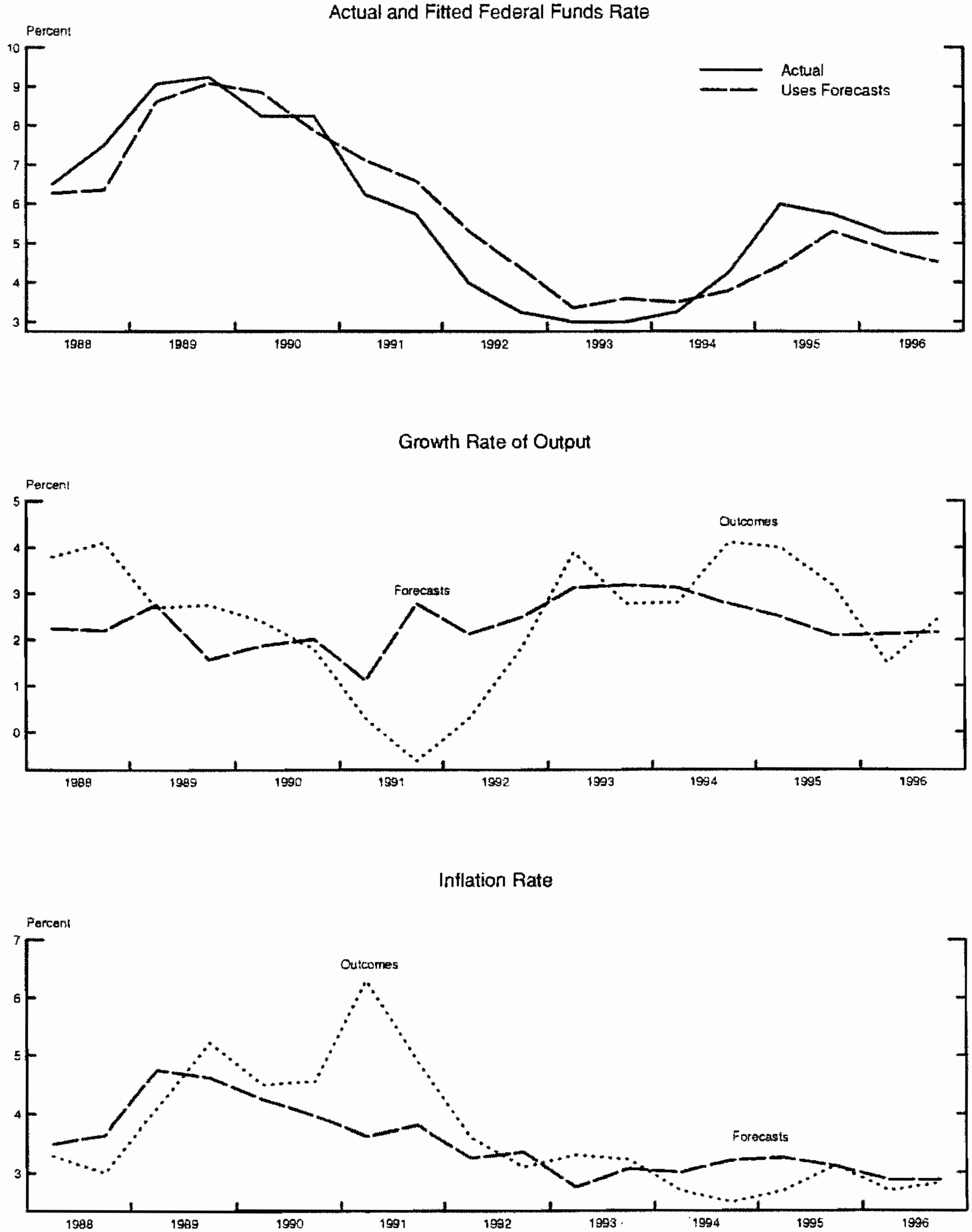


Figure 7

Greenspan Era: Fit Based on Unemployment and Inflation

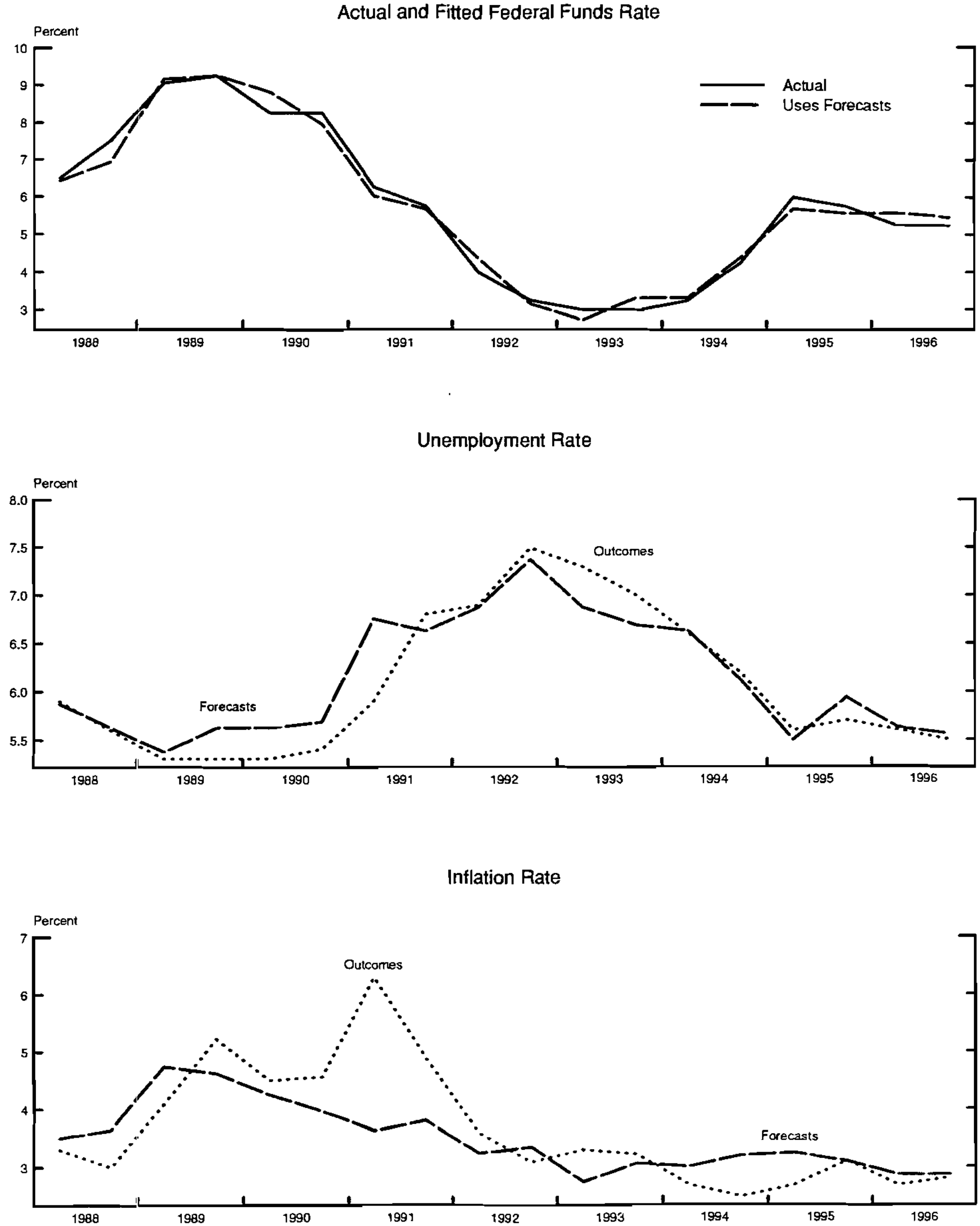
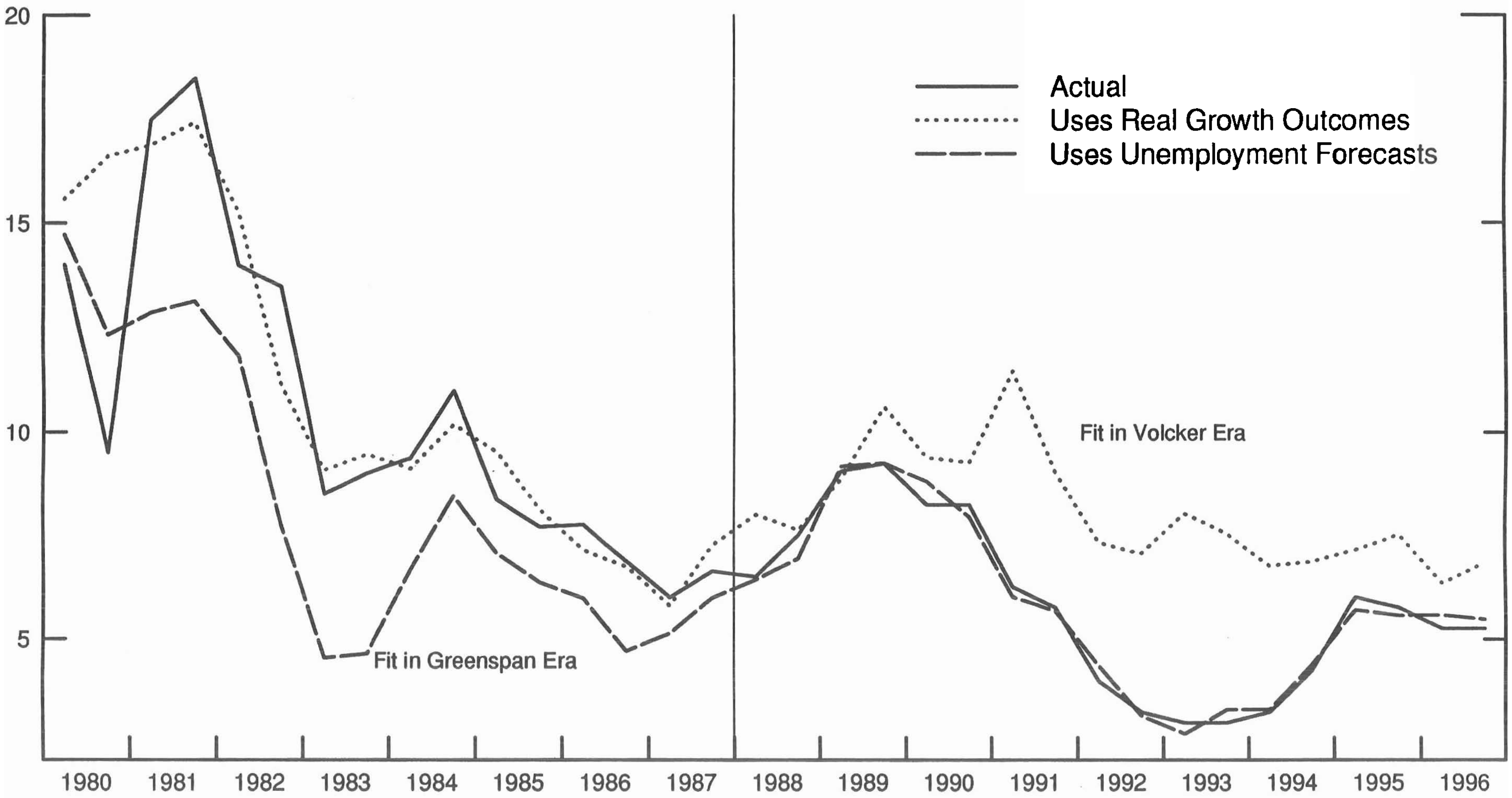


Figure 8

Volcker and Greenspan Eras: Actual and Fitted Federal Funds Rate

Outcomes versus Forecasts



Notes: For the purpose of comparability, we removed the effect of the credit-control dummy in the Volcker era regression for the July 1980 observation.