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Yash P. Mehra
Federal Reserve Bank of Richmond

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Abstract

Using real time estimates of output gaps or Greenbook forecasts of the unemployment rate, this article estimates Taylor-type policy rules that predict the actual behavior of the funds rate during two sample periods, 1968Q1 to 1979Q2 and 1979Q3 to 1994Q4. The inflation rate response coefficient is close to unity over the first sub-period and well above unity over the second, suggesting Fed policy violated the Taylor principle during the first period. The adjustment of the funds rate in response to fundamentals is not as rapid during the first period as it is during the second. Together these results support the conventional view that the Fed was "too timid" and "too sluggish" during the late 1960s and the 1970s. Though the Fed smoothes interest rates, the degree of smoothing exhibited is far less than what was previously estimated. The funds rate response to its fundamentals is complete within one year during the first period and within one quarter during the second.

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** Federal Reserve Bank of Richmond, Yash.Mehra@rich.frb.org

1. Introduction

During the late 1960s and 1970s inflation steadily increased, whereas during the early 1980s inflation declined. This contrast in the inflation performance of the U.S. economy has sparked interest in identifying the nature of monetary policy pursued by the Federal Reserve. One widely held view is that monetary policy has been broadly consistent with Taylor-type policy rules in which the funds rate target responds to actual or expected inflation and the level of the output gap. A key coefficient in these estimated policy rules is the inflation response coefficient, which measures the long-term response of the funds rate to the inflation rate. Taylor (1999a) and Clarida, Gali and Gertler (2000) provide evidence that indicates the inflation response coefficient was below unity during the late 1960s and 1970s, whereas it was well above unity during the early 1980s. This empirical result implies that the Fed did not respond aggressively to inflation during the first period, whereas it did during the second period. This explanation of the poor inflation performance of the U.S. economy in the 1970s relative to the 1980s has received further support from recent research on monetary policy rules. That research indicates that, in order to avoid undesirable economic outcomes, feedback policy rules must satisfy the Taylor principle, which requires the nominal interest rate eventually increase by more than one percentage point in response to one percentage point increase in the inflation rate (Taylor 1999b). This requirement is easily met if the inflation response coefficient in the feedback policy rules is set above unity.[1], [2]

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[1] The exact statement of this requirement in the context of an optimal feedback rule depends upon the nature of the macro model that underlies the policy rule. For example, in the context of the "neo-Wicksellian" model derived in Woodford (2000), the feedback rule must satisfy the following condition $a_p + a_y(1-b)/k > 1$, where a_p is the inflation response coefficient; a_y is the output response coefficient; and b and k are the slope parameters of the expectational Philips curve (Woodford 2001). This requirement is easily met if the inflation response coefficient is above unity.

[2] Some other consequences of the violation of the Taylor principle are a matter of debate among economists. While Woodford (2000) has focused on the absence of determinacy when the Taylor principle is not met, McCallum (2000) has instead emphasized the absence of expectational stability in models with learning in the same case.

The evidence discussed above in Taylor (1999a) and Clarida et al. (2000) that actual Fed policy may have violated the Taylor principle during the late 1960s and 1970s is based on policy rules that are estimated using revised data. As documented recently in Orphanides (1999) and Orphanides and Norden (1999), estimates of inflation and, in particular, of output gap levels have been substantially revised over time. Hence, policy prescriptions based on real-time estimates of the variables used in policy rules may differ substantially from those derived using later estimates, making inferences about the nature of actual policy suspect. In that context, taking the baseline Taylor rule originally proposed in Taylor (1993) and using real-time estimates of output gaps prepared by the Council of Economic Advisors, Orphanides (2000) shows that the funds rate settings that would have been suggested by the baseline Taylor rule during the 1970s do not greatly differ from actual policy during that period.[3] More recently, Orphanides (2002) has estimated a forward-looking version of the Taylor rule, using forecasts of the inflation rate and unemployment rate available to FOMC in real time and assuming partial adjustment. Since the inflation response coefficient both in the baseline Taylor rule and in its estimated forward-looking version in Orphanides (2002) is above unity, this finding raises serious doubts about the stabilization properties of the policy rules that satisfy the Taylor principle.

Orphanides (2000) uses estimates of output gaps prepared by the Council of Economic Advisors (CEA) and asserts them as the "official" series used by the Fed. This assertion has been questioned. Taylor (2000) points out that the Council's estimates of potential GDP and its growth rate had become politicized as early as the late 1960s and hence were ignored by serious economists such as Arthur Burns and Alan Greenspan. Taylor also argues that real-time output gaps derived from the Council's estimates (e.g., minus 15 percent in 1975) are too pessimistic, being comparable to the Great Depression (p.# 4, op. cited). In this article, I consider an alternative real-time estimate of the output gap, generated using a simple linear trend fitted to actual historical data on output. The hypothesis that potential output during the 1960s and the early 1970s may reasonably be

[3] The baseline Taylor rule makes the assumptions that the inflation response coefficient is 1.5, the output response coefficient is .5, the real rate of interest is 2 percent, and the Fed's inflation target is 2 percent.

approximated by a linear trend is quite consistent with the mainstream contemporary thinking that macroeconomic time series possessed deterministic time trends. The alternative real-time output gaps are pessimistic, but not as much as those in Orphanides (2000).

The baseline Taylor rule originally proposed in Taylor (1993) assumes that the Fed adjusts the funds rate in response to changes in fundamentals without any delay. In other words, the policy rule does not assume partial adjustment, implying the absence of interest rate smoothing. This feature of the baseline Taylor rule is in sharp contrast to the evidence in previous empirical work that indicates the presence of considerable interest rate smoothing in Fed behavior i.e., Clarida et. al. (2000) where the forward-looking Taylor rule is estimated using revised data and Orphanides (2002) where the forward-looking Taylor rule is estimated using real-time data. This empirical evidence has recently been challenged. Rudebusch (2001) points out that the presence of monetary policy inertia would imply a large amount of forecastable variation in interests rates at horizons of more than three months, which is contradicted by evidence from the term structure of interest rates. He argues that the monetary policy inertia exhibited in estimated policy rules may be illusionary, reflecting instead the use of revised data in estimation and/or the presence of serially correlated shocks that central banks face but are ignored in estimated policy rules. Some evidence consistent with his view appears in Lansing (2000,2002) where it is shown the presence of real-time output gap errors can spuriously generate significant coefficients on the lagged dependent variable in the estimated policy rules.[4]

In this article, I reexamine the nature of actual Fed policy during the 1970s and 1980s. In particular, I estimate Taylor-type policy rules using alternative, real-time estimates of output gaps and then investigate how well estimated rules predict the actual path of the funds rate and whether or not they satisfy the Taylor principle. To check robustness of results based on output gaps I also consider results derived using Greenbook forecasts of the unemployment rate and inflation rate available in real time to policymakers. The empirical work here focuses on explaining the actual behavior of the funds rate during two sample periods, 1968Q1 to 1979Q2 and 1979Q3 to 1994Q4. The first period is close to the one studied in Orphanides (2000, 2002) and the second period is close to the one studied in Clarida et. al. (2000).[5] As noted in Rudebusch (2001), it is easier to identify empirically the degree of monetary policy inertia if the estimated policy rules control for the influences of serially correlated shocks to policy. The recent evidence in Mehra (2001) indicates actual policy since the 1980s is well predicted by a modified Taylor rule that includes the response of policy to inflation scares, discussed in Goodfriend (1993). Hence for the second period I consider results with and without capturing the response of policy to inflation scares and examine its implication for the presence of partial adjustment in estimated policy rules.

The empirical work that is presented here suggests the following observations. First, Taylor-type policy rules based on alternative real-time output gaps are consistent with actual policy during these two periods. In the first period, the actual funds rate settings are predicted well by an estimated Taylor rule in which the funds rate responds to the lagged inflation rate and the output gap. In the second period, the actual funds rate settings are predicted well by a *modified* Taylor rule in which the funds rate responds to the bond rate, in addition to responding to the lagged inflation rate and the output gap. The results suggest policy was “preemptive” during the second period as the Fed responded to the bond rate in an attempt to establish credibility.[6] The results continue to hold if policy rules are estimated, using instead Greenbook forecasts of the inflation rate and unemployment rate.

Second, the inflation and output response coefficients in these estimated policy rules have correct signs and are generally significant. If we focus on the backward-looking Taylor rule in which policy responds to the lagged inflation rate and the output gap, then the inflation response coefficient is well above unity during the second period,

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[4] In the context of money demand regressions, Goodfriend (1985) much earlier showed that measurement error in the variables determining money demand could result in spuriously significant partial adjustment lags.

[5] I truncate the sample in 1994 to exclude the possible influences of the new economy shifts in trend productivity and the international financial crises on monetary policy in the last half the 1990s.

[6] This result is in line with one in Mehra (2001).

but not during the first. This result continues to hold if Taylor rules are estimated using instead Greenbook forecasts of the inflation rate and unemployment rate.

Third, the extent of partial adjustment estimated here is far less than what was reported in previous empirical work. In the first period, the estimated Taylor rule indicates that the Fed adjusted the funds rate to its desired level within one year. Tests designed to distinguish partial adjustment from serial correlation do not rule out the hypothesis that the partial adjustment found in the estimated Taylor rule is due to serial correlation. In the second period, the estimated modified Taylor rule indicates that the Fed adjusted the funds rate to its desired level within one quarter. The partial adjustment is found only if the Taylor rule is estimated omitting the response of policy to inflation scares. Together the results above indicate that the Fed was "too timid" and "too sluggish" during the first period.

The plan of this article is as follows. Section 2 describes the policy rules and real-time data used in estimation and section 3 presents the empirical results. Concluding observations are given in section 4.

2. The Model and the Method

2.1. Conventional and Modified Taylor Rules

The conventional backward- and forward looking Taylor rule studied here can be derived using the following equations.

$$FR_t^* = a_0 + a_p\,(E_{t-1}\,INFL_{t+k} - INFL^*) + a_y\,E_{t-1}(y_{t+k} - y_{t+k}^*); \tag{1}$$

$$FR_t = r\,FR_{t-1} + (1-r)FR_t^* + v_t; \quad 0 \le r \le 1; \tag{2}$$

where *FR* is the actual funds rate; *FR** is the Fed's funds rate target for period t; $E_{t-1}INFL_{t+k}$ is the expected inflation rate for period *t+k* conditional on the information available in period t-1; *INFL** is the Fed's inflation target; $E_{t-1}(y_{t+k} - y_{t+k}^*)$ is the expected level of the output gap for period *t+k*; and *v* is the disturbance term. The policy rule in (1) specifies the economic determinants of the funds rate target. The policy rule is forward looking if $k \geq 0$ and backward looking if $k < 0$. It is assumed that the Fed has a target for inflation and a target for the level of output. The Fed raises its funds rate target if past or expected future inflation and output are high relative to their respective target levels. Equation (2) specifies the actual funds rate as a weighted average of the last-period funds rate and the current-period funds rate target, indicating the Fed smoothes interest rate changes in the short run (Goodfriend [1991]). The magnitude of the partial adjustment parameter r measures the degree of interest rate smoothing in Fed behavior.

If we substitute (1) into (2), we get (3), which is the conventional Taylor rule.

$$\begin{aligned} FR_t &= a_{00} + r\,FR_{t-1} + (1-r)a_p\, E_{t-1}INFL_{t+k} + (1-r)a_y\, E_{t-1}(y_{t+k} - y^*_{t+k}) + v_t \\ where \quad a_{00} &= (a_0 - a_p\, INFL^*)(1-r) \end{aligned} \tag{3}$$

The funds rate in policy rule (3) responds to the inflation rate, the output gap and the lagged actual funds rate.

Taylor (1999a, p. 339) points out that monetary policy during the early 1980s may have been tighter than what is indicated by the baseline Taylor rule (Taylor [1993]). Such a tighter policy response may have been necessary to keep expectations of inflation from rising and to help establish the credibility of the Fed, as noted in Goodfriend (1993). Mehra (2001) presents evidence that indicates the Fed responded to inflation scares as reflected in the bond rate, and that the Taylor rule modified to include such responses help predict actual policy well during this period. In view of such evidence, the Taylor rule for this period is estimated including the bond rate as in (4).

$$FR^*_t = a_0 + a_p\,(E_{t-1}\,INFL_{t+k} - INFL^*) + a_y\, E_{t-1}(y_{t+k} - y^*_{t+k}) + a_b\,(BR_t - E_{t-1}INF_{t+k}) \tag{4}$$

where BR is the bond rate. If we substitute (4) into (2), we get the modified Taylor rule (5).

$$\begin{aligned} FR_t &= a_{00} + r\,FR_{t-1} + (1-r)a_p\, E_{t-1}INFL_{t+k} + (1-r)a_y\, E_{t-1}(y_{t+k} - y^*_{t+k}) \\ &\quad + (1-r)a_b\,(BR_t - E_{t-1}INF_{t+k}) + v_t \\ where \quad a_{00} &= (a_0 - a_p\, INFL^*)(1-r) \end{aligned} \tag{5}$$

The funds rate in policy rule (5) responds to the bond rate, in addition to responding to past or expected future inflation rate, the output gap, and the lagged funds rate.

2.2. Partial Adjustment, Serial Correlation, and Interest Rate Smoothing

The policy rules in (3) and (5) assume partial adjustment and therefore include the lagged value of the actual funds rate. The presence of the lagged dependent variable in these policy rules is often interpreted as reflecting the presence of interest rate smoothing in Fed behavior, because the Fed's adjustment of the policy rate to its desired level suggested by economic fundamentals is spread over time. However, as is well known, the lagged dependent variable in the policy rule can also arise as a result of the presence of a serially correlated error term (Griliches [1967]). Consider, for example, the following specification that assumes no partial adjustment as in (6.1).

$$FR_t = FR_t^* + v_t; \quad 0 \le s \le 1; \qquad (6.1)$$

$$v_t = s\, v_{t-1} + m_t \qquad (6.2)$$

where v_t is a serially correlated error term and m_t is a white noise disturbance term. The equation (6.1) says the Fed adjusts the actual funds rate to its target (FR_t^*) implied by economic fundamentals within each time period. If we substitute (6.2) into (6.1), we can then express the policy rule as in (7).

Serially Correlated Model

$$FR_t = FR_t^* - sFR_{t-1}^* + sFR_{t-1} + m_t; \; 0 \le s \le 1; \qquad (7)$$

As can be seen, the lagged dependent variable also appears in the serially correlated model (7.1), indicating the adjustment of the actual funds rate to its target implied by economic fundamentals is spread over time, just as in the partial-adjustment model (2). Hence the presence of the lagged dependent variable in an estimated policy rule does not necessarily imply the Fed is smoothing interest rates.

In most previous research Taylor rules have been estimated assuming partial adjustment. However, it is possible that both partial adjustment and serial correlation may be present in the estimated policy rule. The serial correlation may just be capturing the responses of policy to economic factors that are not included in the estimated policy rule. Hence I estimate the policy rules in (3) and (5) allowing for the potential presence of serial correlation. Furthermore, in order to test whether the lagged dependent variable in the estimated policy rule is due to partial adjustment or serial correlation, I estimate the policy rules assuming both partial adjustment and (first-order) serial correlation as in (8).

$$FR_t = r\, FR_{t-1} + (1-r)FR_t^* + v_t; \quad 0 \le r \le 1; \tag{8.1}$$
$$v_t = s\, v_{t-1} + m_t; \qquad 0 \le s \le 1 \tag{8.2}$$

where the parameter *s* is the first-order serial correlation coefficient and where other variables are defined as before. If we substitute (8.2) into (8.1), we can express the policy rule as in (9).

$$FR_t = (r + s)FR_{t-1} + (1-r)(FR_t^* - sFR_{t-1}^*) - s\, r\, FR_{t-2} + m_t \tag{9}$$

where all variables are defined as before. The policy rule in (9) nests partial adjustment and serial correlation.[7] The policy rule is inertial if $s = 0, r \neq 0$ in (9). The policy rule is non-inertial but has serially correlated shocks if $s \neq 0, r = 0$. Alternatively, the policy rule is inertial as well have serial correlation if $r, s \neq 0$. I provide some evidence on the extent of partial adjustment by estimating (9), using the determinants of the funds rate target FR_t^* alternatively defined in (1) and (4).

2.3. Data, Definition of Economic Variables, and Estimation Procedure

The empirical work here estimates the policy rules in (3) and (5) using quarterly data over two sample periods, 1968Q1 to 1979Q2 and 1979Q3 to 1994Q4. All interest rate data used is the average value in the first month of the quarter. The funds rate is the effective federal funds rate and the bond rate is the nominal yield on ten-year U.S. Treasury bonds. The real-time estimates of the inflation rate and output gaps during the sample periods studied are generated using the real-time data compiled by Croushore and Stark (1999). The real-time quarterly value of the inflation rate for any given quarter (1968Q1, for example) is the end-of-sample value of the annualized, quarterly percentage change series constructed using the available real-time price series that starts in 1953Q1 and ends in that quarter. The estimates of potential output for each quarter over 1968Q1 to 1979Q2 are generated fitting each time a linear time trend using historical data on output available each quarter. Thus the real-time value of the output gap in 1968Q1 is the end-of-sample value of the residual from the linear time- trend regression, fitted using the available historical data on real output that begins in 1953Q1 and ends in 1968Q1. A similar procedure is used to generate estimates of the output gap over 1979Q3 to 1994Q4,

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[7] This exercise is qualitatively similar to one in Rudebusch (2001).

except that a quadratic time trend is employed and the historical output series used starts in 1959Q1.

For the first period, the procedure of estimating trend output using a linear time trend is reasonable, because for most of this time period it was thought that economic time series, including potential output, follow deterministic time trends. Since the economy grew quite strongly during the 1950s and the 1960s, the linear trend procedure generates growth estimates of trend output that are optimistic.

The productivity slowdown and the oil price shocks of the 1970s made it clear that potential output could be influenced by supply shocks and hence could not be approximated by simple time trends. Initially, this led to the development of alternative methods over the 1970s, such as the segmented linear trend and the production function approach. It was during the late 1970s that the new thinking on the econometrics of time series with unit roots began to undermine the popularity of segmented time trends to measure the potential, subsequently giving rise to the use of stochastic methods.[8] Hence, for the period 1979Q3 to 1994Q4 I use a quadratic time trend to estimate the level of output gap, as in Clarida et al. (2000).[9]

Figures 1 and 2 provide a cursory look at real-time estimates of the inflation rate and output gaps. In order to get a sense of the size and nature of revisions in measures of inflation and output over the periods studied, I also chart those measures based on the data currently available in 2000. Figure 1 charts the data for the period 1968Q1 to 1979Q2 and Figure 2 for 1979Q3 to 1994Q4. If we focus on the inflation rate for the first period, real-time estimates of the inflation rate do not differ much from those generated using the revised data (see Figure 1A). In contrast, estimates of the output gap based on the revised data differ substantially from those derived using real-time data. As can be seen in Figure 1B, real-time estimates of output gaps are pessimistic in the 1970s, but not quite so much as argued in Orphanides (2000). The gap between the revised and real-time estimate of the output gap was about 1 percentage point at the start of the sample in

[8] This view of the historical evolution of potential output is in Laxton and Tetlow (1992).
[9] For this period I examine the sensitivity of results to the choice of an alternative de-trending procedure used to estimate the potential output. In particular, real-time estimates of output gaps were also generated using alternatively a linear trend and a Hodrick-Prescott filter.

1968Q1, but then it increased considerably during the early 1970s -- exceeding almost 9 percentage points during the first quarter of 1975 (see Figure 1B). In contrast, the output gap series in Orphanides (2000) shows a gap of 15 percent in the mid-1970s.[10]

Figure 2 charts the data for the period 1979Q3 to 1994Q4. As can be seen, the revised estimates of inflation do not differ consistently from those based on real-time data. However, estimates of the output gap based on real-time data still differ consistently from those based on the revised data. In contrast to the first period, real-time estimates of the output gap appear mostly optimistic following the 1980 recession, indicating the presence of less slack than indicated by revised estimates. The gap between the revised and real-time estimates of the output gap has not varied as much, however, in the 1980s and early 1990s as it did in the 1970s.

The policy rules in (3) and (5) include the lagged value of the funds rate. Ordinary least squares are inconsistent if the disturbance term in these policy rules is serially correlated. The presence of serial correlation implies the disturbance term (v_t in (3) or (5)) is correlated with the lagged funds rate (FR_{t-1}) included in these policy rules (Johnston 1972). Furthermore, the policy rule in (5) includes the current-period bond rate, which may also be correlated with the disturbance term. The preliminary work indicated that in the first period the residuals from the estimated Taylor rule are serially correlated, whereas no such serial correlation is found in the second period.[11] I therefore estimate the policy rules using the instrument variables procedure. The instrument set used for the policy rule in (3) consists of a constant, past values of the inflation rate and the output gap and the period t-2 lagged values of the funds rate. For the modified Taylor rule, the

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[10] It may be pointed out that estimates of output gaps generated here are reasonable in that they imply estimates of the natural rate that are in the mainstream contemporary thinking. For example, for the first half of the 1970s and using the Okun’s Law coefficient of 3, the natural unemployment rate implied by the output gap is 5.1 percent. For the full sample period 1968Q1 to 1979Q2, the implied natural rate is 4.9 percent.

[11] The autocorrelation function fitted to residuals from the conventional Taylor rule (3) estimated over the first period 1968Q1 to 1979Q2 is consistent with the presence of first-order serial correlation. In contrast, the autocorrelation function fitted to residuals from the modified Taylor rule (5) estimated over 1979Q3 to 1994Q4 indicates the residuals are not serially correlated (see Table 1 for the first four autocorrelations).

instrument set is expanded to include past values of the spread between the bond rate and the funds rate.

3. Empirical Results

3.1 Estimates of Policy Rules

Table 1 presents instrument variables estimates of the conventional and modified Taylor rules specified in (3) and (5) and with k set to minus unity. Panel A presents the estimates for the period 1968Q1 to 1979Q2 and Panel B for the period 1979Q3 to 1994Q4. I estimate the rules smoothing the inflation rate with and without assuming partial adjustment.[12] If we focus on estimates of the conventional Taylor rule for the earlier period, we see that inflation and output gap variables appear with expected signs and are statistically significant (see t-values in parentheses below estimates in Panel A, Table 1). Those estimates indicate that the funds rate rises if the inflation rate rises, or if actual output is above the potential. The inflation response coefficient is 1.1 to 1.2 and the output response coefficient is .54 to .65. The statistic ST that tests the hypothesis the inflation response coefficient is unity is small, implying the policy rule during this period may have violated the Taylor principle. The estimated partial adjustment coefficient r is .44, indicating 56 percent of a desired change in the policy rate is reflected in the funds rate within the quarter of the change. This result means that during this period most of the Fed's adjustment of the funds rate to its desired level is complete within a year.

Panel B in Table 1 presents estimates of the Taylor rule for the period 1979Q3 to 1994Q4. I present results with and without the bond rate and with and without assuming partial adjustment. As can be seen, inflation and the bond rate variables have expected signs and are significant. The inflation response coefficient is 1.7 to 1.9. The statistic ST that tests the hypothesis the inflation response coefficient is unity is large, suggesting the inflation response coefficient is above unity. The output gap response coefficient is positive and generally significant. Finally, as can be seen in Panel B of Table 1, the lagged dependent variable appears with a positive and statistically significant coefficient

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[12] Following Taylor (1999a), the smoothed inflation rate is the average value of the inflation rate over the past four quarters. The quarterly data on the output gap variable is not smoothed.

only if the Taylor rule is estimated without the bond rate. Hence the lagged dependent variable seems to be picking up the response of policy to inflation scares that is omitted from the estimated conventional Taylor rule. The estimated modified Taylor rule implies that during this period 100 percent of a desired change in the policy rate is reflected in the funds rate within the quarter of the change.

3.2. Assessing the Predictive Accuracy of Policy Rules

I now assess how well these estimated Taylor-type policy rules predict the actual behavior of the funds rate during the two sample periods considered here. Figures 3 and 4 provide a casual look at the performance of these rules in predicting actual funds rate settings. Figure 3 charts the funds rate predicted by the conventional Taylor rule in the late 1960s and the 1970s. I use the Taylor rule with r set to zero. Figure 4 does so using the modified Taylor rule in the 1980s and early 1990s. Actual values of the funds rate are also charted. These figures clearly indicate that the policy rules estimated here track the actual settings of the funds rate over these two periods very well.

In order to further assess whether actual funds rate settings systematically differ from those prescribed by these estimated policy rules, I perform the test of unbiasedness with the following regression (10).

$$FR_t = f_0 + f_1 PFR_t + e_t; \qquad (10)$$

where FR is the actual funds rate and *PFR* is the value predicted by the estimated policy rule. The predicted values used are the dynamic within-sample values, generated using actual values of the inflation rate and the output gap. The predicted funds rate is an unbiased predictor of the actual funds rate if $f_0 = 0$ and $f_1 = 1$ in (10).

Table 2 reports estimates of regression (10). Panel A presents the results for the period 1968Q1 to 1979Q2 and Panel B does so for the period 1981Q1 to 1994Q4. I present results using the policy rules estimated with and without partial adjustment. If we focus on the results for the first sample period, they indicate that the conventional Taylor rule estimated with partial adjustment provides unbiased forecasts of the actual funds rate. This result continues to hold even when the Taylor rule is estimated without partial adjustment, suggesting actual policy settings may have been generated by a Taylor rule with no partial adjustment. This result also implies that in the first period it is difficult to distinguish between partial adjustment and serial correlation. In contrast, if we focus on results for the second period 1979Q3 to 1994Q4, only the modified Taylor rule provides unbiased forecasts of actual funds rate settings. Together these results indicate that during the late 1960s and the 1970s the Fed was “too timid” as well as probably “too sluggish” in adjusting the funds rate in response to changes in economic fundamentals including the inflation rate.

3.3. Additional Results

In this section I present and discuss some additional work that suggests the main conclusions reached here are robust to changes in the specification of the policy rule. The policy rules discussed above are estimated without directly allowing for the presence of serial correlation. I now consider the policy rules that allow both partial adjustment and (first-order) serial correlation as in (9). Table 3 presents estimates of the conventional and modified Taylor rules for the two sample periods. As can be seen, the inflation response coefficient is way above unity only in the second period. In the first sample period, the coefficients that measure partial adjustment and serial correlation are both positive and jointly significant, though individually neither coefficient is significant at the conventional significance level (see F and t-values in Panel A, Table 3). This result indicates that in this sample period the hypothesis that the policy rule is non-inertial can not be distinguished from the hypothesis that the policy rule is inertial.[13] In contrast, the coefficients that measure partial adjustment and serial correlation are both zero in the modified Taylor rule estimated over the second period. The partial adjustment coefficient is different from zero only if the policy rule is estimated without capturing the response of policy to the bond rate (see estimates in Panel B, Table 3). This result indicates the partial adjustment found in the estimated conventional Taylor rules may be capturing the influences of variables on policy that are omitted from the policy rule.

[13] This result is consistent with unbiasedness test results reported in Table 2, which is the Taylor rule without partial adjustment provides unbiased forecasts of actual policy rate settings as do the Taylor rule with partial adjustment

In order to explore further the role of revised data in generating high estimates of partial adjustment reported in previous research, Table 4 presents the conventional and modified Taylor rules estimated using revised data. Rows 1.2 and 2.2 of Table 4 present instrumental variables estimates of the conventional Taylor rule with partial adjustment and revised data. In both sample periods, the use of revised data in the estimated conventional Taylor rule yields an estimate of quarterly partial adjustment that is slower than what we get with real-time data (compare estimates of $(1-r)$ in rows 1.1 with 1.2 and 2.1 with 2.2, Table 4). However, the use of revised data has no effect on estimates of the partial adjustment coefficient if the modified Taylor rule is estimated as in the second period. Together these results suggest that omitted variables and hence the consequent presence of serial correlation in estimated conventional Taylor rules may have played a greater role in generating high estimates of partial adjustment found in previous research (Taylor 1999a, Clarida et al. 2000).

One key result here is that the inflation response coefficient is close to unity in the first period. This result is based on the Taylor rule that is backward-looking in the sense that policy responds to the lagged inflation rate and output gap. It has been suggested that policy may have been forward-looking during the first period. In fact, Clarida et al. (2000) report estimates of the forward-looking version of the Taylor rule using revised data, whereas Orphanides (2002) report estimates using forecasts of the inflation rate and unemployment rate available to FOMC in real time. The inflation response coefficient reported in Clarida et al. (2000) is generally below unity, but that reported in Orphanides (2002), however, is above unity. In order to test whether the results here are sensitive to the chosen specification, I now consider results from the forward-looking versions of the Taylor rule estimated using instead the unemployment rate gap as in (11).

$$FR_t^* = a + a_p\,(E_{t-1}INF_{t+1} - INF^*) - a_u\,(E_{t-1}UR_{t+1} - NUR_{t+1}) \qquad (11)$$

where *UR* is the unemployment rate and *NUR* is the natural unemployment rate. In order to estimate (11) I use Greenbook forecasts of the inflation rate and unemployment rate available to policy makers in real time. However, one also needs estimates of the natural unemployment rate available to policymakers in real time. Orphanides (2002) estimates a Taylor rule like (11) assuming the policymakers' views about the level of the natural unemployment rate have remained constant in the first period. I however consider the possibility that policymakers' views about the natural rate might have changed in real time. Following the suggestion in Friedman (1968) that the unemployment rate fluctuates around the natural rate irrespective of monetary regime, Hall (1999) has suggested that the average value of the unemployment rate over the sample period is a good estimate of the natural rate. Hence I construct real-time estimates of the natural rate for each quarter in 1968Q1 to 1979Q2 by taking the one-sided simple average of the historical time series on the unemployment rate.[14] Figure 5 charts the natural rate series. Greenbook forecasts and actual values of inflation and the unemployment rate are also charted there.

Table 5 reports estimates of forward-looking Taylor rules. For the first period I report results with and without partial adjustment and with and without assuming constant natural rate. Ordinary least squares are used to estimate the Taylor rule without partial adjustment. If we focus on the Taylor rule without partial adjustment, then the estimated inflation response coefficient is close to unity and this result is not sensitive to whether the natural rate is assumed to be constant or time-varying over the sample period (see estimates in Panel A, Table 5). In contrast, when we focus on the Taylor rule with partial adjustment, then the inflation response coefficient is significantly above unity if the Taylor rule is estimated using least squares and assuming constant natural rate. This regression is similar in spirit to the one reported in previous research (Orphanides 2002). But the result that the inflation response coefficient is significantly above unity is subject to the omitted variable biases arising as a result of the failure to account for the presence of serially correlated shocks[15] and incorrectly assuming constant natural rate. If we use instrumental variables to estimate the Taylor rule[16] and allow varying natural rate, then the estimated inflation response coefficient is 1.2, not significantly different from unity

[14] The historical series used begins in 1953Q1.

[15] As indicated before, least-square estimates are inconsistent in the presence of serial correlation if the regression contains the lagged dependent variable. The first three autocorrelation coefficients estimated using the residuals from the Taylor rule (with no partial adjustment) are large (see $s_i, i = 1, 2, 3$ in Table 5).

[16] Since the disturbance term is correlated with the lagged dependent variable due to the presence of serial correlation, the instrumental variables procedure corrects for the presence of this correlation. The instrument set used consists of a constant, three lagged values of Greenbook forecasts of the inflation rate, unemployment rate, and period t-2 lagged values of the actual funds rate.

(see estimates and the ST statistic in the pertinent regression, Panel A, Table 5). Alternatively, if we estimate the Taylor rule assuming both partial adjustment and first-order serial correlation as in (9) and use non-linear least squares, then the estimated inflation response coefficient is again 1.2 with a t-value of 5.0. The F statistic that tests the null hypothesis the inflation response coefficient is unity is small (.89), implying the inflation response coefficient is not different from unity. Together these results suggest that greater than unitary inflation response coefficient found in the forward-looking Taylor rule reported here and in previous research arises, in part, because the estimation procedure chosen does not properly account for the presence of serially correlated shocks.

Panel B in Table 5 reports estimates of forward-looking Taylor rules for the second period. As before, once the Taylor rule is modified to capture the response of policy to the bond rate, the estimated inflation response coefficient is way above unity and the partial adjustment coefficient is small and not different from zero (see estimates in Panel B, Table 5). The modified Taylor rule provides unbiased forecasts of actual funds rate settings during the second period, with and without partial adjustment.

Figures 6 and 7 chart the values predicted by the forward-looking Taylor rules estimated without partial adjustment for both the sample periods. Actual values of the funds rate are also charted there. The figures clearly suggest that the estimated policy rules track actual policy fairly well. Together the results based on Greenbook forecasts support the conclusion reached before that the Fed during the first period was “too timid” and “too sluggish.”

3. Concluding Observations

This paper presents and estimates Taylor-type policy rules for the two sample periods 1968Q1 to 1979Q2 and 1979Q3 to 1994Q4, using real-time data on inflation and output gaps or Greenbook forecasts of the inflation rate and unemployment rate available to policymakers in real time. The results indicate that these policy rules track actual funds rate settings fairly well during these two sample periods.

Recent research on monetary policy rules indicate that in order to avoid undesirable inflation outcomes, feedback monetary policy rules like those estimated here should satisfy the Taylor principle, which requires the nominal interest rate eventually increase by more than one percentage point, in response to one percentage point increase in the inflation rate. This requirement is easily met if the inflation response coefficient in the feedback policy rule is well above unity. The policy rules estimated using real-time data indicate that Fed policy during the late 1960s and the 1970s may have violated the Taylor principle in that the estimated inflation response coefficient is not different from unity. This result is in line with the previous evidence in Taylor (1999a) and Clarida et al. (2000) that used revised data, but not in line with one in Orphanides (2002) based on real-time data. The use of somewhat different real-time estimates of output gaps and/or the more careful choice of estimation procedures in the joint presence of serial correlation and partial adjustment may accounts for different results.

The empirical work here is consistent with the presence of partial adjustment inertia, suggesting that the Fed has smoothed the adjustment of the policy rate to economic fundamentals. However, the extent of interest rate smoothing exhibited by the policy rules estimated here is less than what is indicated by policy rules in previous empirical work. The partial adjustment coefficients estimated here indicate most of the adjustment was complete within one year during the late 1960s and the 1970s and within one quarter during the 1980s and early 1990s. The use of real-time as opposed to revised data partly accounts for these different results. Another contributory factor may have been the inadequate attention paid to the empirical problem of distinguishing quarterly partial-adjustment from serial correlation in the estimated policy rules, emphasized recently in Rudebusch (2001). The much faster speed of adjustment estimated here supports the view that in reality the Fed may not be as sluggish as is widely believed.

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Table 1

Instrumental Variables Estimates of Policy Rules

Panel A: Sample Period: 1968Q1-1979Q2

Policy Rule	a_Π	a_y	a_b	r	ST	*SER*	s_1	s_2	s_3	s_4
Taylor Rule										
With r=0	1.2	.54			1.0	1.26	.6	.1	.0	.0
	(6.9)	(6.3)								
With r#0	1.1	.65		.44	.3	1.01	.4	-.2	.0	.2
	(4.7)	(6.1)		(3.0)						

Panel B: Sample Period: 1979Q3-1994Q4

Policy Rule	a_Π	a_y	a_b	r	ST	*SER*	s_1	s_2	s_3	s_4
Taylor Rule										
With r=0	1.7	.32			37.8*	1.79	.4	.5	.5	.1
	(14.9)	(3.1)								
With r#0	1.8	.47		.39	26.0*	1.53	-.1	.1	.4	-.2
	(11.0)	(3.0)		(3.8)						
Taylor Rule With the Bond Rate										
With r=0	1.9	.37	.79		149.8*	1.12	-.2	-.1	.2	-.3
	(25.4)	(5.6)	(8.5)							
With r#0	1.9	.35	.80	-.11	174.9*	1.13	-.1	.0	.2	-.3
	(27.7)	(5.8)	(9.5)	(1.0)						

Notes: The coefficients (with t-values in parentheses) reported above are from policy rules of the form

$$FR_t = r\,FR_{t-1} + (1-r)(a + a_p INF_{t-1} + a_y GAP_{t-1}) \quad (1)$$

$$FR_t = r\,FR_{t-1} + (1-r)(a + a_p INF_{t-1} + a_y GAP_{t-1} + a_b(BR_t - INF_{t-1})) \quad (2)$$

where FR is the federal funds rate; INF is the inflation rate(smoothed); GAP is the level of the output gap and BR is the bond rate. Instrumental variables are used when $r \neq 0$ or when the bond rate is included; otherwise ordinary least squares (OLS) are used. For policy rules in (1), the instrument set consists of a constant, four past values of inflation and the output gap and period t-2 lagged values of the funds rate. For estimating policy rules in (2), the instrument set is expanded to include past values of the spread. t-values corrected for the presence of serial correlation. ST is a statistic that tests $a_p = 1$; it has t-distribution if the rule is estimated with OLS and Chi-square if IV is used. *SER* is the standard error of regression; $s_i, i = 1,2,3,4$ are the first four autocorrelation coefficients. *Significant at the 5 percent level

Table 2

Test of Unbiasedness

	ρ = 0			ρ # 0		
	f_0	f_1	c^2	f_0	f_1	c^2
Panel A: Sample Period: 1968Q1-1979Q2						
Taylor Rule Estimated						
With $r = 0$	-.10	1.0	.62			
	(.2)	(8.8)				
With $r \neq 0$	.10	1.0	.42	-.7	1.1	1.25
	(.1)	(9.1)		(.9)	(8.6)	
Panel B: Sample Period: 1981Q1-1994Q4						
Taylor Rule						
With $r \neq 0$	-1.0	1.2	8.9*	-1.4	1.2	63.2*
	(1.9)	(20.6)		(.9)	(8.6)	
Taylor Rule With the Bond Rate						
With $r \neq 0$	-.1	1.0	2.7	-.1	1.0	1.6
	(.6)	(67.9)		(.3)	(56.8)	

Notes: The coefficients (with t-values in parentheses) reported above are from regressions of the form $FR_t = f_0 + f_1 PFR_t + u_t$, where FR is the actual federal funds rate, and PFR is the funds rate predicted by the relevant policy rule. The predicted values used are the dynamic, within sample values, generated using policy rules reported in Table 1. The predicted funds rate is an unbiased predictor of actual if $f_0 = 0, f_1 = 1.0$. c^2 is the Chi-squared statistic with two degrees of freedom that tests $f_0 = 0, f_1 = 1$.

* Significant at the 5 percent level

Table 3

Estimation With Partial Adjustment and Serial Correlation

Policy Rule	a_{Π}	a_y	a_b	r	s	F
Panel A: Sample Period: 1968Q1-1979Q2						
Taylor Rule	1.0	.62		.41	.41	15.3*
	(3.9)	(3.7)		(1.6)	(1.6)	
Panel B: Sample Period: 1979Q3-1994Q4						
Taylor Rule	1.9	.55		.60	-.3	22.1*
	(9.3)	(2.7)		(6.5)	(2.0)	
Taylor Rule With the Bond Rate	1.9	.36	.78	-.03	-.1	.9
	(29.1)	(5.8)	(10.0)	(.2)	(.7)	

Notes: The coefficients (with t-values in parentheses) reported above are from policy rules of the form

Taylor Rule

$$FR_t^* = (a + a_p INF_{t-1} + a_y GAP_{t-1})$$

$$FR_t = r\,FR_{t-1} + (1 - r)FR_t^* + u_t$$

$$u_t = s u_{t-1} + m_t$$

Taylor Rule With the Bond Rate

$$FR_t^* = a + a_p INF_{t-1} + a_y GAP_{t-1} + a_b(BR_t - INF_{t-1})$$

$$FR_t = r\,FR_{t-1} + (1 - r)FR_t^* + u_t$$

$$u_t = s u_{t-1} + m_t$$

where u and m are disturbance terms. Instrumental variables are used when the bond rate is included; otherwise non-linear least squares are used. F is the F-statistic that tests $(r = 0, s = 0)$.

* Significant at the 5 percent level

Table 4

Additional Results: Estimates With Final Data

Panel A: Sample Period: 1968Q1-1979Q2

Row Number	a_p	a_y	a_b	r	*SER*
Taylor Rule					
1.1 Real/IV	1.1	.65		.44	1.01
	(4.7)	(6.1)		(3.0)	
1.2 Final/IV	.85	1.3		.60	.78
	(3.4)	(6.1)		(8.0)	

Panel B: Sample Period: 1979Q3-1994Q4

Row Number	a_p	a_y	a_b	r	*SER*
Taylor Rule					
2.1 Real/IV	1.9	.58		.56	1.57
	(7.8)	(2.5)		(4.7)	
2.2 Final/IV	1.9	.9		.84	1.74
	(2.6)	(.9)		(7.2)	
Taylor Rule With the Bond Rate					
3.1 Real/IV	1.9	.35	.80	-.11	1.13
	(27.7)	(5.8)	(9.5)	(1.1)	
3.2 Final/IV	1.8	.3	1.0	.09	1.27
	(20.3)	(3.3)	(9.5)	(.9)	

Notes: The coefficients (with t-values in parentheses) reported above are from policy rules of the form given in Table 1. Real/IV means the relevant policy rule is estimated using real-time data and instrumental variables. Final means the final data.

Table 5

Additional Results: Forward-Looking Policy Rules With Greenbook Forecasts

Panel A: Sample Period: 1968Q1-1979Q2

Policy Rule	a_{Π}	a_u	a_b	r	ST	SER	s_1	s_2	s_3	s_4
Taylor Rule With r =0; Non-Linear Least Squares										
Constant Natural Rate										
	1.0	1.0			1.3	1.22	.5	.3	.3	.1
	(9.5)	(7.5)								
Varying Natural Rate										
	1.1	1.0			.1	1.23	.6	.4	.4	.2
	(8.2)	(6.4)								
Taylor Rule With $r \neq 0$										
Constant Natural Rate; Non-Linear Least Squares										
	1.4	1.6		.57	4.7*	.77	.1	-.3	.1	.1
	(7.4)	(7.5)		(8.1)						
Varying Natural Rate; Non-Linear IV Estimates										
	1.2	1.5		.59	.9	.79	.2	-.2	.1	.2
	(5.4)	(4.9)		(5.7)						

Panel B: Sample Period: 1979Q3-1994Q4

Policy Rule	a_{Π}	a_u	a_b	r	ST	SER	s_1	s_2	s_3	s_4
Taylor Rule; Varying Natural Rate; Non-Linear IV Estimates										
With r #0	1.5	.2		.68	2.4	1.75	-.2	-.1	.2	.1
	(4.6)	(.4)		(7.3)						
Taylor Rule With the Bond Rate										
With r #0	1.8	.5	1.1	.19	48.4*	1.42	-.1	.0	.1	-.1
	(14.8)	(2.2)	(7.6)	(1.6)						

Notes: The coefficients (with t-values in parentheses) reported above are from policy rules of the form

$$FR_t = r\,FR_{t-1} + (1-r)(a \ + a_p\,INF^{gb}_{t+1} - a_u(UR^{gb}_t - NUR_t)) \qquad (1)$$

$$FR_t = r\,FR_{t-1} + (1-r)(a \ + a_p\,INF^{gb}_{t+1} - a_u(UR^{gb}_t - NUR_t) + a_b(BR_t - INF^{gb}_{t+1})) \qquad (2)$$

where INF^{gb}_{t+1} is the Greenbook inflation forecast; UR^{gb}_t is the Greenbook unemployment rate forecast; and NUR_t is the natural unemployment rate. The natural unemployment rate is just the real-time, simple average of the actual unemployment rates. ST tests $a_p = 1$ and has F distribution if the rule is estimated with Least Squares and Chi-Square distribution if the rule is estimated with IV. SER is the standard error of the regression. See notes in Table 1

* Significant at the 5 percent level

Figure 1A

Inflation:1968Q1-1979Q2

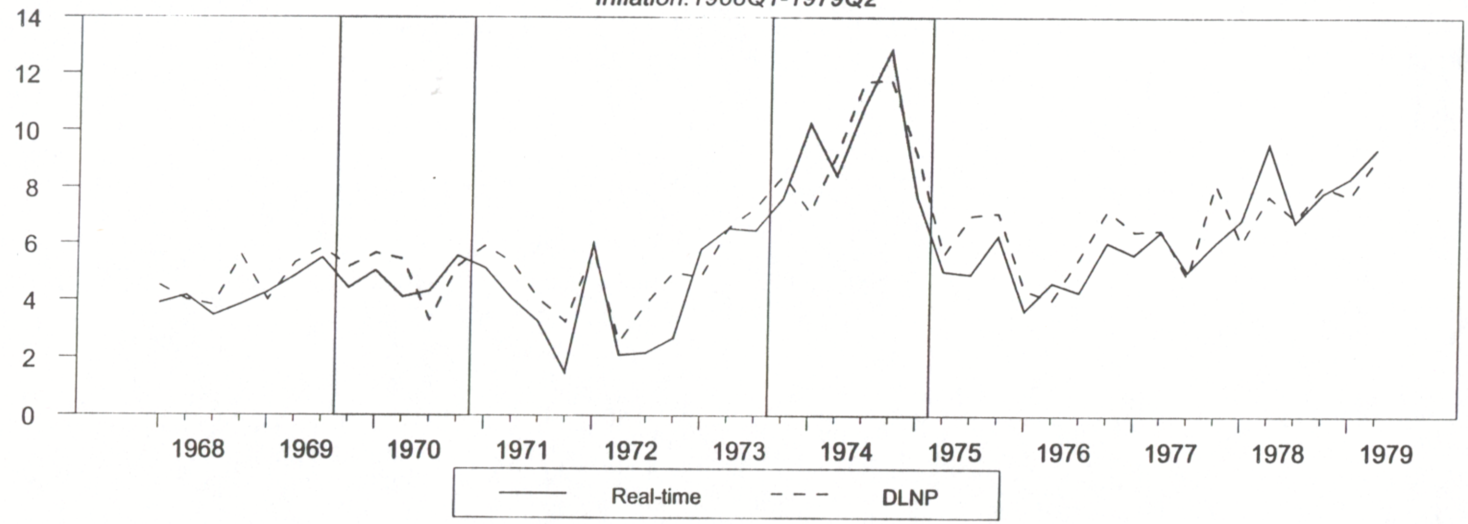

Figure 1B

Output Gap:1968Q1-1979Q2

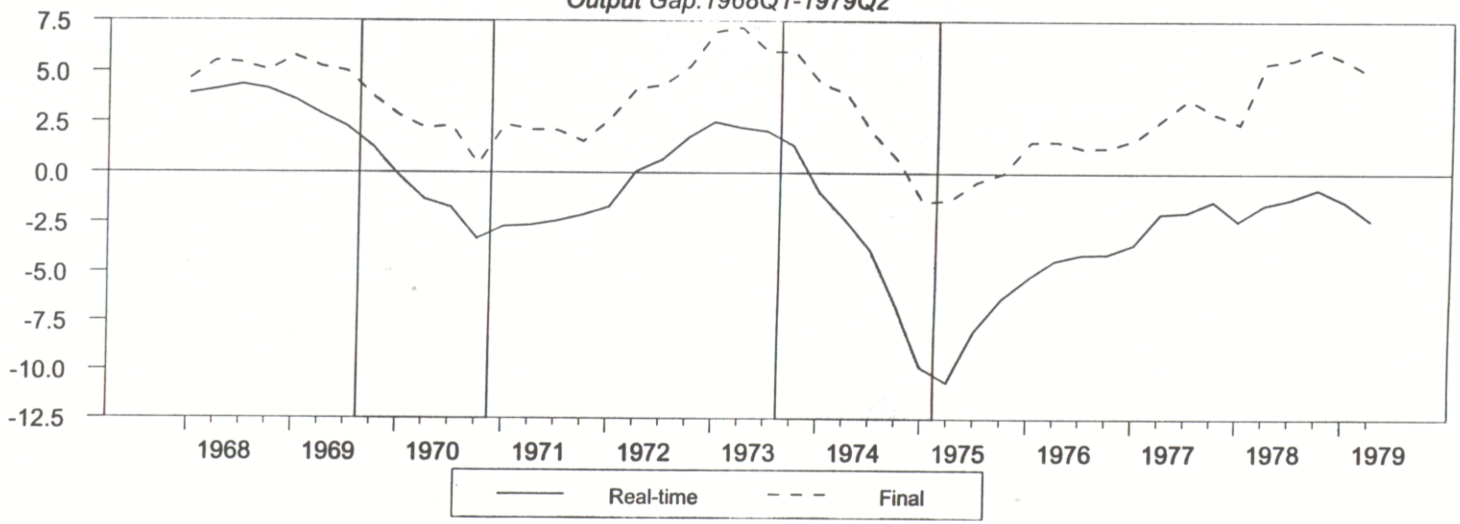

Figure 2A

Inflation: 1979Q3-1994Q4

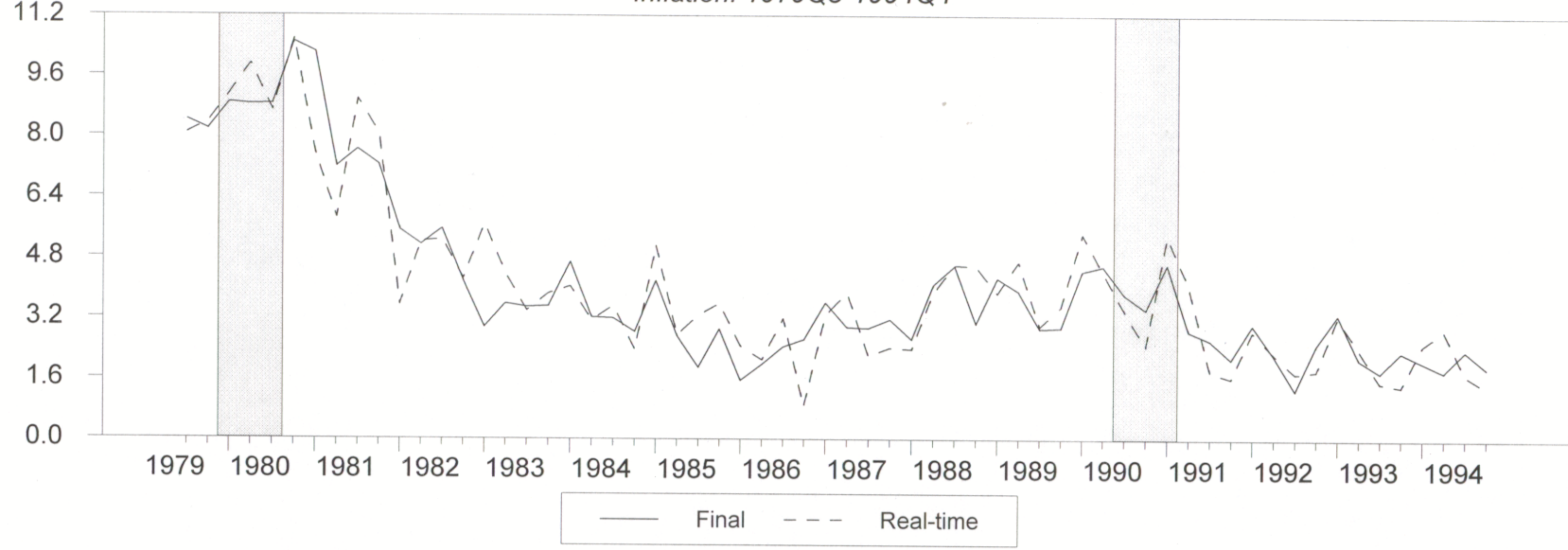

Figure 2B

Output Gap: 1979Q3-1994Q4

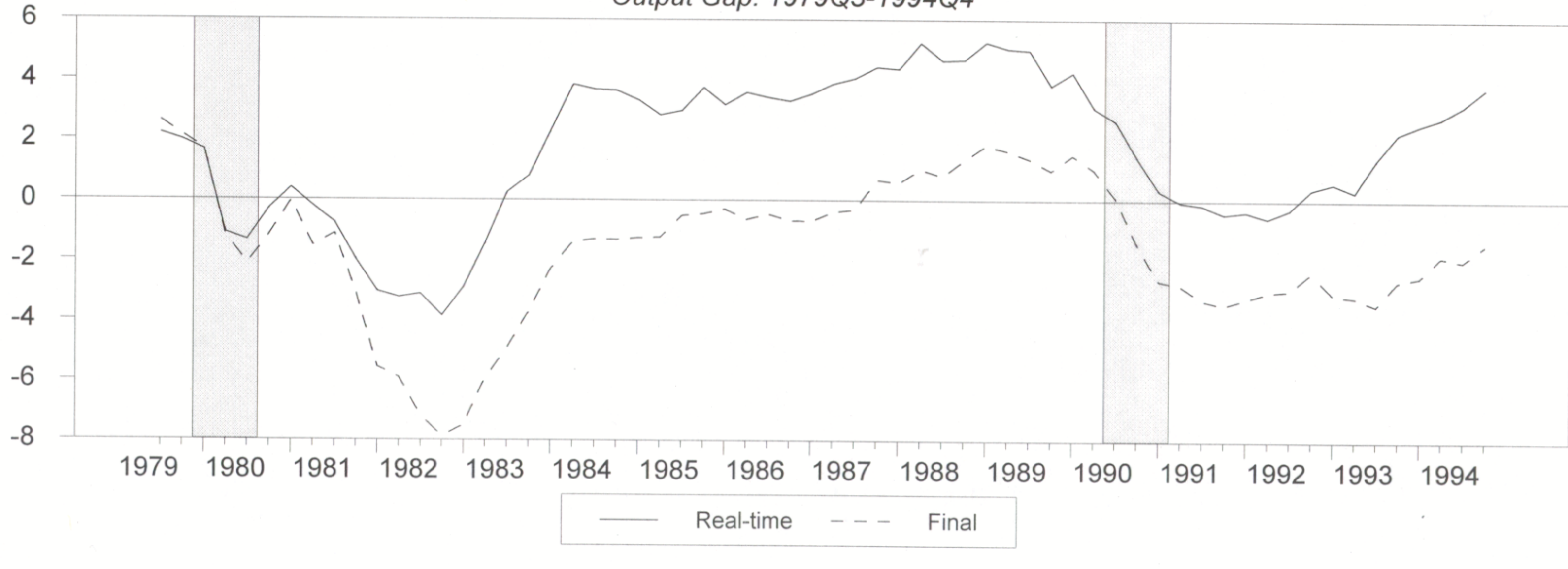

Figure 3: Taylor Rule (Smoothed)

Actual & Predicted Funds Rate: 1968Q1-1979Q2

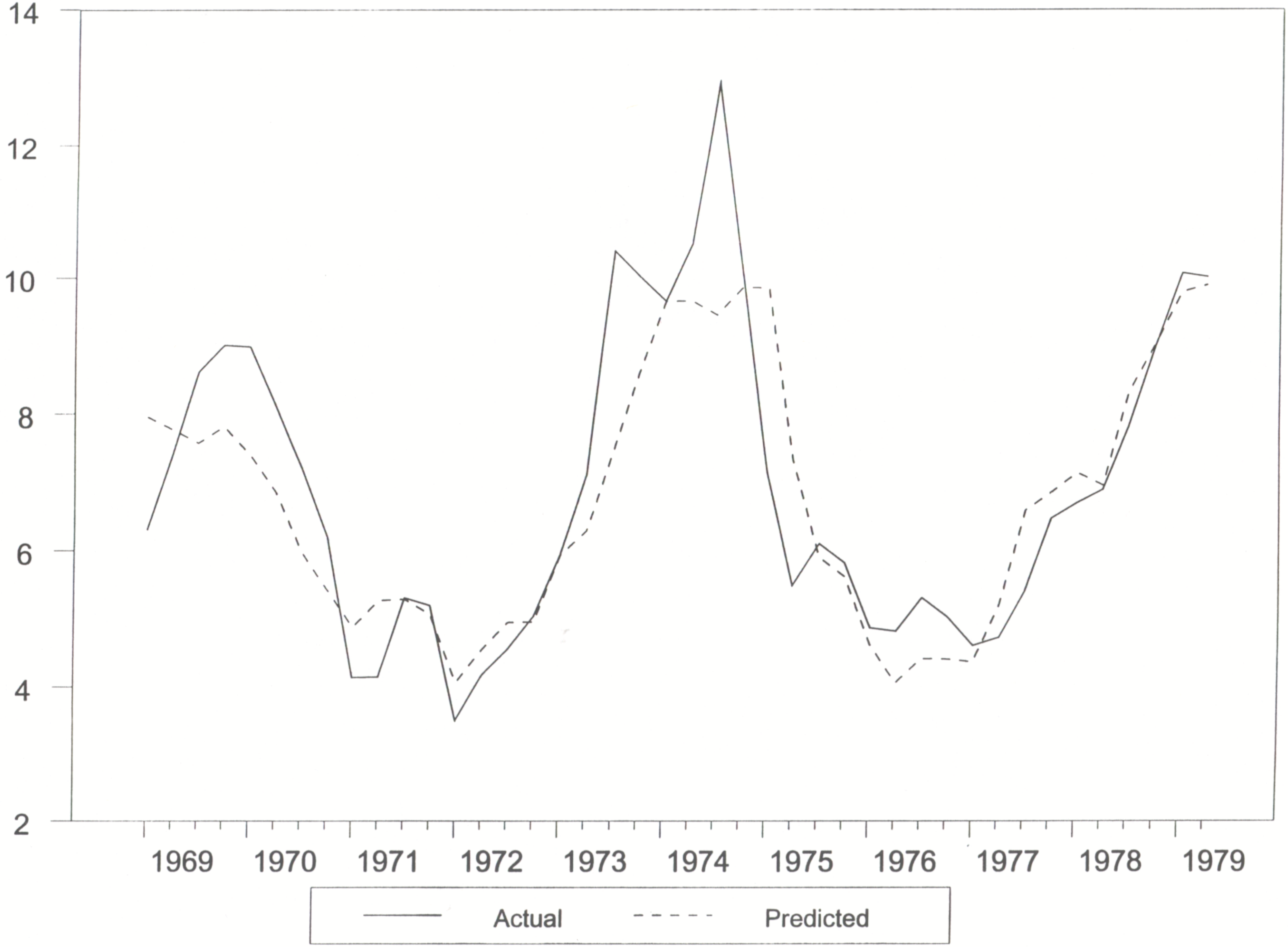

Figure 4: Modified Taylor Rule (Output Gap)

Actual & Predicted Funds Rate: 1981Q1-1994Q4

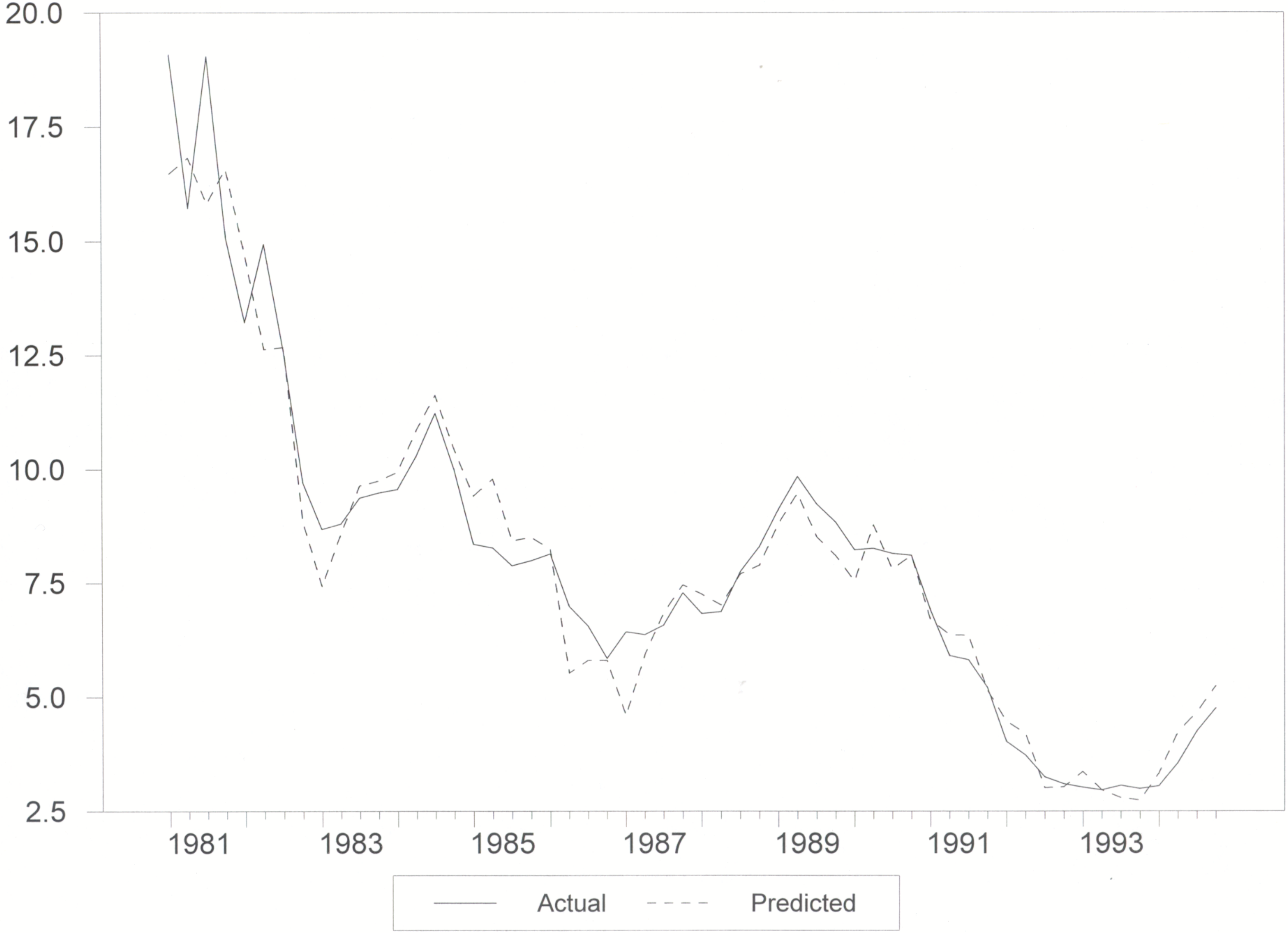

Figure 5A: Greenbook

Inflation:1968Q1-1979Q2

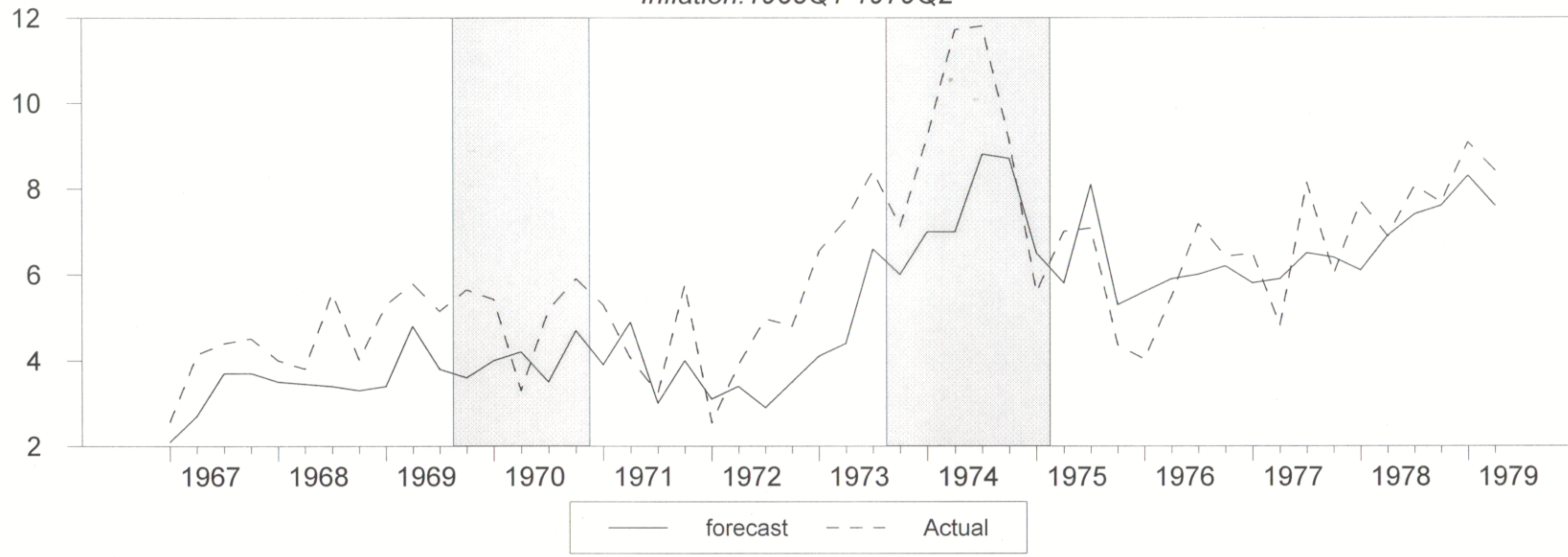

Figure 5B: Greenbook

Unemployment Rate:1968Q1-1979Q2

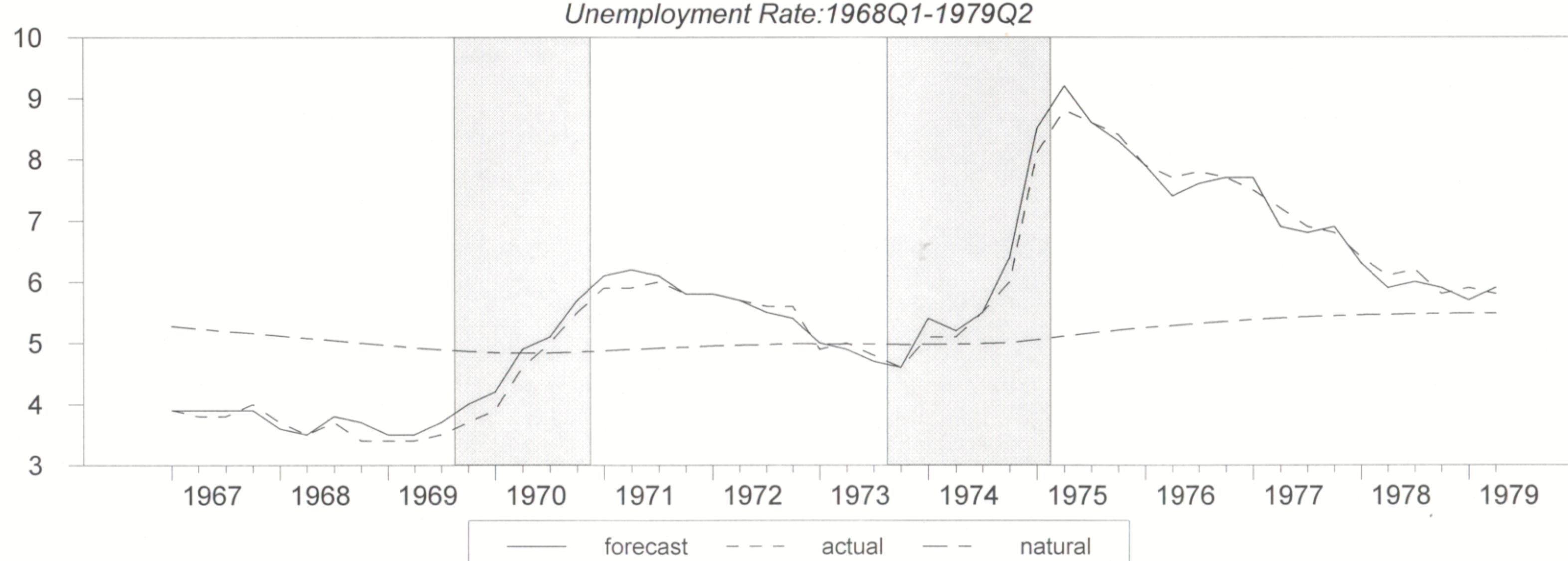

Figure 6: Taylor Rule (Greenbook)

Actual & Predicted Funds Rate: 1968Q1-1979Q2

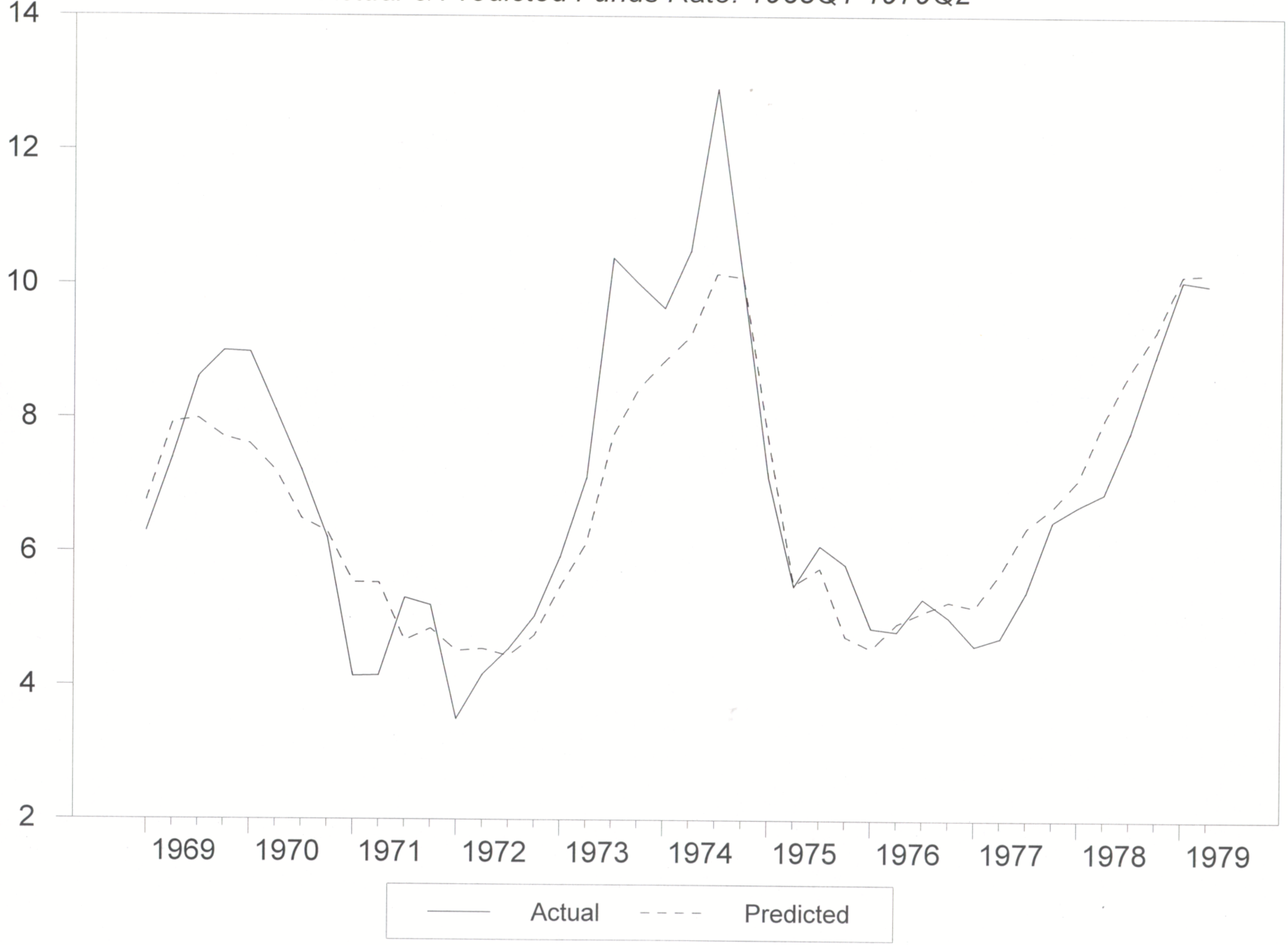

Figure 7: Modified Taylor Rule (Greenbook)

Actual & Predicted Funds Rate: 1981Q1-1994Q4