Working Paper Series

A Federal Funds Rate Equation

WP 95-03

Yash P. Mehra
Federal Reserve Bank of Richmond

THE FEDERAL RESERVE BANK OF RICHMOND
RICHMOND ▪ BALTIMORE ▪ CHARLOTTE

This is a preprint of an article which appeared in *Economic Inquiry*, vol. XXXV, No. 3, July 1997.

WORKING PAPER 95-3

A FEDERAL FUNDS RATE EQUATION

Yash P. Mehra*

Research Department
Federal Reserve Bank of Richmond
May 1995

Abstract

This paper presents evidence that indicates that U.S. interest rate policy during most of the 1980s can be described by a reaction function in which the federal funds rate rises if real GDP rises above trend GDP, if actual inflation accelerates, or if the long-term bond rate rises. Money growth when included in the reaction function is significant, indicating that money also influenced policy. The results presented here however indicate that in recent years the Fed has discounted the leading indicator properties of money. In contrast, the bond rate has been a key determinant of the funds rate during the period 1979 to 1992.

*Vice President and Economist. The views expressed in this paper are those of the author and do not necessarily represent those of the Federal Reserve Bank of Richmond or the Federal Reserve System. The author thanks Tim Cook, Marvin Goodfriend, Robert Hetzel, and Bennett McCallum for comments.

This paper estimates an equation that explains the behavior of the federal funds rate during the period 1979 to 1992. This funds rate equation has two parts: a long-run part and a short-run part. The long-run part, which assumes that the funds rate moves with the inflation rate and that the real federal funds rate is mean stationary, determines the long-run, equilibrium component of the funds rate. In the short run, however, the funds rate differs from its long-run equilibrium value. The short-run part has the feature that the federal funds rate rises if real GDP is above trend GDP, if inflation rises, or if the long-term bond rate rises.

The funds rate equation estimated here incorporates some salient features of monetary policy in Taylor (1992) and Goodfriend (1993). The policy rule in Taylor (1992) has the property that the funds rate rises if real income rises above trend income, if inflation increases above an assumed target of 2 percent, or if the long-run equilibrium funds rate rises.[1] Taylor shows that this policy rule, though not estimated from the data, is consistent with the actual path of the funds rate during the period 1987Q1 to 1992Q3. Goodfriend (1993) has argued that in order to establish and maintain credibility the Fed has during the period 1979 to 1992 reacted to the information in the bond rate about long term, expected inflation. Goodfriend, however, does not estimate any policy reaction function.

---

[1]The particular policy rule studied there is $FR_t = 2 + p + .5\ (y - y^*) + .5\ (p-2)$, where FR is the federal funds rate, y is real GDP; y^* is trend GDP; and p is the inflation rate. The term (2+p) captures the long-run equilibrium component of the federal funds rate, which equals the assumed, equilibrium real rate (2 percent) plus the inflation rate. The rule assumes that the Fed has a short-run inflation target of 2 percent and real output target equal to the trend rate. The funds rate rises one-for-one with inflation and responds equally to positive discrepancies between the actual inflation rate and the inflation target and between actual real GDP and trend GDP. Thus, if the Fed achieves its real output and inflation objectives, then the proper funds rate is given by its long-run equilibrium component (2+p).

Money growth is not included in the policy rule examined in Taylor (1992), nor does it receive much prominence in Goodfriend (1993). In contrast, the reaction functions recently reported in McNees (1992) indicate that the funds rate has reacted to money growth during the 1970s and the 1980s. The funds rate equation here is estimated with and without including money. Money growth when included in the equation is however highly significant. The results indicate that over the longer sample period, 1979 to 1992, the funds rate equation with money predicts better the funds rate. Furthermore, money appears to be a significant determinant of the funds rate during the 1970s, when direct measures of inflation and/or real output are not significant in the funds rate equation. These results indicate that money influenced policy during the 1970s and the 1980s. However, over the recent shorter sample period 1987 to 1992 considered in Taylor (1992), the funds rate equation without money is quite consistent with the actual path of the funds rate. This result indicates that the Fed may have discounted in recent years the leading indicator properties of money.

The bond rate is found to be a key determinant of the funds rate during the sample period 1979 to 1992. The funds rate equation without the bond rate significantly underpredicts the funds rate. The results here indicate that movements in the funds rate accounted for by the bond rate are significant during periods when inflation scares occurred (Goodfriend 1993).

The plan of this paper is as follows. Section 2 discusses the premises that underlie the federal funds rate equation estimated here. It also discusses the estimation methodology. Section 3 presents empirical results, and Section 4 contains conclusions and summary observations.

2. The Model and the Method

2.1 A Discussion of the Determinants of the Federal Funds Rate

This paper assumes that the Fed targeted the federal funds rate directly or indirectly during the period 1954Q3 to 1992Q4.[2] This section discusses the factors that might have influenced the Fed in setting the funds rate.

The federal funds rate equation studied here has two parts: a long-run part and a short-run part. Equation (1) specifies the long-run economic determinants of the funds rate.

$$FR_t^* = rr_t^* + p_t^* \tag{1}$$

where FR is the federal funds rate; rr^* is the economy's underlying equilibrium real rate; and p^* is the long-term expected inflation rate. The real rate rr^* can be viewed as the rate which equates the flows of desired saving and investment in the economy. It is the real natural rate of Wicksell. The term $rr_t^* + p_t^*$ in (1) thus measures the nominal natural rate.

---

[2]This assumption is only approximately correct. During the sample period examined here the Fed has not always focused on the federal funds rate and when it did it has used varying monetary policy operating procedures to manage it. Thus, the Fed focused on free reserves and short-term money market rates (including the funds rate) during most of the 1950s and 1960s, used 'direct' funds rate targeting during most of the 1970s, and 'indirectly' managed the funds rate using the nonborrowed reserves procedure during 1979Q4 to 1982Q3 and the borrowed-reserve procedure during 1982Q4 to 1992Q4 (Cook and Hahn 1989; Wallich 1984; and Thornton 1988). Goodfriend (1993) has argued that the period from 1979Q4 to 1982Q3 should be viewed as the one of 'aggressive' federal funds rate targeting rather than one of nonborrowed reserve targeting. The reason is that during this period only one-third of funds rate changes resulted from automatic adjustments of non-borrowed reserve targets. The remainder of funds rate changes during this period resulted rather from 'judgmental' actions of the Fed (Cook 1989).

Equation 1 says that the nominal federal funds rate depends upon the nominal natural rate. This relationship which holds in the long run assumes that the Fed lets the federal funds rate move with the real rate plus the long-term inflation rate expected by the public. Failure to hold this equality in the long run results in monetary accelerations (decelerations) and inflation (deflation).

In the short run, however, the funds rate can differ from the long-run equilibrium value (the nominal natural rate) determined in (1) for a number of reasons. Both the real rate and long-term expected inflation are unobservable variables. The Fed has to track them in the short run, which it may do so by focusing on the behavior of observables such as actual money, real growth, inflation etc. More importantly, the Fed may have some short-run objectives pertaining to real growth and inflation. For all these reasons the actual funds rate differs from the nominal natural rate in the short run.[3]

How will then one specify a short-run federal funds rate equation? Following Taylor (1992), this paper investigates a funds rate equation that focuses directly on real output and inflation as in (2).

$$FR_t - FR_{t-1} = d_o + d_1 \, (FR^*_{t-1} - FR_{t-1}) + d_2 \, ((y - y^*)/y^*)_t$$
$$+ d_3 \, \Delta p^*_t + \epsilon_t \; ; \; d_1, \, d_2, \, d_3 > 0 \qquad (2)$$

where

$$FR^*_t = rr^*_t + p^*_t$$

[3]Hetzel (1994) discusses some of these issues in detail.

where y is real GDP; y^* is trend or potential GDP; FR^* is the long-run equilibrium funds rate and ϵ_t is a random disturbance term. The funds rate equation given in (2) makes some key assumptions about Fed behavior. It assumes that in the short run the Fed targets real GDP and change in inflation. The Fed raises the funds rate if real GDP rises above trend GDP, or if the long-term expected inflation accelerates. The parameters d_2 and d_3 measure the vigor with which monetary policy "leans against the winds": the larger are d_2 and d_3, the more vigorously the Fed moves the funds rate in response to deviations of output from trend and accelerations in long-term inflation.

While the Fed is free to pursue its short-run objectives, its short-run behavior is assumed to be constrained by the long-run relationship postulated in (1). Thus, equation (2) also assumes that the Fed raises the funds rate if the actual funds rate is below its long-run equilibrium value. The long-run equilibrium funds rate equals the nominal natural rate. The parameter d_1 measures the vigor with which the Fed keeps the actual level of the funds rate in line with the nominal natural rate.[4] If this parameter is unity, then the funds rate equation given in (2) can be expressed as in (3).

$$FR_t = d_o + FR^*_{t-1} + d_2\ ((y - y^*)/y^*) + d_3\ (p^*_t - p^*_{t-1}) + \epsilon_t \qquad (3)$$

---

[4]The funds rate equation (2) is specified in first differences rather than levels of the funds rate. Moreover, the Fed is assumed to target changes in the inflation rate. These features permit drift in the rate of inflation and hence in the nominal natural rate. The inclusion of the term d_1 $(FR^*_{t-1} - FR_{t-1})$ in (2) however ensures that the nominal funds rate converges to the nominal natural rate in the long run.

As can be seen, the actual funds rate differs from the nominal natural rate only to the extent that the Fed pursues some short-run objectives. If the Fed achieves such objectives ($y = y^*$, $p_t^* =$ constant), the proper funds rate is the nominal natural rate, which equals the real natural rate plus the long-term inflation rate expected by the public.

2.2 Data, Definition of Variables, and Empirical Specifications of the Funds Rate Equation

The empirical work uses quarterly data over 1954Q3 to 1992Q4. The long-run part of the funds rate equation estimated here is given in (4).

$$FR_t = a + b\ p_t + U_t \tag{4}$$

where FR is the actual, nominal federal funds rate (average for the quarter); p is the actual, annualized quarterly inflation rate measured by the behavior of the implicit GDP deflator; and U is a stationary random disturbance. The specification (4) thus assumes that actual inflation is a good proxy for the long-term, expected inflation and that the random disturbance term is stationary. The parameter b measures the long-run response of the funds rate to inflation. If this parameter is unity, then the real federal funds rate ($FR_t - p_t \equiv a + U_t$) is mean stationary. If the Fed has on average kept the real federal funds rate in line with the natural real rate, then the real federal funds rate may be a good proxy for the real natural rate. Under these assumptions, the long-run equilibrium nominal funds rate equation (which proxies the nominal natural rate) may be expressed as follows

$$FR_t^* = p_t + \bar{m}$$

where $\bar{m}$ is the mean real federal funds rate.

The short-run funds rate equation given in (3) requires proxies for the equilibrium funds rate (FR^*), the long-term expected inflation rate (p^*), and trend GDP (y^*). The empirical work here calculates the equilibrium funds rate (FR^*) from equation (4). As indicated above, actual inflation (p) is used as a proxy for long-term expected inflation (p^*). The variable $(y - y^*)/y^*$ is measured as $\ln y - \ln y^*$, where lny is the natural logarithm of real GDP; and $\ln y^*$ is the value predicted by the regression of lny on a constant and linear trend. This reflects the assumption made here that the long-run secular component of real GDP can be approximated by a linear trend. I however also examine results using potential GDP as proxy for the secular component.[5]

Goodfriend (1993) has convincingly argued that in order to establish and maintain credibility the Fed has reacted to the information the long-term bond rate has had about long-term, expected inflation. The empirical work here captures this reaction by including in equation (3) an additional variable measured as the ten-year bond rate (R10) minus the actual inflation rate (p). This variable provides information about long-term expected inflation (plus perhaps about real rate) that is not in the actual inflation rate. Hence, the short-run funds rate equation estimated is of the form (5).

---

[5]The empirical work uses the data--real GDP and the implicit GDP deflator--that reflect latest revisions, assuming that data revisions are unlikely to alter the long-run secular nature of the series. The interest rate data are averages for the quarter. All the data are from Citibank's data base, except the series on potential GDP which is from the Board of Governors.

$$\Delta FR_t = d_o + d_1\ (FR^*_{t-1} - FR_{t-1}) + d_2\ (\ln y_{t-1} - \ln y^*_{t-1})$$

$$+ d_3\ \Delta p_{t-1} + d_4\ (R10_t - p_t) + \sum_{s=1}^{n} d_{5s}\ \Delta FR_{t-s} + \epsilon_{2t} \tag{5}$$

where all variables are as defined before. Lagged values of changes in the funds rate included in (5) capture short-run dynamics of the funds rate behavior. If the funds rate moves rapidly in response to the short- and long-run economic variables discussed above, then changes in the funds rate are likely to be serially uncorrelated. Furthermore, the Fed is assumed to react to known information, so that only lagged values of inflation and real output are included in the funds rate equation, except for the long-term bond rate that enters contemporaneously.

2.3 Estimation issues: The Long-run Federal Funds Rate Equation

If the time series FR_t and p_t are nonstationary but cointegrated as in Engle and Granger (1987), then the long-run equation (4) can be consistently estimated by ordinary least squares. The coefficient b that appears on the inflation rate in this equation captures the long-run response of the funds rate to inflation. Tests of the hypothesis that b = 1 in (4) can be carried out by estimating Stock and Watson's (1993) dynamic OLS regressions of the form

$$FR_t = a + b\ p_t + \sum_{s=-n}^{n} C_s\ \Delta p_{t-s} + \epsilon_t \tag{6}$$

where all variables are as defined before. Equation (6) includes, in addition to current inflation, past, current and future values of changes in the inflation rate.

In order to determine whether the series FR_t and p_t have unit roots or whether they are mean stationary, unit root tests are performed by estimating the Augmented Dickey-Fuller (1979) regression of the form

$$X_t = \alpha + \rho X_{t-1} + \sum_{s=1}^{k} e_s \Delta X_{t-s} + n_t \qquad (7)$$

where X_t is the pertinent variable; n_t is the random disturbance term; and k is the number of lagged first-differences of X_t necessary to make n_t serially uncorrelated. If $\rho=1$, X_t has a unit root and is thus nonstationary in levels. The null hypothesis $\rho=1$ is tested using the t-statistic. The lag length k used in tests is chosen using the procedure given in Hall (1990), as advocated by Campbell and Perron (1991).

Recently, some authors including Dejong et al. (1992) have shown that Dickey-Fuller tests have low power in distinguishing between unit roots and mean stationarity. The long-run relationship (4) is therefore estimated under the alternative that the series FR_t and p_t may be mean stationary. In that case, the long-run relationship is estimated as (8).[6]

$$FR_t = a + \sum_{s=o}^{n1} b_{1s}\, p_{t-s} + \sum_{s=1}^{n2} b_{2s}\, FR_{t-s} + U_t \qquad (8)$$

---

[6]If the series are non-stationary, then the long-run relationships among the series can be estimated without completely specifying short-run dynamics. However, that is not the case if the series are stationary (Wickens and Breusch 1988).

The coefficient that measures the long-run response of the funds rate to inflation can be calculated as $(\sum_{s=o}^{n1} b_{1s}/(1 - \sum_{s=1}^{n2} b_{2s}))$. The restriction that this long-run coefficient equals unity implies that slope coefficients sum to unity $(\sum_{s=0}^{n1} b_{1s} + \sum_{s=1}^{n2} b_{2s} = 1$ in (8)).

The empirical work on policy reaction functions summarized in Khoury (1990) indicates that the long-run relationship postulated in (4) may not be stable during the sample period 1954Q3 to 1992Q4. The reason is that the relative weight the Fed assigned to the inflation objective may have varied over time. The power of the conventional test for cointegration given in Engle and Granger (1987) falls sharply when the cointegrating relationship is subject to a structural break. Hence, the test for cointegration used here is the one proposed in Gregory and Hansen (1992). This test examines cointegration under the possibility that the cointegration regression (4) is subject to a one-time regime shift of unknown timing.

The structural change considered here is of the form (9).

$$FR_t = a_1 + a_2 D_{t\tau} + b_1 p_t + b_2 D_{t\tau} p_t + u_t \tag{9}$$

where $D_{t\tau}$ is a dummy variable that is zero if $t \leq \tau T$ and unity otherwise. The unknown parameter $\tau \epsilon (0,1)$ denotes the relative timing of the change point and T is the sample size. In the new parameterization a_1 and b_1 represent intercept and slope coefficients in the cointegrating regression before the regime shift and a_2 and b_2 denote changes in them.

The test for cointegration given in Gregory and Hansen (1992) examines the presence of a unit root in the residuals of equation (9) for all possible breakpoints. The test uses residuals ($\hat{u}$) from (9) and is implemented by running an Augmented Dickey-Fuller regression of the form

$$\Delta\hat{u}_{t\tau} = \rho_\tau \hat{u}_{t\tau} + \sum_{s=1}^{k} e_s \Delta\hat{u}_{t\tau-s} \qquad (10)$$

and then computing a t-statistic for the hypothesis $\rho_\tau = 0$. The null hypothesis in this test is that of non-cointegration. The test rejects the null hypothesis if the largest (absolute) of t-statistics exceeds the critical value (given in Gregory and Hansen (1992)). The test also generates the date of the break suggested by the data.

3. Estimation Results

3.1 The Long-run Federal Funds Rate Equation

Table 1 presents unit root tests for determining whether the series FR_t, p_t, and $FR_t - p_t$ have a unit root, or are mean stationary. The t-statistic for the hypothesis $\rho = 1$ in (7) is small for FR_t and p_t, but large for $FR_t - p_t$. These results indicate that the series FR_t and p_t have a unit root, whereas the series $FR_t - p_t$ does not. The latter result implies that the series FR_t and p_t are cointegrated as in Engle and Granger (1987).[7]

[7]The conventional Engle-Granger test for cointegration examines whether the residuals in (4) have a unit root or not. The t-statistic for the hypothesis $\rho = 0$ in an Augmented Dickey-Fuller regression (with one lag) is 3.23 (The 5 percent critical value taken from Table 3 in Engle and Yoo 1987 is 3.17). This result indicates that the series FR_t and p_t are cointegrated.

Panel A in Table 2 presents the dynamic OLS estimates of the long-run funds rate equation (4). χ_1^2 is a Chi square statistic that tests the hypothesis that the coefficient that appears on p_t in (4) is unity. This statistic is small, indicating that the funds rate does adjust one-for-one with actual inflation in the long run.

Panel B in Table 2 reports an estimate of the long-term coefficient on p_t in (8) under the alternative assumption that the series FR_t and p_t are mean stationary. This estimated coefficient is not different from unity either. These results together then suggest that the long-run, equilibrium federal funds rate equation is of the form

$$FR_t^* = \bar{m} + p_t$$

where $\bar{m}$ is the mean real federal funds rate.

3.2 Stability of the Long-run Federal Funds Rate Equation

As indicated before, the long-run funds rate equation reported in Table 2 may not be stable during the sample period 1954Q3 to 1992Q4. Though the unit root test results discussed above suggest that the real federal funds rate does not have a unit root and thus the series FR_t and p_t are cointegrated, I nevertheless re-examine this issue using the test of cointegration proposed in Gregory and Hansen (1992). This test examines cointegration under the possibility that the cointegrating relationship may be subject to a one-time regime shift of unknown timing.

Chart 1 graphs the relevant t-statistic for the hypothesis $\rho_\tau = 0$ in the Augmented Dickey-Fuller regression (with k=2) of the form (10). As can be seen, this Chart has a well-defined minimum and at this minimum the absolute value of the t-statistic is large. (The t-value is 4.88, which exceeds the 10 percent critical value 4.68 given in Table 1A, Gregory and Hansen (1992).) This result indicates that the series FR_t and p_t are cointegrated and that this cointegrating relationship may have shifted once during the sample period 1954Q3 to 1992Q4.

The date of the break suggested by the test is 1980Q3. This date is very close to the date 1979Q4, when the Fed changed its monetary policy operating procedures. I therefore examine the nature of the shift in the cointegrating relationship (4), assuming that the data of the break instead is 1979Q4. Table 3 presents the dynamic versions of the cointegrating regression with slope and intercept dummies. As can be seen, the long-run coefficient that appears on inflation is close to unity and the slope dummy is generally small and not statistically significant. This result indicates that the federal funds rate has adjusted one-for-one with actual inflation during pre- and post-1979 periods.[8,9] However, the intercept shift dummy is large and

---

[8]I also tested for the presence of cointegration between inflation and the federal funds rate using the test for cointegration proposed by Johansen and Juselius (1990). The test procedure consists of estimating a VAR model that includes levels as well as differences of variables. The matrix of coefficients that appear on levels of these time series contain information about the long-run properties of the model.

The VAR model (with lag length set at 4) estimated here included also a dummy defined to be unity over 1979Q4 to 1992Q4 and zero otherwise. The trace test statistic has a value of 18.9 (the 5 percent critical value is 17.8) and the maximum eigen value test statistic a value of 15.0 (the 5 percent critical value is 14.6). These test results are consistent with the presence of cointegration between the funds rate and inflation. The cointegrating regression generated by this procedure is

$$FR_t = 1.1\ p_t$$

The coefficient that appears on p_t is not different from unity.

statistically significant. This may be because the real natural rate had increased or because the Fed may have been reacting differently to certain economic factors than it did before this subperiod. These issues are examined in the next section where the short-run funds rate equation is estimated.

3.3 A Short-run Funds Rate Equation

The empirical results presented in the previous section suggest that the short-run funds rate equation (5) may not have stable parameters during pre- and post-1979 sample periods. The short-run equation is, therefore, estimated including slope dummies. Since the bond rate enters

---

[9]Alternatively, if FR_t and p_t are stationary, then stability of the long-run slope coefficient on p_t can be examined by estimating a regression of the form

$$FR_t = a + \sum_{s=o}^{n1} b_{1s}\, p_{t-s} + \sum_{s=1}^{n2} b_{2s}\, FR_{t-s} + D_t + \sum_{j=o}^{n1} \delta_{1s}\, (D \cdot p)_{t-s} + \sum_{s=1}^{n2} \delta_{2s}\, (D \cdot FR)_{t-s} \qquad (a)$$

where D is a dummy variable that is unity over 1979Q4 to 1992Q4 and zero otherwise. The long-run slope parameter b is $(\sum_{s=o}^{n1} b_{1s}/1 - \sum_{s=1}^{n2} b_{2s})$ for the pre-79Q3 period and $(\sum_{s=o}^{n1} b_{1s} + \sum_{s=o}^{n2} \delta_{2s})/(1-(\sum_{s=1}^{n2} b_2 s + \sum_{s=1}^{n2} \delta_{2s}))$ for the period thereafter. Equation (a) was estimated by IV over 1954Q4 to 1992Q4. With nl = o, n2 = 8, slope coefficients sum to <u>.97</u> over 56Q2 to 1979Q3 and <u>1.22</u> over 56Q2 to 1992Q4. These results indicate that the long-run slope coefficient on p_t is not different from unity over the subperiods 1956Q2 to 1979Q3 and 1956Q2 to 1992Q4.

It should however be pointed out that slope dummies are generally significant, whereas the intercept shift dummy is not. These results suggest the presence of different short-run dynamics during pre- and post- 1979Q4 periods.

contemporaneously in (5), the equation is also estimated using the instrumental variables procedure.

Table 4 presents ordinary least squares (OLS) and instrumental variables (IV) estimates of the short-run funds rate equation (5) over 1955Q4 to 1992Q4.[10] Since OLS estimates are similar to IV estimates, the discussion hereafter focuses on OLS estimates. [All standard errors have been corrected for the possible hetroscedascity of the regression error.] The coefficients that appear on various economic variables are strikingly different over pre- and post-1979 sample periods. In particular, the estimates reported there indicate that for the sample period 1955Q4 to 1979Q3 the funds rate equation is

$$\Delta FR_t = \underset{(1.5)}{-.07} (FR - FR^*)_{t-1} + \underset{(2.3)}{.04} (\ln y - \ln y^*)_{t-1}$$

$$+ \underset{(4.1)}{.57} \Delta FR_{t-1} - \underset{(2.6)}{.38} \Delta FR_{t-2}$$

where parentheses contain t-values (absolute). For the period 1979Q4 to 1992Q4 the funds rate equation is

$$\Delta FR_t = \underset{(2.2)}{-.30} (FR - FR^*)_{t-1} + \underset{(2.0)}{.24} (\ln y - \ln y^*)_{t-1}$$

$$+ \underset{(3.0)}{.33} \Delta p_{t-2} + \underset{(3.0)}{.20} (R10 - p)_t + \underset{(2.6)}{.09} \Delta FR_{t-1}$$

$$- \underset{(2.6)}{.38} \Delta FR_{t-2}$$

[10]Lag lengths on various economic variables in the funds rate equation were selected on the basis of experimentation. In OLS regressions only the bond rate enters contemporaneously. In IV regressions the instruments chosen are just the lagged values of the economic variables included in the reaction functions. Thus, the instruments used in the reaction function (without money) are a constant, one-period lagged values of $(FR - FR^*)_t$, $(\ln y - \ln y^*)_t$, and $(R10 - p)_t$, two-period lagged values of Δp_t, and two lagged values of ΔFR_t. The instruments for interactive-dummy variables enter similarly.

Thus, during the sample period 1979Q4 to 1992Q4 the funds rate moved strongly in response to the discrepancy between the actual funds rate and its long-run equilibrium value, cyclical expansions in real GDP, accelerations in actual inflation, and the long-term bond rate.

The responses of the funds rate to above mentioned economic variables are either weak or non-existent during the pre-1979 sample period. In particular, the funds rate equation presented above indicates that during the pre-1979 sample period the funds rate has responded weakly to the discrepancy between the actual funds rate and its long-run equilibrium value and responded not at all to accelerations in actual inflation. The coefficient that appears on the cyclical expansion variable in the funds rate equation is small, though statistically significant. One possible explanation of these results is that the Fed may have focused during this subperiod on some other indirect measures of real growth and/or inflation. McNees (1992) has in fact presented evidence that indicates that the Fed paid considerable attention to money growth during the sample period 1970 to 1992. To test robustness, the funds rate equation here is also estimated including money. Following McNees (1992), money is defined by M2 over 1982Q4 to 1992Q4 and by M1 over the period before, and slope coefficients on money growth are assumed to be different during the subperiods 1955Q4 to 1979Q3, 1979Q4 to 1982Q3, and 1982Q4 to 1992Q4.[11]

[11]The financial innovations and deregulation of the financial industry that occurred during the early part of the 1980s changed the character of M1 demand (Hetzel and Mehra 1989), leading the Fed to de-emphasize M1 in 1982Q4. The Fed however continued setting annual targets for other monetary and credit aggregates including M2. Hence, money is measured by M1 over 1954Q3 to 1982Q3 and by M2 thereafter, necessitating the use of different slope coefficients on money during these subperiods.

The funds rate equation estimated including money is also presented in Table 4. As can be seen, money growth is highly significant. Including money in the reaction function reduces somewhat the magnitudes of coefficients that appear on inflation and real output including the bond rate. Nevertheless, direct measures of inflation and real output remain significant in the reaction function that spans 1979Q4 to 1992Q4.

3.4 Examining the Predictive Ability of the Federal Funds Rate Equation over 1979 to 1992

This section examines whether funds rate equations reported in Table 4 are consistent with the actual path of the federal funds rate during the period 1979Q1 to 1992Q4.[12] The equations given in Table 4 are re-estimated by OLS over 1955Q4 to 1986Q4 and then dynamically simulated over 1979Q1 to 1992Q4.[13]

Predicted values of the funds rate generated using the funds rate equation without money are reported in column (2) of Table 5 and those generated using the one with money are in column (5). Charts 2 and 3 graph these values, predicted as well as actual. As can be seen, the funds rate equation with money tracks the actual path of the funds rate somewhat better than does the one without money. Both the mean error and the root mean squared error decline when money is included in the funds rate equation (see

---

[12]The federal funds rate equation reported here is less successful in tracking the actual behavior of the funds rate during the pre-1979 period.

[13]Simulations are partly within- and partly out-of-sample. The out-of-sample period 1987Q1 to 1992Q4 chosen here is the one studied by Taylor (1992) and happens to span most of Greenspan's term as Fed Chairman. These simulations thus implicitly assume that reaction functions display stable parameters over the period 1979Q4 to 1992Q4 that spans Volcker's and Greenspan's terms as Fed Chairman.

Table 5). The reason is that the funds rate equation with money explains the actual path of the funds rate during the early part of the 1980s much better than does the one without money. Including money in the funds rate equation reduces substantially the size of the prediction error that occurs over the subperiod 1979 to 1982 (compare columns (2) and (5), Table 5).

In order to evaluate further the role of money in the funds rate equation, Table 5 presents dynamic simulations of the funds rate over the shorter sample period 1987Q1 to 1992Q4 examined by Taylor (1992). Predicted values given in column (3) are from the funds rate equation without money and those in column (4) from the one with money.[14] Charts 4 and 5 graph these values, actual and predicted. As can be seen, during this period the funds rate equation without money tracks better the actual path of the funds rate than does the one with money. Both the mean error and the root mean squared error rise when money is included in the funds rate equation.

One explanation of the results presented above is that the Fed may have discounted in recent years the leading indicator properties of money as measured by M2. The evidence reported in Carlson and Sharron (1991) and Mehra (1992) indicates that the relationship between M2 demand and its traditional determinants (like income, prices and interest rates) has deteriorated in recent years. Hence, the reaction function that focuses directly on prices

---

[14]Predicted values use OLS regressions estimated over rolling horizons and are the dynamic, one-year ahead sample forecasts conditional on actual values of other economic variables. The forecasts are generated as follows. The reaction functions are initially estimated over 1955Q4 to 1986Q4 and then dynamically simulated over 1987Q1 to 1987Q4. The end of the estimation period is then advanced four quarters, reaction functions re-estimated and forecasts prepared as above. This process is repeated until the end of the estimation period reaches 1991Q4.

and real output (including the bond rate) can describe actual policy in recent years much better than the one that also includes money, a finding that is similar in spirit to the one in Taylor (1992).

Chart 6 highlights the role of the bond rate in predicting the behavior of the funds rate during the period 1979 to 1992. The upper panel in this Chart graphs the funds rate predicted with and without the bond rate in the funds rate equation.[15] Actual values of the funds rate are also charted there. The lower panel graphs changes in the funds rate that are predicted by the bond rate against changes in the bond rate. This Chart suggests two observations. First, the bond rate is quantitatively important in predicting the funds rate over 1979 to 1992. The funds rate equation without the bond rate seriously underpredicts the level of the funds rate (see the upper panel). Second, movements in the funds rate accounted for by movements in the bonds rate are significant in 1981, 1983-1984, and 1987. These periods coincide with what Goodfriend (1993) calls periods of inflation scare.

3.5 Additional Results

The short-run federal funds rate equations reported in Table 4 here are estimated over the period that includes the late-1950s and 1960s. During most of the 1950s and 1960s the Fed's attention was focused more on free

---

[15]These predictions, which use the funds rate equation without money reported in Table 4, were generated as follows. The funds rate predicted including the bond rate is given by the dynamic simulations of the funds rate equation in which the bond rate takes the historical values over the simulation period 1979Q4 to 1992Q4 (see Table 5). The funds rate predicted without the bond rate is then given by the dynamic simulations in which the bond rate is held fixed at the 1979Q4 value during the simulation period. The differences between these two sets of simulations give predictions of the funds rate that are due to the bond rate.

reserves and money market rates in general (Poole 1971) than on the federal funds rate. To test robustness, the funds rate equation is also estimated excluding the 1950s and 1960s. Furthermore, potential GDP is alternatively used as proxy for the long-run secular GDP, which the Fed is assumed to use as a target.

Table 6 presents funds rate equations estimated over 1970Q4 to 1992Q4. The long-run part of the funds rate equation is still measured as the inflation rate plus the mean real funds rate, the latter now approximated by its sample mean over 1970Q1 to 1992Q4.[16] As can be seen, money growth is highly significant in these reaction functions. However, direct measures of inflation and real GDP remain significant. The estimated funds rate equation still indicates that during the sample period 1979Q4 to 1992Q4 the funds rate responded strongly to cyclical expansions in real GDP, accelerations in actual inflation, and increases in the long-term bond rate and the long-run equilibrium funds rate. Furthermore, the results are also robust with respect to the alternative proxy used for the secular component of real GDP (see regressions in Table 6).

The funds rate equations reported above indicate that the Fed has reacted to accelerations in actual inflation during the subperiod 1979 to 1992. This behavior is tantamount to inflation targeting in which the short-term inflation target at any time is the previous period's inflation rate. I now examine a version in which the Fed's short-term inflation targets are assumed to be viewed differently. During the sample period 1979 to 1992 actual inflation declined by almost 6 percentage points from 8.3 percent in

[16] I get similar results if the sample mean over 1954Q3 to 1992Q4 is instead used.

1979 to 2.7 percent in 1992. However, most of this deceleration in inflation occurred during two subperiods 1979 to 1982 and 1990 to 1992. Inflation declined by about 4 percentage points from 8.3 percent in 1979 to 4.3 percent in 1982, then hovered around 4.0 percent until 1990, declining thereafter to 2.7 percent in 1992. I assume that the decline in inflation observed during this subperiod was due to Fed policy and that the Fed behaved as if it had short-term inflation targets. Hence, I assume short-term inflation targets that successively decline over time, so that they roughly match the temporal pattern and the overall reduction of inflation rates during this subperiod. In the particular scenario assumed here, the inflation target variable takes values 8.3 in 1979, 7.3 in 1980, 6.3 in 1981, 5.3 in 1982, 4.3 in 1983 -1984, 4.0 in 1985-1990, 3.5 in 1991, and 3.0 in 1992. Table 7 presents funds rate equations estimated with this new measure of the inflation target. The funds rate equation is estimated with and without including money growth. As can be seen, all variables appear with theoretically correct signs and are statistically significant. The dynamic within-sample simulations graphed in Chart 7 indicate that this reaction function is consistent with the actual path of the federal funds rate during the period 1979 to 1992.[17]

The funds rate equations reported in some other recent studies (Khoury 1990, McNees 1992) use forecasts of inflation and real GDP (growth). These studies thus assume that the Fed raises the funds rate if predicted real

---

[17]Alternatively, one could use as target values the midpoint of inflation predictions made by FOMC members at their July meetings each year. These predictions are made public by the Chairman as part of his Humphrey-Hawkins testimony to Congress. In this scenario, the inflation target variable takes values 10.2 in 1979, 9.5 in 1980, 8.2 in 1981, 5.4 in 1982, 4.6 in 1983, 3.9 in 1984, 3.8 in 1985, 2.2 in 1986, 3.6 in 1987, 3.4 in 1988, 4.6 in 1989, 4.2 in 1990, 3.2 in 1991 and 3.0 in 1992. The funds rate equation estimated using this measure of inflation target gave qualitatively similar results.

GDP rises, or if predicted inflation increases. The predicted values used in these reaction function studies usually come from the forecasts presented at the Federal Open Market Committee meetings and the private forecasts prepared by some prominent commercial forecasting services. In contrast, the funds rate equation here includes actual, lagged values of real GDP and inflation. The results here however do not rule out the Fed behavior assumed in these other studies. If the Fed and private forecasters use past inflation and real GDP in predicting future inflation and real GDP, then the funds rate will be correlated with past inflation and real GDP.[18]

3.6 A Counterfactual Simulation

The short-run, federal funds rate equations estimated here use the latest revised data, rather the data the FOMC actually observed at the time. This raises the question whether the short-run reaction functions are robust

---

[18]This can be easily seen as follows. Assume that the Fed's reaction function is of the form

$$\Delta FR_t = a_o + a_1 \, (p_t^e - p_{t-1}^e) + a_2 \, (\ln y_t - \ln y_t^T)^e,$$

where p_t^e is predicted inflation; and $(\ln y_t - \ln y_t^T)^e$ is predicted real GDP gap. Assume that these variables are determined as follows.

$$p_t = d_o + d_1 \, p_{t-1} + e_{1t}$$

$$(\ln y_t - \ln y_t^T) = f_o + f_1 \, (\ln y_{t-1} - \ln y_{t-1}^T) + \epsilon_{2t}$$

If the Fed and private forecasters use these equations to generate their forecasts, then the funds rate equation that include only know information can be expressed as follows.

$$\Delta FR_t = a_o + a_2 \, f_o + a_1 \, d_1 \, (p_{t-1} - p_{t-2}) + a_2 \, f_1 \, (\ln y_{t-1} - \ln y_{t-1}^T)$$

Thus, the funds rate will be correlated with lagged inflation and real GDP.

to revisions in the data used. Rather than re-estimate the equations using the preliminary available data I examine this robustness issue in a different way.

I begin with the assumption that the Fed behavior since 1979 can be described by a reaction function of the form

$$\Delta FR_t = .25\ (\ln y_{t-1} - \ln y^*_{t-1}) + .4(p_{t-2} - \bar{p}_{t-2})$$

$$+ .2\ (R10_{t-1} - p_{t-1}) + .4\ (FR^*_{t-1} - FR_{t-1}) \qquad (11)$$

where

$$FR^*_t = \bar{m} + p_t$$

The reaction function (11) embodies the key properties of the short-run federal funds rate equations estimated here. The coefficients that appear on economic variables in (11) come from those reported in Table 4. I then conduct a counterfactual simulation of (11) over 1979 to 1992, using not actual but model-generated values of real GDP and inflation. The results of this exercise provide a somewhat different evidence on the issue whether the reaction function estimated here is consistent with actual policy during this subperiod. [The macromodel used is the Keynesian model[19] employed recently by McCallum (1988) and Judd and Motley (1992), and simulations assume the economy

---

[19]The Keynesian model, estimated over 1959Q1 to 1992Q4, consists of four equations (Judd and Motley 1992). The first is the real aggregate demand equation in which the growth rate of real GDP is a function of the lagged growth rate of real M2, real government spending, and its own lagged value. The second is the aggregate supply equation in which the current inflation rate depends upon past inflation and the gap between actual and trend GDP. The third equation defines trend GDP, $\ln y^*$, as the fitted values of a log linear time trend of real GDP. The fourth equation is the real M2 demand equation in which the growth rate of real M2 is a function of current and lagged growth rates of real GDP, short-term interest rates (measured here by the funds rate) and own lagged values. In addition, lagged levels of these variables also appear in the real money demand equation, because M2 is found cointegrated with real GDP and interest rates.

was hit by the same set of shocks that actually occurred during this subperiod.] The variable $\bar{p}$ in (11) was either measured by lagged inflation rates or followed the disinflation path assumed in the previous section. Table 8 presents values of the funds rate, simulated and actual. Chart 8 graphs these values. As can be seen, simulated paths of the funds rate generated by (11) are fairly close to actual paths. These results confirm that short-run reaction functions estimated here capture the key determinants of the funds rate during the period 1979 to 1992.

4. Concluding Observations

This paper finds that the federal funds rate and the inflation rate are cointegrated during the sample period 1954Q3 to 1992Q4. The results indicate that the funds rate adjusts one-for-one with the actual inflation rate in the long run. In the short run, however, the funds rate differs substantially from the value given by this cointegrating relationship. Furthermore, in the short-run the funds rate has responded to some direct and and indirect measures of inflation and real GDP, the two final goal variables the Fed cares about.

These short-run responses however have not been stable over time. In particular, the evidence reported here indicates that the actual behavior of the funds rate during most of the 1980s is well predicted by a reaction function in which the funds rate rises if real GDP is above trend GDP, if actual inflation accelerates, or if the long-term bond rate and the equilibrium funds rate rise. Many of these short-run responses are missing, or found to be weak during the pre-1979 period.

Money growth when included in the short-run funds rate equation is generally significant, indicating that in the 1970s and the 1980s the funds rate has reacted to the information in money about inflation and/or real growth. The evidence reported here however indicates that in recent years the Fed may have discounted the leading indicator properties of the empirical M2 measure of money.

References

Campbell, J.Y. and P. Perron. "Pitfalls and Opportunities: What Macroeconomists *Should Know About Unit Root*." *in* O.J. Blanchard and S. Fischer, ed., NBER Macroeconomics Annual, MIT Press, Cambridge, 1990, pp. 141-200.

Carlson, John B. and Sharon F. Parrott. "The Demand for M2, Opportunity Cost, and Financial Change." Federal Reserve Bank of Cleveland Economic Review, vol. 27, Q2, 1991, pp. 2-11.

Cook, Timothy. "Determinants of the Federal funds Rate: 1979-1982", Federal Reserve Bank of Richmond Economic Review, vol. 75, January/February 1989, pp. 3-19.

Cook, Timothy and Thomas Hahn. "The Effect of Changes in the Federal Funds Rate Target on Market Interest Rates in the 1970s." Journal of Monetary Economics, vol. 24, November 1989, pp. 331-51.

Dejong, David N. and John C. Nankervis, N.E. Savin, and Charles H. Whiteman." Integration vs. Trend Stationarity in Time Series." Econometrica Vol. 60, March 1992, pp. 423-33.

Dickey, David A., and Wayne A. Fuller. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." Journal of the American Statistical Association, Vol. 74, June 1979, pp. 427-31.

Engle, Robert F. and Byung Saun Yoo. "Forecasting and Testing in Cointegrated Systems." Journal of Econometrics, vol. 35, May 1987, pp. 143-59.

Engle, Robert F. and C.W. Granger. "*Cointegration and Error-Correction*: Representation, Estimation and Testing." Econometrica, vol. 55, March 1987, pp. 251-76.

Goodfriend, Marvin. "Interest Rate Policy and the Inflation Scare Problem 1979-1992." Federal Reserve Bank of Richmond Economic Quarterly, Winter 1993.

Gregory, Allan N. and Bruce E. Hansen. "Residual-Based Tests for Cointegration Models with Regime Shifts." Mimeo. November 1992.

Hall, A. "Testing for a Unit Root in Time Series with Pretest Data Based Model Selection." Manuscript, North Carolina State University, 1990.

Hetzel, Robert L. "Why the Price Level Wanders Aimlessly": Federal Reserve Bank of Richmond, 1994, Mimeo.

Khoury, Salwa S. "The Federal Reserve Reaction Function: A Specification Search." The Political Economy of American Monetary Policy. edited by Thomas Mayer, Cambridge University Press, Cambridge 1990.

Johansen, S. and K. Juselius. "Maximum Likelihood Estimation and Inference on Cointegration--With Applications to the Demand for Money." Oxford Bulletin of Economics and Statistics, Vol. 52, May 1990, pp. 169-210.

Judd, John P. and Brian Motley. "Controlling Inflation with an Interest Rate Instrument." Federal Reserve Bank of San Francisco Economic Review, Number 3, 1992, pp. 3-22.

McCallum, Bennett T. "Robustness Properties of a Rule for Monetary Policy," in Carnegie-Rochester Conferences Series in Public Policy, 1988, pp. 173-204.

McNees, Stephen K. "A Forward Looking Monetary Policy Reaction Function: Continuity and Change." New England Economic Review. November/December 1992.

Mehra, Yash P. "Has M2 Demand Become Unstable?" Federal Reserve Bank of Richmond Economic Review, September/October 1992, pp. 27-35.

Poole, William. "Rules-of-Thumb for Guiding Monetary Policy." in Open Market Policies and Operating Procedures - Staff Studies, Board of Governors of the Federal Reserve System, pp. 135-89.

Stock, James H. and Mark W. Watson. "A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems." Econometrica, 61, 1993, 783-820.

Taylor, John B. "Discretion versus Policy Rules in Practice." A paper prepared for the November 1992 Carnegie-Rochester Conference on Public Policy.

Thornton, Daniel. "The Borrowed-Reserves Operating Procedure: Theory and Evidence." Federal Reserve Bank of St. Louis Economic Review, Vol. 10, January/February 1988, pp. 30-54.

Wallich, Henry C. "Recent Techniques of Monetary Policy." Federal Reserve Bank of Kansas City Economic Review, Vol. 69, May 1984, 21-30.

Wickens and Breusch. "Dynamic Specification, The Long-Run and the Estimation of Transformed Regression Models." The Economic Journal, vol. 98, 1988, pp. 189-205.

Table 1

Unit Root Test Results; 1954Q3 - 1992Q4

Z_t	ρ	t-statistic for ρ=1	Lag n	$x^2(1)$	$x^2(4)$	Q(36)
FR_t	.95	-1.97	7	.35	.97	33.6
p_t	.89	-2.09	2	.47	.55	24.2
$FR_t - p_t$	.85	-2.62^{*}	3	.06	.04	18.3

Notes: FR is the federal funds rate; and p_t is the inflation rate measured by the behavior of the implicit GDP deflator. The t-statistic and ρ above are from the Augmented Dickey-Fuller regression of the form

$$Z_t = \alpha + \rho Z_{t-1} + \sum_{s=1}^{n} e_s \Delta Z_{t-s},$$ where Z is the pertinent series. The number of lagged first differences (n) included in these regressions are chosen using the procedure given in Hall (1990). $X^2(1)$ and $x^2(4)$ are Lagrange Multiplier tests for 1st- and fourth-order serial correlation in the residuals of the Augmented Dickey-Fuller regression. Q(36) is the Ljung-Box Q-statistic, which tests for the presence of higher order serial correlation.

* significant at the 10 percent level.

Table 2

Long-run Federal Funds Rate Equation

A. FR_t and p_t Nonstationary; Dynamic OLS Regressions;

1954Q3 - 1992Q4

Leads and Lags		
(-4, 4)	1.	$FR_t = \underset{(1.3)}{1.6} + \underset{(3.7)}{1.1}\, p_t$; MA(10); $\chi_1^2(1) = .08$
(-8, 8)	2.	$FR_t = \underset{(1.6)}{2.3} + \underset{(3.3)}{.96}\, p_t$; MA(10); $\chi_1^2(1) = .02$

B. FR_t and p_t Stationary; IV Estimates;

1955Q4 - 1992Q4

3. $$FR_t = \underset{(.3)}{.05} + \underset{(2.9)}{.18}\, p_t + \underset{(11.3)}{1.09}\, FR_{t-1} - \underset{(3.3)}{.43}\, FR_{t-2}$$

$$+ \underset{(2.4)}{.30}\, FR_{t-3} - \underset{(1.3)}{.10}\, FR_{t-4}$$

Long-run Coefficient on $p_t = \underset{(23.6)}{1.04}$ DW = 1.9 Q(36) = 34.1

Notes: Parentheses contain t-values. Standard errors in Dynamic OLS regressions have been corrected for the presence of moving-average serial correlation. MA(10) indicates the presence of tenth-order moving-average serial correlation in the residuals. The order of moving-average is chosen by examining autocorrelations of residuals at various lags. X_1^2 is the Chi-square statistic that tests the hypothesis that the slope coefficient on p_t is unity and is distributed with one degree of freedom.

Regression (3) above is estimated by instrumental variables (IV). The instruments used are a constant, one lagged p_t, and four lagged values of FR_t. The long-run coefficient on p_t is calculated as the short-run coefficient on p_t divided by one minus the sum of coefficients that appear on lagged values of FR_t.

Table 3

Stability Test Results; Long-run Federal Funds Rate Equation

Leads and Lags	Regression
	A. Dynamic OLS Regressions
(-4, 4)	1. $FR_t = 1.0 + .91\ p_t + 2.4\ D_t + .34\ D_t p_t$; MA(3)
	(2.0) (6.7) (2.9) (2.1)
(-6, 6)	2. $FR_t = 1.1 + .90\ p_t + 2.7\ D_t + .32\ D_t p_t$; MA(3)
	(2.3) (6.5) (2.3) (2.3)
(-8, 8)	3. $FR_t = 1.3 + .86\ p_t + 3.1\ D_t + .23\ D_t p_t$; MA(3)
	(2.7)(6.4) (3.9) (1.4)
	B. Dynamic GLS Regressions
(-4, 4)	4. $FR_t = .6 + 1.1\ p_t + 2.9\ D_t + .05\ D_t p_t$; AR(1)
	(.6) (6.1) (2.9) (.4)
(-6, 6)	5. $FR_t = .51 + 1.1\ p_t + 3.2\ D_t + .03\ D_t p_t$; AR(1)
	(.5) (5.6) (3.1) (.2)
(-8, 8)	6. $FR_t = 1.1 + .96\ p_t + 3.5\ D_t + .02\ D_t p_t$; AR(1)
	(1.1)(5.2) (3.4) (.1)

Notes: Parentheses contain t-values corrected for the presence of serial correlation. MA(3) indicates that residuals have third-order moving average serial correlation. The order of moving-average is chosen by examining autocorrelations of residuals at various lags.

Regressions (4) through (6) are the dynamic GLS regressions estimated assuming that the residuals follow a first-order autoregressive process (AR(1)).

D is a zero-one dummy variable that takes values 1 over 1979Q4 to 1992Q4 and 0 otherwise.

Table 4

Short-run Federal Funds Rate Equations; 1955Q4 - 1992Q4

Independent Variables	Dependent Variable: ΔFR_t			
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
$(FR - FR^*)_{t-1}$	-.07 (1.5)	-.07 (1.5)	-.05 (1.3)	-.05 (1.3)
$D_{t-1}(FR - FR^*)_{t-1}$	-.23 (2.2)	-.21 (1.7)	-.37 (4.9)	-.36 (4.0)
$(lny - lny^*)_{t-1}$	.04 (2.3)	.03 (2.3)		
$D_{t-1}(lny - lny^*)_{t-1}$	.20 (2.0)	.19 (1.7)	.17 (3.3)	.16 (2.6)
$D_{t-2}\ \Delta p_{t-2}$	.33 (3.0)	.34 (2.9)	.27 (3.4)	.27 (3.2)
$D_t(R10 - p)_t$	.20 (3.0)	.18 (2.2)	.12 (1.8)	.11 (1.2)
ΔFR_{t-1}	.57 (4.1)	.57 (4.0)	.45 (3.0)	.45 (3.0)
ΔFR_{t-2}	-.38 (2.6)	-.38 (2.5)	-.19 (1.8)	-.19 (1.7)
$D_{t-1}\ \Delta FR_{t-1}$	-.48 (2.6)	-.48 (2.0)	-.44 (2.4)	-.44 (2.4)
$D1M1_{t-1}$			.03 (1.2)	.03 (1.2)
$D1M1_{t-2}$			.07 (2.3)	.07 (2.3)
$D2M1_{t-1}$			.28 (4.7)	.28 (4.8)
$D3M2_{t-1}$			.13 (3.6)	.14 (3.3)
$\bar{R}^2$	.37	.37	.54	.54
DW	2.0	2.0	1.87	1.87
Q(36)	30.8	30.4	46.0	45.7

Notes: FR^* is the long-run equilibrium value determined as $FR^*_t = 1.89 + p_t$; lny is the natural logarithm of real GDP; lny^* is the value predicted from a regression of lny on constant and linear trend; p_t is the inflation rate; R10 is the ten-year bond rate; and M1 and M2, respectively, are M1 (one-quarter annualized growth rate) and M2 (four-quarter growth rate) measures of money. D1 is a dummy variable that is 1 over 1954Q3 to 1979Q3 and 0 otherwise; D2 is a dummy that is 1 over 1979Q4 to 1982Q3 and 0 otherwise; and D3 is a dummy that is 1 over 1982Q4 to 1992Q4 and 0 otherwise. Parentheses contain heteroscedastic-consistent t-values.

Table 5

Actual and Predicted Values of the Funds Rate

Year		Reaction Function Without Money		Reaction Function With Money	
	Actual (1)	Predicted (Error) (3)	Predicted (Error) (2)	Predicted (Error) (4)	Predicted (Error) (5)
1979	11.1		10.4 (.8)		11.0 (.1)
1980	13.3		11.9 (1.4)		13.5 (-.1)
1981	16.4		13.4 (2.9)		16.2 (.2)
1982	12.2		11.6 (.6)		12.4 (-.2)
1983	9.1		8.3 (.7)		8.7 (.3)
1984	10.2		9.9 (.2)		9.9 (.3)
1985	8.1		9.3(-1.2)		8.6 (-.5)
1986	6.8		7.6 (-.8)		7.2 (-.4)
1987	6.6	7.0 (-.3)	7.3 (-.6)	7.0 (-.4)	7.2 (-.5)
1988	7.5	7.7 (-.2)	7.9 (-.3)	7.3 (.3)	7.2 (.3)
1989	9.2	8.1 (1.1)	8.2 (.9)	7.6 (1.6)	7.4 (1.8)
1990	8.1	8.1 (.0)	7.4 (.6)	7.7 (.3)	6.8 (1.2)
1991	5.7	6.1 (-.4)	5.6 (.1)	6.1 (-.4)	5.2 (.5)
1992	3.5	3.6 (-.1)	3.5 (.0)	3.7 (-.2)	3.0 (.5)
Mean Error		.01	.38	.21	.26
RMSE		.49	1.07	.73	.68

Notes: Predicted values given in columns (2) and (5) above are generated using the policy reaction functions given in Table 4 that are re-estimated (by OLS) over 1955Q4 to 1986Q4 and then dynamically simulated over 1979Q1 to 1992Q4. Predicted values given in columns (3) and (4) above are the dynamic, one-year ahead forecasts generated using rolling regressions (see footnote 10 in the text).

Table 6

Short-run Federal Funds Rate Equations; 1970Q4 - 1992Q4

Independent Variables	Dependent Variable: ΔFR_t			
	$\ln y^*$: Trend GDP		$\ln y^*$: Potential GDP	
	IV	OLS	IV	OLS
$(FR - FR^*)_{t-1}$	.03 (.5)	.03 (.5)	.03 (.5)	.04 (.6)
$D_{t-1}\,(FR - FR^*)_{t-1}$	-.44 (6.0)	-.44 (6.0)	-.44 (5.9)	-.44 (5.9)
$(\ln y - \ln y^*)_{t-1}$	.19 (3.6)	.19 (3.9)	.19 (3.2)	.18 (3.6)
$D_{t-2}\;\Delta p_{t-2}$	.37 (4.8)	.37 (4.9)	.36 (4.8)	.36 (4.9)
$D_{t-3}\;\Delta p_{t-3}$	.24 (3.4)	.23 (3.3)	.23 (3.3)	.23 (3.2)
$(R10 - p)_t$	.25 (2.7)	.23 (3.5)	.25 (2.7)	.24 (3.5)
$D1M1_{t-1}$	.11 (2.7)	.11 (2.5)	.10 (2.4)	.10 (2.2)
$D1M1_{t-2}$	.17 (3.4)	.17 (3.6)	.17 (3.3)	.17 (3.4)
$D2M1_{t-1}$	.32 (6.6)	.32 (6.5)	.33 (6.9)	.33 (6.8)
$D3M2_{t-1}$	.12 (4.1)	.12 (4.8)	.13 (4.9)	.14 (5.5)
ΔFR_{t-1}	-.23 (1.9)	-.23 (1.9)	-.20 (1.7)	-.20 (1.7)
$\bar{R}^2$	.67	.67	.66	.66
DW	2.1	2.1	2.1	2.0
Q(22)	23.8	23.8	23.2	23.1

Notes: See notes in Table 4. The long-run federal funds rate equation used above is $2.6 + p_t$, where 2.6 is the sample mean of the real funds rate over 1970Q1 to 1992Q4.

Table 7

Short-run Federal Funds Rate Equations With Assumed Inflation Targets Over 1979 to 1992; 1955Q4 - 1992Q4

Independent Variables	Dependent Variable: ΔFR_t	
	IV	IV
$(FR - FR^*)_{t-1}$	-.07 (1.8)	-0.5 (1.3)
$D_{t-1}\ (FR - FR^*)_{t-1}$	-.45 (3.3)	-.53 (6.7)
$(\ln y - \ln y^*)_{t-1}$	.04 (2.5)	
$D_{t-1}\ (\ln y - \ln y^*)_{t-1}$	.26 (2.8)	.16 (2.6)
$D_{t-2}\ (p - \bar{p})_{t-2}$	.41 (2.7)	.39 (3.4)
$D_{t-1}\ (R10 - p)_t$	.33 (3.8)	.18 (2.3)
ΔFR_{t-1}	.57 (4.3)	.45 (3.0)
ΔFR_{t-2}	-.40 (3.4)	-.20 (2.3)
$D_{t-1}\ \Delta FR_{t-1}$	-.48 (2.3)	-.42 (2.3)
$D1M1_{t-1}$		.02 (.8)
$D1M1_{t-2}$		.08 (2.4)
$D2M1_{t-1}$		.24 (4.9)
$D3M2_{t-1}$		.17 (4.5)
$\bar{R}^2$	.39	.55
DW	1.84	1.84
Q(36)	36.8	46.2

Notes: $\bar{p}_t$ is the inflation target. All other variables are defined as before (see notes in Table 4). $\bar{p}_t$ takes values 8.3 in 1979, 7.3 in 1980, 6.3 in 1981, 5.3 in 1980, 4.3 in 1983-1984, 4.0 in 1985-1990, 3.5 in 1991, and 3.0 in 1992.

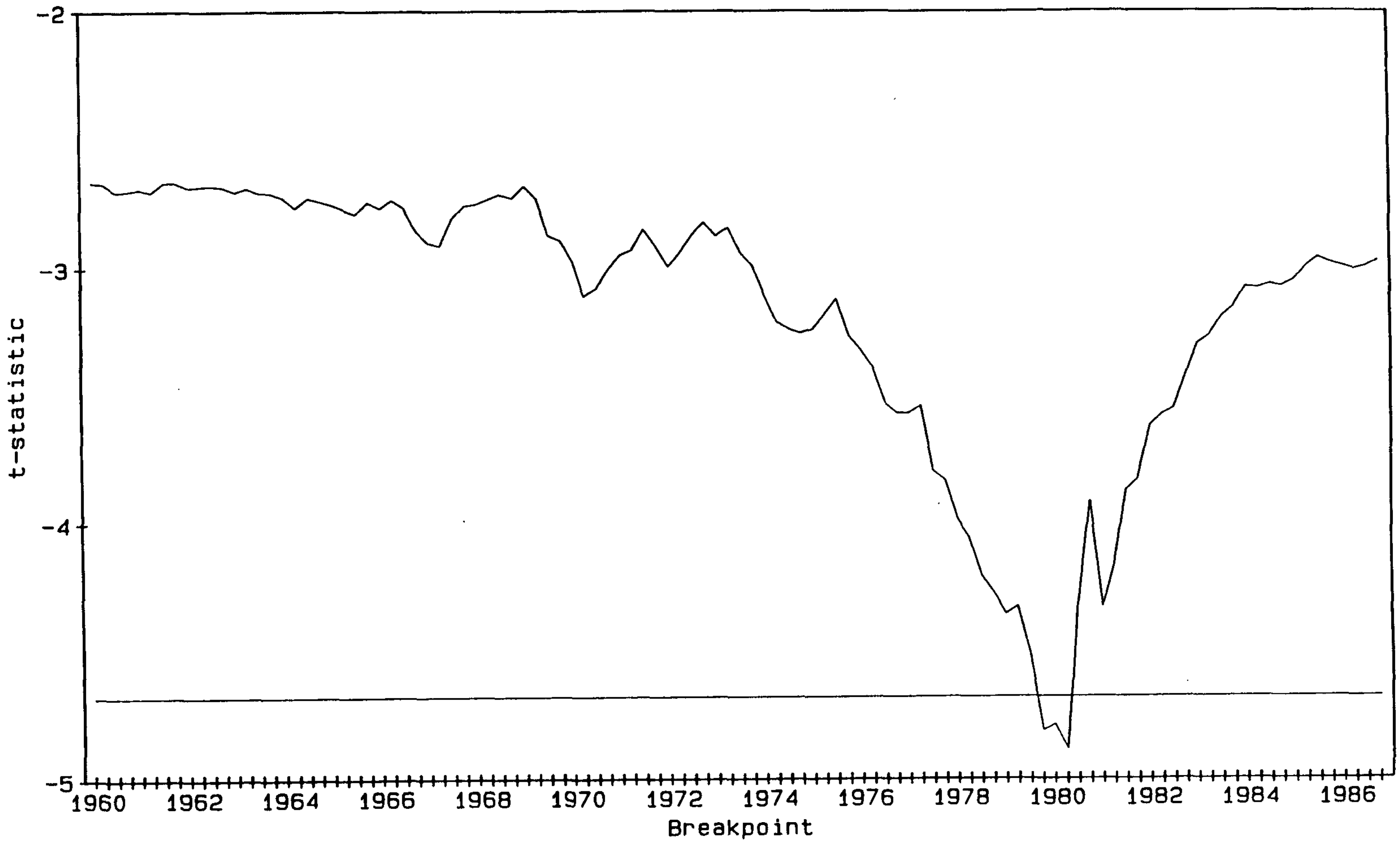
Table 8

Actual and Simulated (Using a Policy Rule) Values of the Funds Rate

Year	Inflation Target ($\bar{p}_t$): Last Period Inflation Rate			Inflation Target ($\bar{p}_t$): Disinflation Path Given in Table 7	
	Actual	Simulated	Error	Simulated	Error
1979	11.2	12.1	-.9	12.4	-1.20
1980	13.3	13.3	.06	13.6	-.2
1981	16.4	13.6	2.8	15.6	.8
1982	12.2	11.5	1.7	13.0	-.7
1983	9.1	7.6	1.5	6.6	2.4
1984	10.2	9.9	.3	9.6	.6
1985	8.1	9.4	-1.3	10.2	-2.1
1986	6.8	7.1	-.3	6.8	.0
1987	6.6	6.6	.1	5.4	1.2
1988	7.6	8.2	-.7	7.8	-.2
1989	9.2	9.0	.2	9.7	-.4
1990	8.1	8.3	-.2	8.5	-.4
1991	5.7	6.3	-.6	6.4	-.7
1992	3.5	3.8	-.3	3.5	0
Mean Error			.1		-.1
RMSE			1.00		1.08

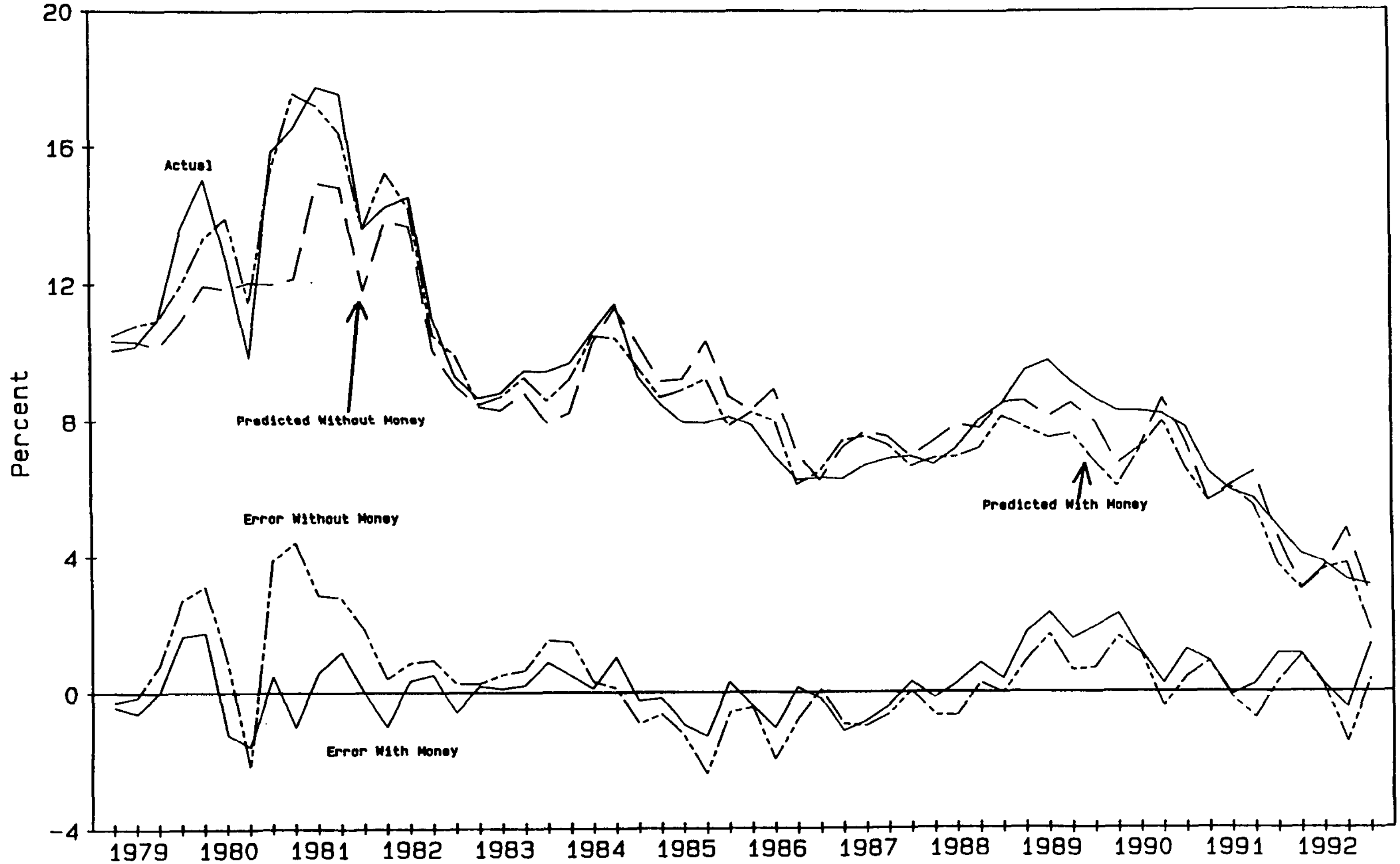
Notes: Simulations use the policy rule (11) and the Keynesian model summarized in footnote (12) of the text. Simulations begin in 1979.

Chart 1
Test for Cointegration With Regime Shift



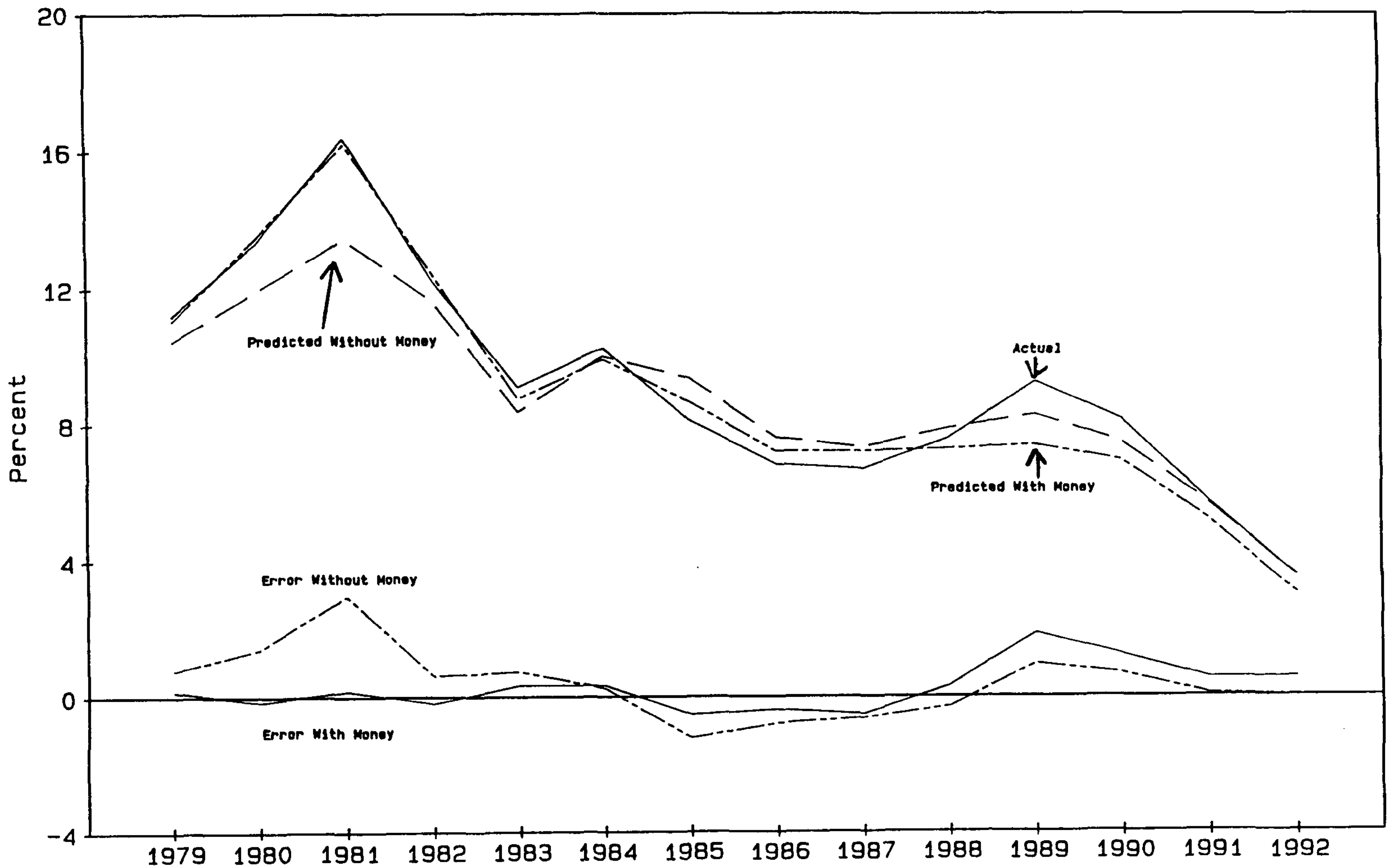
Notes: T-statistic tests the null hypothesis that rho=0 in the Augmented Dickey-Fuller regression of the form (12) given in the text for a given breakpoint in the interval (.15T, .85T), where T is the sample size. Solid line at -4.68 represent 10 percent critical value.

Chart 2
The Federal Funds Rate; Quarterly,
1979Q1 to 1992Q4



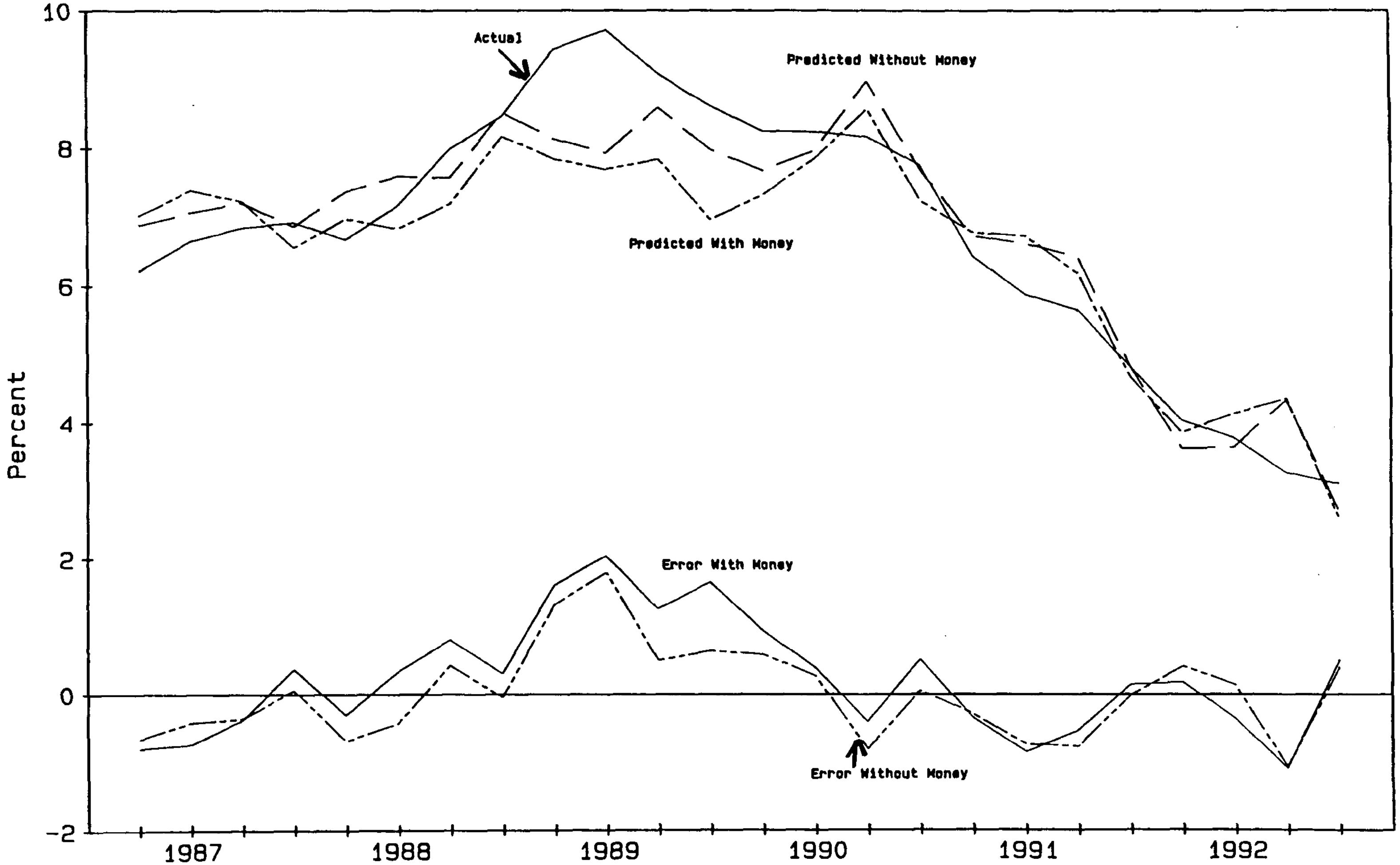
Notes: Predicted values are the quarterly values of annual numbers reported in columns (2) and (5), Table 5.

Chart 3
The Federal Funds Rate; Annual,
1979 - 1992



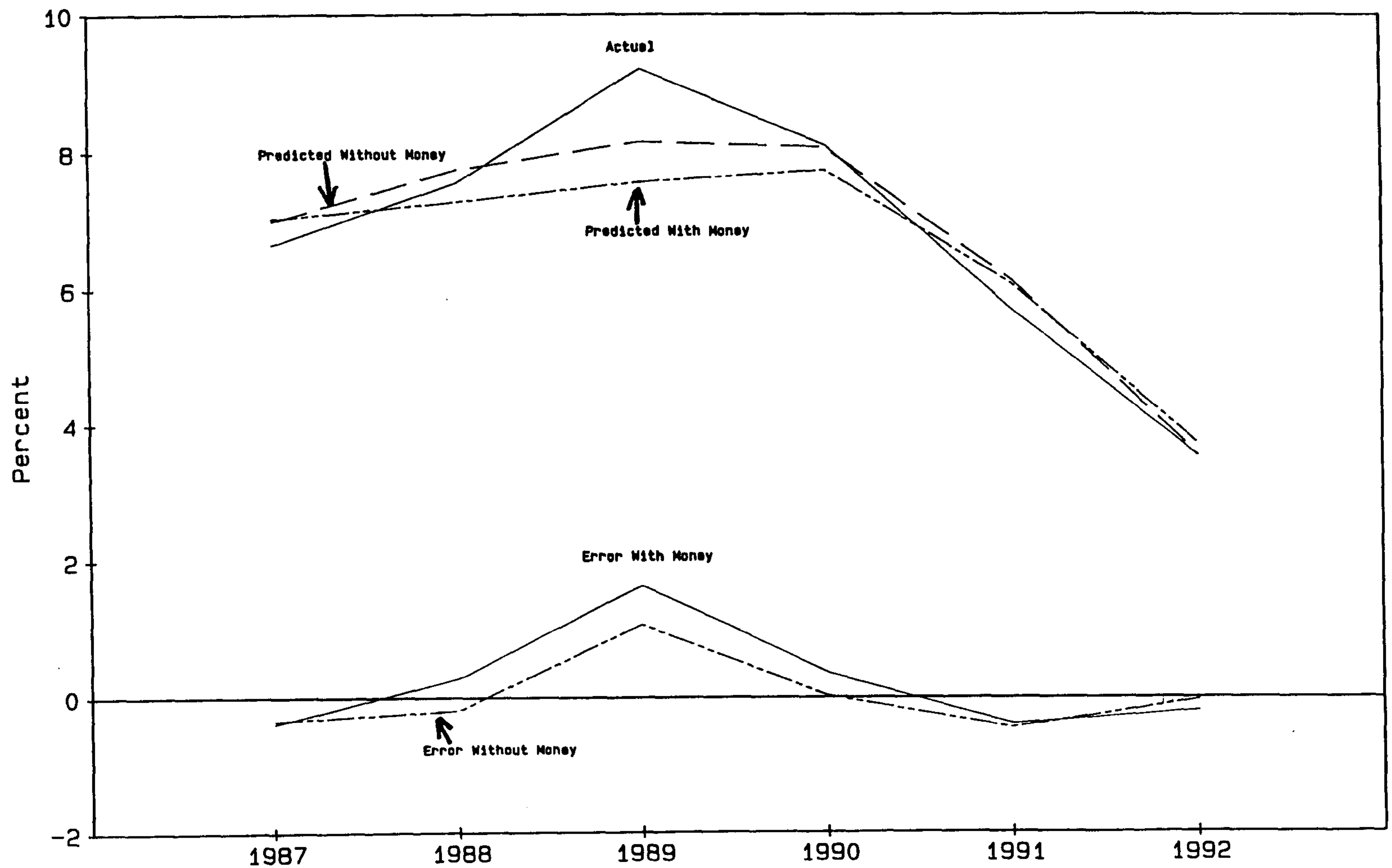
Notes: Predicted values are the annual numbers reported in columns (2) and (5), Table 5.

Chart 4
The Federal Funds Rate; Quarterly,
1987Q1 to 1992Q4



Notes: Predicted values are the quarterly values of annual numbers reported in columns (3) and (4), Table 5.

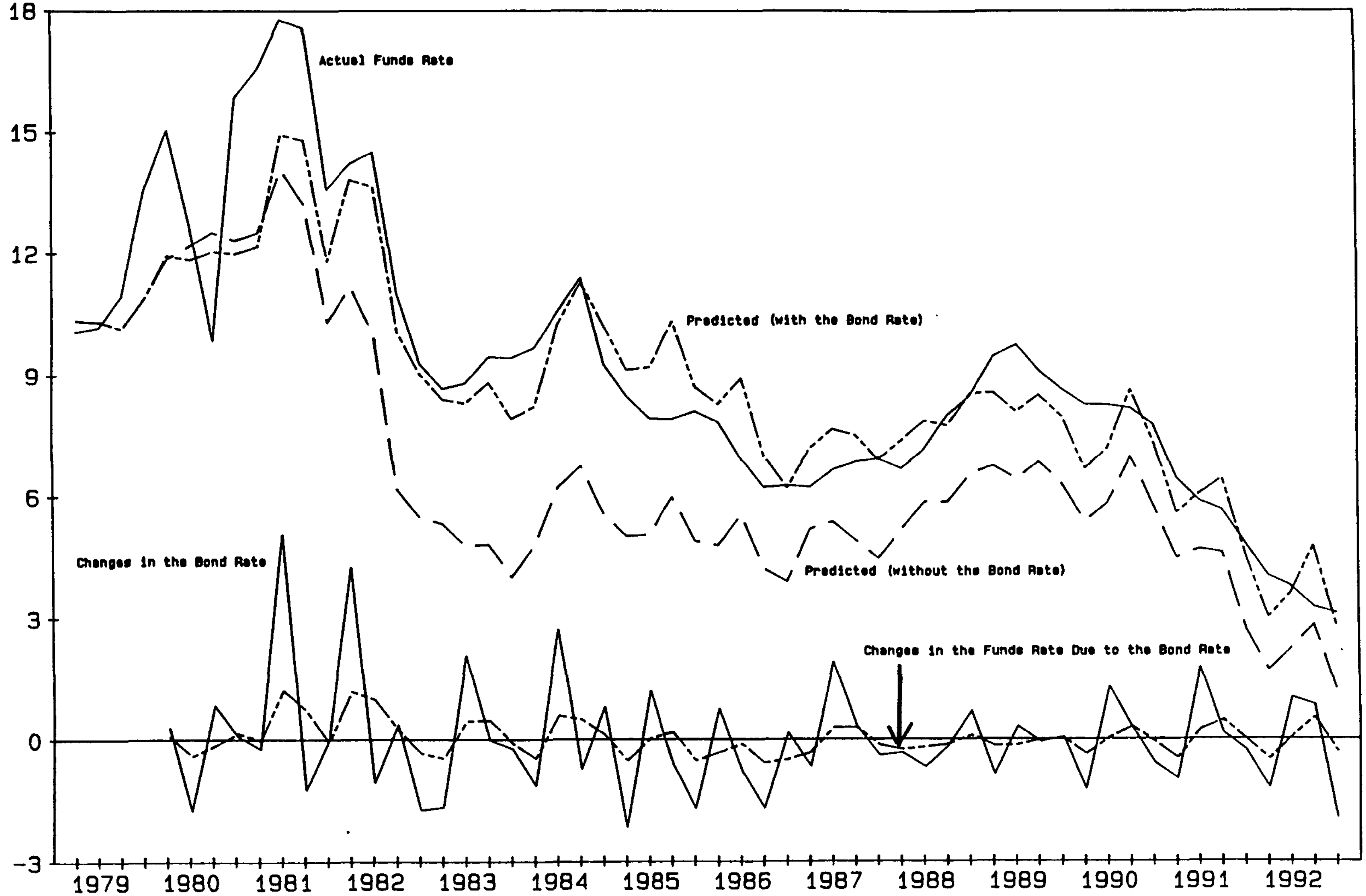
Chart 5
The Federal Funds Rate; Annual,
1987 - 1992



Notes: Predicted values are the annual numbers reported in columns (3) and (4), Table 5.

Chart 6

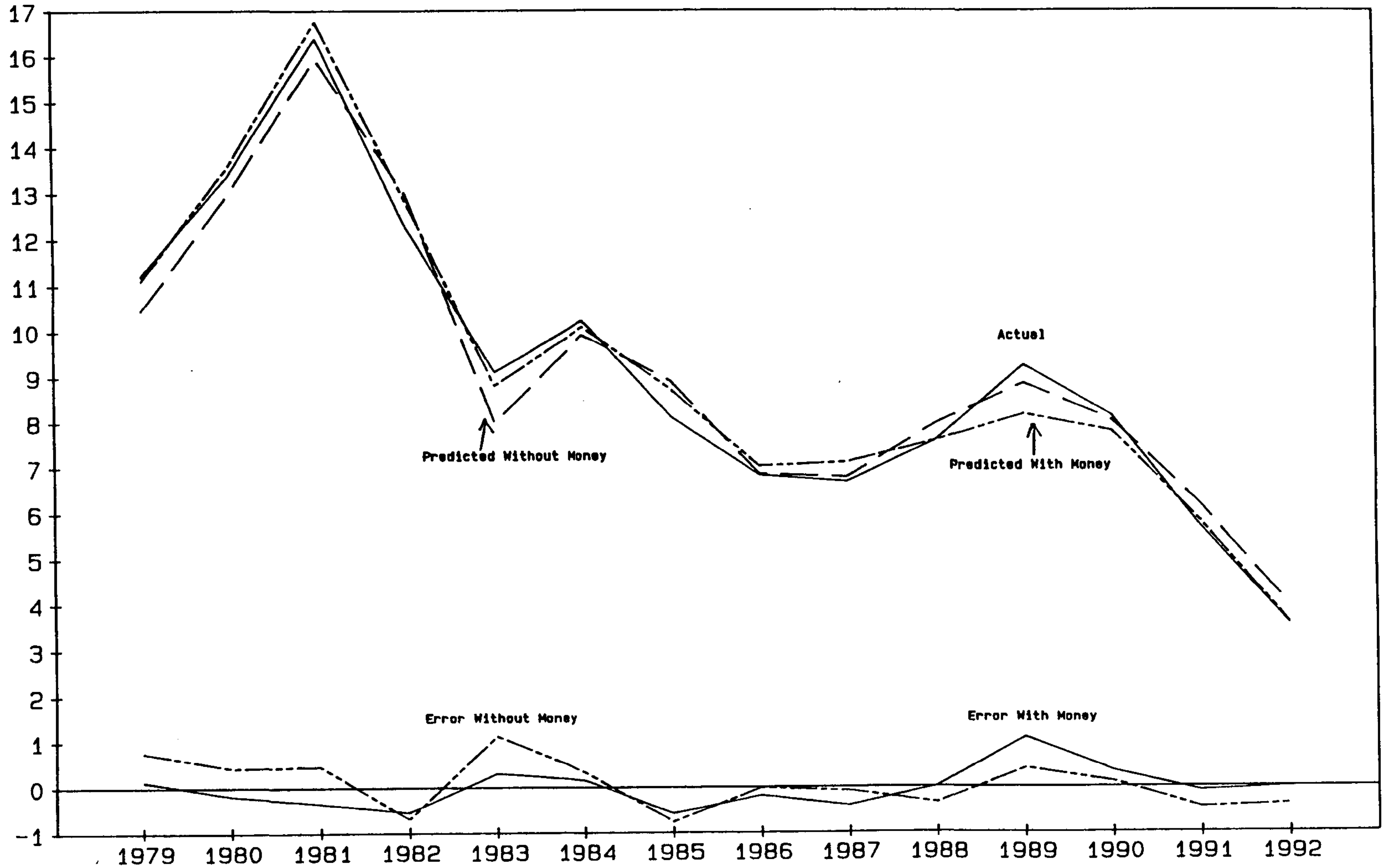
The Role of the Bond Rate



Notes: Predicted values are generated using the funds rate equation without money. See footnote 15 in the text.

Chart 7

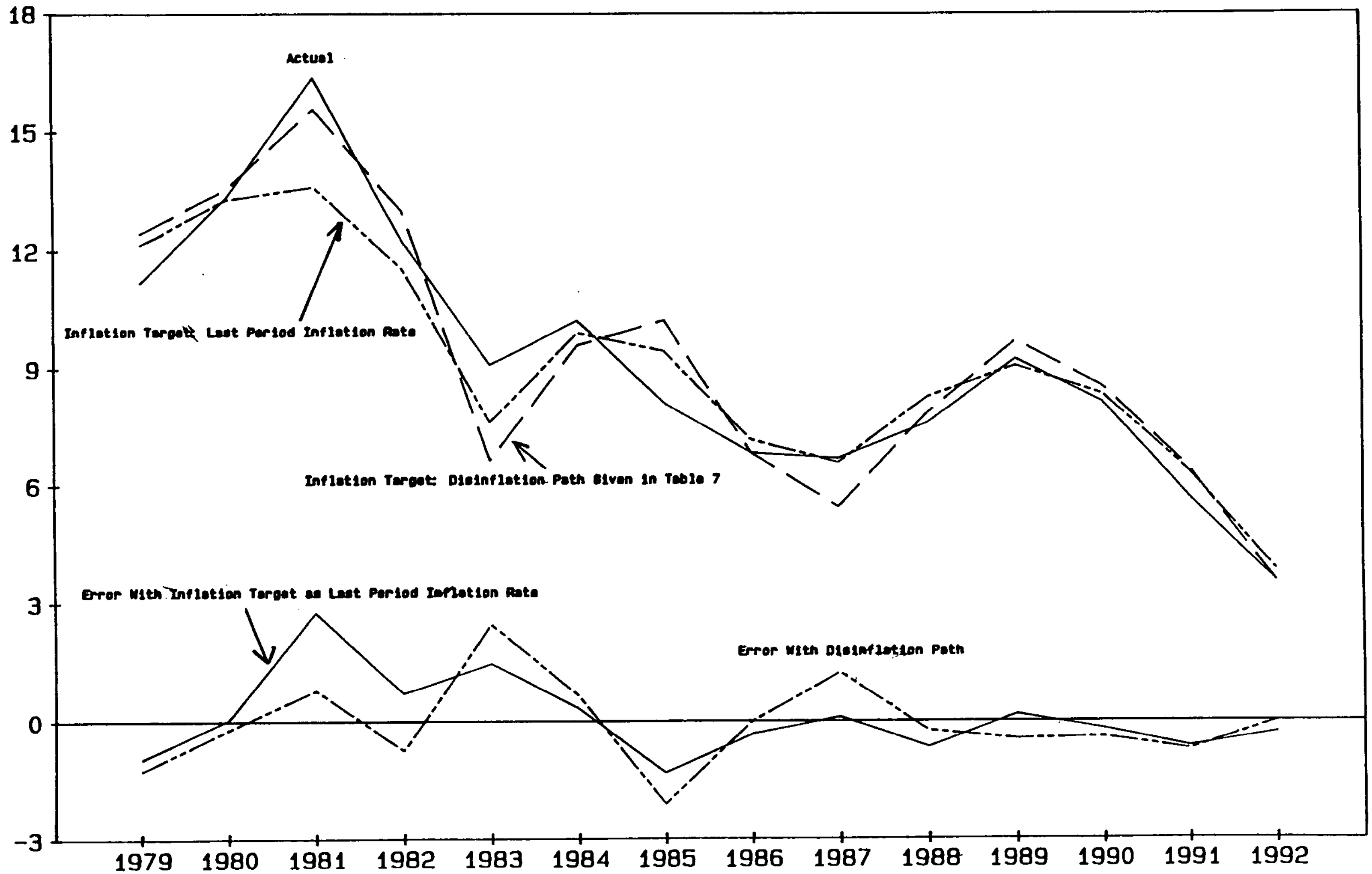
Actual and Predicted Funds Rate;
Annual Averages



Notes: Predicted values are the dynamic, within-sample forecasts generated using the regressions reported in Table 7.

Chart 8

Actual and Simulated Funds Rate; Annual Averages



Notes: Simulated values are generated using the policy rule (11) of the text.