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Keywords: Discount rate, stationarity, cointegration, market efficiency, federal funds rate targeting.

JEL subject numbers: E4, E43, E44, E60

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Why Do T-Bill Rates React to Discount Rate Changes?

Abstract

This paper investigates the hypothesis suggested by Cook and Hahn (1988) that the T-bill rates respond to the announcement of discount rate changes because the market takes discount rate changes to be a signal that the Fed has changed its target for the federal funds rate. Re-Interpreting Cook and Hahn's empirical evidence and using theirs and an alternative methodology, we show that the evidence cannot differentiate their hypothesis from a number of others that have been suggested in the literature. We further find that there is no difference in the relative magnitude or timing of the response during periods when the Fed was directly targeting the funds rate or using a "fuzzy" funds rate target. This result suggests that the market does not simply interpret discount rate changes as a signal that the Fed has changed its target for the funds rate.

Keywords

Discount rate, stationarity, cointegration, market efficiency, federal funds rate targeting

JEL Classification

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WHY DO T-BILL RATES REACT TO DISCOUNT RATE CHANGES?

by Daniel L. Thornton

> "Unfortunately, it has always seemed to me that the country has given exaggerated importance to change of the discount rate."
>
> -- Benjamin Strong, Testimony to the House Banking and Currency Committee, 1926.

The view that the Fed exerts a dominant influence on short-term interest rates through direct control of the federal funds rate has now become commonplace, not only among Federal Reserve officials and market participants but, increasingly, among professional economists. Indeed, Goodfriend (1991) asserts that "the Fed targets the Federal funds rate with the aim of stabilizing and manipulating longer-term money market rates." According to this view, the relationship of short-term interest rates to the federal funds rate is consistent with the expectations theory of the term structure of interest rates, i.e., longer-term interest rates are determined by the average expected *level* of the funds rate over the relevant holding period of the longer-term assets. The Fed thus controls longer-term interest rates by manipulating the federal funds rate. Rather than targeting the funds rate directly, however, Goodfriend notes that the Fed has often preferred to operate surreptitiously, targeting the funds rate indirectly by "using the *discount rate* and borrowed reserve targets."

Recently Cook and Hahn (1988) have argued that non-technical changes in the discount rate (i.e., changes made for reasons other than to keep the funds rate in line with market rates) affect the T-bill rate in a manner consistent with what Goodfriend calls the "standard view." Arguing

that the Fed signals its intention to change its target for the *level* of the federal funds rate through non-technical changes in the discount rate, Cook and Hahn (1988) provide evidence which they claim shows that non-technical changes in the discount rate have a permanent effect on the average level of the funds rate over the holding periods that correspond to those of 3-month and 6-month Treasury bills. Elsewhere, Cook and Hahn (1989) interpret their results as providing evidence that the Federal Reserve plays a dominant role in the evolution of short-term interest rates through its direct control over the federal funds rate.

Unfortunately, Cook and Hahn perform their test in a framework where the alternative hypothesis--that discount rate changes have a *temporary* effect on the level of the funds rate--is not feasible.[1] Moreover, because their estimating equation results from a particular, if not somewhat peculiar, stationarity-inducing transformation of interest rates, it does not provide an estimate of the effect of a change in the discount

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1. This may stem from their failure always to clearly distinguish persistence in the <u>changes</u> in the federal funds rate from persistent changes in the <u>level</u> of the federal funds rate. For example, Cook and Hahn (1989) state, "under the expectations theory, this stable pattern of bill rate responses across these maturities arises if changes in the funds rate target are expected to persist for the subsequent year. It also arises if the funds rate is expected to change in the near future and then stay at its new level for the subsequent year. For example, suppose a discount rate announcement generates expectations of a 50 basis point change in the funds rate the following week, after which no further change in the rate is expected. In such a case under the expectations theory the effect on the slope of the yield curve from 3 to 6 months and 6 to 12 months would be negligible. The difference between the current 1-week and 1-month rates would be 37 basis points, but the difference between the 3-month and 6-month rates would be only 2 basis points and the difference between the 6- and 12-month rates would be only one basis point." Obviously, if the federal funds rate changes 50 basis points with no further changes, the expectations theory would suggest that the level of rates would change by 50 basis points at all maturities.

rate on the level of market rates over the hypothesized holding periods. Instead, it merely provides estimates of the combined immediate and lagged responses of the funds rate to discount rate changes.

Using both a modified form of Cook and Hahn's procedure and an alternative procedure based on a simpler stationarity-inducing transformation, I test the hypothesis that the federal funds and T-bill rates respond immediately and simultaneously to announcements of discount rate changes. If the rates respond simultaneously, the evidence cannot distinguish Cook and Hahn's hypothesis of why markets respond to discount rate changes from a number of observationally equivalent alternative hypotheses that have been suggested in the literature.

I investigate the assertion that non-technical discount rate changes signal a change in the target for the level of the funds rate by testing for the presence of a lag in the response of T-bill rates to discount rate changes during periods when the Fed was targeting the federal funds rate indirectly. Goodfriend (1991) argues that when the Fed uses indirect or "fuzzy" funds rate targeting, "it generally takes the market longer to perceive changes in the target." If the market interprets non-technical changes in the discount rate as a signal that the Fed has changed its target for the federal funds rate, during periods of a "fuzzy" federal funds rate peg there should be a lag in the response of the T-bill rate to non-technical changes in the discount rate.

Finally, I propose an alternative test that permits discount rate changes to have either a permanent or temporary effect on the structure of interest rates by first testing for the existence of a stationary relationship between the <u>levels</u> of the federal funds and T-bill rates, and then testing whether changes in the discount rate alter the structural

relationship between the levels of these rates. If discount rate changes provide information about the Fed's target for the funds rate and the standard view of the evolution of short-term interest rates is correct, then discount rate changes should temporarily alter the relationship between the levels of the federal funds and T-bill rates. If, however, the response of interest rates to an announcement of a non-technical discount rate change is simultaneous, then such information provides no explanation for the market's response.

1. *WHY DO MARKETS RESPOND TO DISCOUNT RATE CHANGES?*

That market interest rates respond significantly to discount rate changes is well-established. Recently, it has been shown that this response is solely attributable to discount rate changes that the Fed announces are made for non-technical reasons, i.e., for reasons other than to keep the discount rate in line with market interest rates, [Smirlock and Yawitz (1985), Cook and Hahn (1988) and Thornton (1982, 1986, 1991)]. What remains unclear is the reason for this response.

There has been a long-standing debate among monetary policy analysts about the interpretation of changes in the discount rate, and why markets respond to them. Early critics of the discount mechanism focused on the difficulty of interpreting the meaning of changes in the discount rate.[2] Nevertheless, it is frequently asserted that discount rate changes signal changes in monetary policy, with increases in the rate signaling a move toward restraint and decreases a move toward ease. Alternatively, some analysts believe that discount rate changes merely confirm policy changes

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2. See Smith (1956, 1958) and Friedman (1959). Many money and banking texts still allude to the difficulty interpreting the meaning of a discount rate change. For example, see Mishkin (1992), p.432-4.

that have already taken place. Still others contend that they convey information about the Fed's belief concerning future changes in economic activity or interest rates--whether or not the Fed *causes* these changes.[3]

Cook and Hahn (1988) have offered a novel and very specific form of the hypothesis that discount rate changes signal a change in monetary policy. Specifically, they assert that such changes signal changes in the Fed's target for the level of the federal funds rate. If this hypothesis is correct, changes in the discount rate should be associated with persistent changes in the level of the funds rate. If this hypothesis is correct and T-bill rates are related to the federal funds rate via the expectations theory of the term structure, discount rate changes should be associated with corresponding changes in the T-bill rate. On the other hand, if the change is not expected to persist, the effect on the T-bill rate should be nil.

There are several crucial aspects to Cook and Hahn's interpretation. First, the response of the T-bill and federal funds rates to discount rate changes cannot be simultaneous. If it is, there is simply no way to conclude that "revisions in funds rate expectations *caused* movements in the bill rates." [Cook and Hahn (1989)].

Second, it must be the case that changes in the discount rate produce permanent changes in the level of the funds rate. This would certainly be the case if the federal funds and discount rates are cointegrated. If they are not and if the funds rate itself is non-stationary, the effect of any shock to the funds rate is permanent--a discount rate change has no different affect than any other shock.[4] In

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3. See Thornton (1991) for a discussion of these and other interpretations of the effect of a change in the discount rate.

this instance, the statement that discount rate changes have a permanent effect on the level of the federal funds rate is not a hypothesis, but a tautology!

Third, because the announcement of a discount rate change is made known at a point in time, the response of the T-bill market should be delayed only if market participants are uncertain as to how to interpret the action. Otherwise, all rates should respond simultaneously and completely to the new information that the announcement of a discount rate change provides. Hence, if discount rate changes signal changes in the target for the funds rate, the response of the T-bill rate to changes in the discount rate should vary only with the degree to which the Fed is targeting the funds rate, with the adjustment being relatively swift when the Fed is targeting the funds rate directly and in a narrow range, and being relatively slow when the Fed is using a "fuzzy" funds rate target.

2.0 *ESTIMATING THE EFFECT OF DISCOUNT RATE CHANGES ON INTEREST RATES*

If the level of the funds rate is related to the level of the discount rate, it would make sense to estimate the equation

(1) $i_t = \mu + \beta DR_t + \epsilon_t$.

Here i_t denotes the level of a market interest rate (in the present discussion, the funds rate) at time t and DR_t is the level of the discount rate, and ϵ_t denotes a random error. β and μ are fixed parameters, with β measuring the response of the interest rate to a change in the discount

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4. For the purpose of this paper, I am agnostic about the deeper theoretical question of whether interest rates (nominal or real) are non-stationary. Instead, I will be content to note that one cannot reject the null-hypothesis of a unit root for the interest rates used here and that Cook and Hahn's analysis--as that of all others who have estimated the response of market interest rates to changes in the discount rate--is based on the assumption that empirically interest rates cannot be distinguished from non-stationary processes.

rate. One problem with Equation 1 is that the estimated error term, $\hat{\epsilon}_t$ tends to exhibit considerable persistence, i.e., $\hat{\epsilon}_t = \alpha\hat{\epsilon}_{t-1} + \eta_t$, where η_t is a stationary stochastic process and $\alpha \simeq 1$.[5] Indeed, tests of the hypothesis $\alpha = 1$ cannot be rejected.[6] Because of this, it is common to estimate the effect of discount rate changes by taking the first-difference of Equation 1. This yields

(2) $\Delta i_t = \beta\Delta DR_t + \eta_t$,

where ΔDR_t is the change in the discount rate between t-1 and t [note that the discount rate is changed infrequently, so that often, $\Delta DR_t = 0$]. As is well known, in this framework the effect of a change in the discount rate on the level of the interest rate is permanent.

Cook and Hahn estimate β for the federal funds rate by applying an alternative filter to Equation 1. Specifically, they estimate the equation,

(3) $i_{ave} - i_{t-1} = \beta'\Delta DR_t + \omega_t$

where i_{ave} is the average rate on the federal funds rate for either 91 or 182 days following the announcement of a non-technical change in

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5. The problem is that if α is large but less than one, the long-run effect of a change in the discount rate is implausibly large. The k-period effect is α^k and the permanent effect is $1/(1-\alpha)$. If α is 1, the immediate response is permanent. Alternatively stated, there is no long-run relationship between the market interest rate and the discount rate because even the conditional in the discount rate, i_t is non-stationary.

6. The estimates of α from the residuals from estimates of Equation 1 are larger than those reported in Table 2. Indeed, the estimates of β from Equation 1 are often negative and are never statistically significant.

the discount rate.[7] They interpret their estimates of β as measures of the persistent change in the funds rate over three-month and six-month holding periods, implying that β' measures the permanent change in the funds rate over these periods. However, as we have already noted, if interest rates are non-stationarity, all responses to discount rate changes in the level of rates are permanent. Moreover, because Equation 3 is obtained simply by using an alternative method for achieving stationarity, estimates of β' from it offer no more information about permanence of the interest rate changes than do estimates of β from Equation 2.

The correct interpretation of β' from Equation 3 can be obtained by noting that $i_{ave}-i_{t-1}$ can be decomposed into the initial change in the interest rate, i.e., i_t-i_{t-1}, and the average change over the next 90 or 181 days.[8] Hence β' really measures the immediate response plus the

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7. Actually, applying Cook and Hahn's filter to Equation 1 results in an equation that is slightly different from the one that they estimate, Equation 3. If α=1, Equation 1 can be rewritten as $i_t = i_{t-1} + \beta\Delta DR_t + \eta_t$. Therefore,

$$i_{t+j} = i_{t-1} + \beta\Delta DR_t + \sum_{i=0}^{j} \eta_{t-i}.$$ Using this fact

$$i_{ave} = (\sum_{j=1}^{N} i_t)/N = (\sum_{j=1}^{N} \alpha^j \; i_{t-1})/N + \beta \; \Delta DR_t + \sum_{j=0}^{N} \sum_{i=0}^{j} \eta_{t-i}/N, \text{ or}$$

$$i_{ave} = i_{t-1} + \beta\Delta DR_t + \sum_{j=0}^{N} \sum_{i=0}^{j} \eta_{t-i}/N.$$

Therefore, $i_{ave}-i_{t-1} = (i_{t-1}-i_{t-2}) + \beta\Delta DR_t + \omega_t$. Excluding the term $(i_{t-1}-i_{t-2})$ from Equation 3 will bias the estimate of β upward because $(i_{t-1}-i_{t-2})$ and ΔDR_t are positively correlated, i.e., discount rate changes follow movements in market interest rates in the same direction. Moreover, note that the error term ω_t follows a high-order MA process.

8. Note that $i_{ave}-i_{t-1} = \sum_{j=0}^{N-1} i_{t+j}/N - i_{t-1} = (i_t-i_{t-1})+[(N-1)/N](\tilde{i}_{ave}-i_t)$

$\simeq (i_t-i_{t-1}) + (\tilde{i}_{ave}-i_t)$,

where $\tilde{i}_{ave}$ is the average rate over the next N-1 days.

subsequent response of the interest rate to changes in the discount rate. Finding that the estimate of β' from Equation 3 is significantly larger than the estimate of β from Equation 2 would indicate that there is a lag in the response of the interest rate to changes in the discount rate. Such a finding for the federal funds rate would be odd because it would tend to suggest that the Fed signals a change in its target for the funds rate but delays in adjusting the rate to the new target level.

2.1 *An Alternative Test of Delayed Response*

An alternative, simpler and more straightforward test of a delayed reaction to discount rate changes is obtained by regressing changes in the interest rate on a distributed lag of changes in the discount rate. That is, estimating the equation

(4) $\Delta i_t = \beta(L)\Delta DR_t + \eta_t$,

where $\beta(L)$ is the usual polynomial lag operator, i.e., $\beta(L)=\beta_0 + \beta_1 L + \beta_2 L^2 + \ldots + \beta_K L^K$. Equation 4 can be conveniently reparameterized as

(5) $\Delta i_t = \Theta\Delta DR_t - \Gamma(L)\Delta^2 DR_{t-1} + \eta_t$.

The coefficient Θ, which is equal to $(\beta_0 + \beta_1 + \ldots + \beta_K)$, gives the "long-run" response of the **change** in the interest rate to a change in the discount rate. The coefficient Γ_1, which is equal to $(\beta_1+\beta_2+\ldots+\beta_K)$, gives the subsequent response after the initial response, β_0. If there is no delayed response to changes in the discount rate, the null hypothesis that $\Gamma_1 = 0$ should not be rejected. Hence, if the hypothesis is rejected for the funds rate, but not for the T-bill rate, either the Fed prevents the full adjustment of the federal funds rate or the T-bill market is efficient in incorporating the new information, but the federal funds market is not--an extremely unlikely alternative.

2.2 *An Alternative Test of the Effect of a Discount Rate Change on the T-bill Rate*

The problem with determining the effect of discount rate changes on the level of interest rates comes from the fact that the hypothesis that interest rates are non-stationary cannot be rejected. If interest rates are non-stationary, nothing meaningful can be said about the effect of discount rate announcements on the level of interest rates. A meaningful statement about the effect of a change in the discount rate on the level of interest rates can be made only if the empirical analysis is carried out in a framework where interest rates are stationary in the levels. Such a framework comes by noting that while unconditionally interest rates appear integrated, market efficiency and arbitrage suggest that rates on assets that are close substitutes will be cointegrated.

If the federal funds and T-bill rates are cointegrated, there is an alternative test of the transmission of the effect of discount rate changes to the T-bill rate through the federal funds rate. To illustrate this test, assume the federal funds rate, FFR, and the Treasury bill rate, TBR, are unconditionally integrated of order one, i.e., I(1), but they are cointegrated. Cointegration implies that

(7) $(1 \quad \delta)(TBR_t - FFR_t)' = u_t$

where $(1 \ \delta)$ is the cointegrating vector normalized on the T-bill rate, and u_t is a stationary--but not necessarily white noise--random variable. The hypothesis that discount rate changes are transmitted to the T-bill rates through the funds rate implies a causal chain running from the funds rate to the T-bill rates.[9] Consequently, an increase (decrease) in the

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9. For example, see Cook and Hahn (1988), p. 177, Cook and Hahn (1989), p. 342 and Goodfriend (1991), p. 24.

discount rate should cause the federal funds rate to rise (fall) relative to the T-bill rate. This effect is likely to be short-lived, however, for it seems unlikely that discount rate changes, or any other monetary policy actions for that matter, can alter the structure of short-term interest rates permanently.

The hypothesis that discount rate changes temporarily alter the structure of short-term interest rates can be tested by estimating the equation

$$(8) \quad u_t = \gamma(L)u_{t-1} + \beta(L)\Delta DR_t + \upsilon_t.$$

If this hypothesis is correct, $\beta(L)$ (especially, β_0) should be negative and statistically significant. The long-run effect of a change in the discount rate on the structure of federal funds and T-bill rates can be obtained from the steady-state solution of Equation 8.

3. *THE EMPIRICAL RESULTS*

The following analysis uses daily data for the federal funds rate and the 3-, 6- and 12-month T-bill rates, denoted TBR3, TBR6 and TBR12, respectively. The data are for the period January 3, 1973 through August 23, 1989. FFR is the weighted average of rates on daily transactions for a group of federal funds brokers and the T-bill rates are at "market close," around 4 p.m., E.S.T. All rates are compiled by the Federal Reserve Bank of New York. During this period there were 33 non-technical discount rate changes. The amount of each change and the date and day when each initially affected the market are presented in Table 1.

3.1 *Tests for Non-Stationarity*

Dickey-Fuller tests for a unit root are presented in Table 2 for each of the four market interest rates, along with the estimate of the root α. Dickey-Fuller tests were performed with and without an intercept

and the augmented Dickey-Fuller test was performed with an intercept and three lags of the first-difference of the interest rate. For the T-bill rates the results indicate a unit root. In all cases the estimate of α is very close to one and in no case was the null hypothesis of a unit root rejected. For the federal funds rate the test statistics reject the null hypothesis of a unit root, except for the most basic Dickey-Fuller test; however, all of the estimates of α are very close to unity. Consequently, it appears that all of the interest rates should be considered non-stationary.[10]

3.2 *Estimates of a Lag in the Response to Discount Rate Changes*

The empirical analysis begins by assessing the results obtained by estimating Equation 3. Because this stationarity-inducing transformation induces serial correlation in the residuals, only the 33 observations corresponding to the discount rate changes are used. To determine how much of the response to the discount rate change is due to the immediate or one-day response of the federal funds rate, the 91- and 182-day average changes were decomposed into the immediate or one-day change and the average change over the next 90 days and 181 days. Because the discount rate frequently was changed again within the 91-day and 182-day intervals, however, the average is calculated over the shorter interval when another discount rate change occurs within these time periods.[11] All of these

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10. The same qualitative results are obtained from tests of the residuals from Equation 1. Hence, there is no relationship between the level of the discount rate and the level of these market interest rates.

11. This is what Cook and Hahn call their "adjusted" estimates. Their "unadjusted" estimates are biased upward because discount rate changes in close succession are always in the same direction. Cook and Hahn also deleted the discount rate change that occurred in October 1979 because the Fed simultaneously announced its intention to pay more attention to the monetary aggregates. We estimated the equations over Cook and Hahn's period exactly as they did and reproduced their results. There were no substantive differences from the results presented here.

changes were regressed separately on changes in the discount rate.

The results are reported in Table 3.[12] The coefficients on the one-day change and on the 91-day change are large and statistically significant for all four interest rates. However, the coefficient on the 182-day change is statistically significant only for the federal funds rate. Moreover, for the three T-bill rates all of the response appears to be immediate. [As expected, the sum of the coefficients on the one-day change and those of the 90- and 181-day averages are nearly identical to the coefficients on the 91- and 182-day averages]. This is not the case for the federal funds rate. While the average change in the funds rate over the 182 days following a change in the discount rate is due solely to the immediate response of the funds rate, this does not appear to be the case for the 91-day average. Thus, it appears that there is a lag in the response of the federal funds rate to changes in the discount rate. On average, the funds rate changes by an additional 44 basis points following the initial response to an announcement of a discount rate change, suggesting that it continues to adjust to discount rate changes after the T-bill rates have adjusted fully.

Furthermore, the response of the T-bill rate is significantly smaller than the response of the funds rates. Hence, the results are at odds with a strict interpretation of the expectations theory of the term structure of interest rates. Indeed, in every case, the difference in the responses of the federal funds and T-bill rates is quantitatively large and is statistically significant at the 5 percent level.

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12. The reported t-statistics in Tables 3 and 4 are based on standard errors obtained from applying White's (1980) heteroskedasticity adjustment.

3.3 *Results From The Alternative Test*

The above results suggest that the federal funds rate responds with a lag to discount rate changes, but the T-bill rates do not. Given the unusual nature of the filter used to achieve stationarity, however, it is useful to re-test this hypothesis by estimating Equation 5. The order of the distributed lag was determined by the minimum number of market days between successive discount rate changes, nine. Also, the estimated equations include lags of the dependent variable; however, only estimates of the constant term, β_0, Θ and Γ_1 are presented in Table 4.

In all cases the long-run response to a change in the discount rate, Θ, is larger than the initial response, β_0. The results for the T-bill rates are consistent with those reported in Table 3--the T-bill rates incorporate the information associated with a discount rate change immediately. The lagged response for the federal funds rate, however, is statistically significant at the 10 percent significance level. This suggests the possibility that for some reason the federal funds rate does not respond completely to the information conveyed by the announcement of a discount rate change. However, the estimated initial response is not significantly different from unity, indicating that, on average, the funds rate responds immediately point-for-point with the change in the discount rate. Moreover, the estimates subsequent effect, Γ_1, and the total effect, Θ, are too large. There is simply no reason to believe that the long-run response of the funds rate is nearly twice the change in the discount rate. Hence, there is little reason to believe that Γ_1 measures a true lagged response of the funds rate. Consequently, the evidence suggests that all four rates respond simultaneously to non-technical

changes in the discount rate. Such responses cannot be used to differentiate among competing hypotheses of why T-bill rates respond to announcements of non-technical discount rate changes.

3.4 *The Market's Response Under a Direct and Fuzzy Funds Rate Target*

Goodfriend (1991) has argued that the market should have a more difficult time interpreting the Fed's intentions when the Fed uses a fuzzy funds rate target than when the Fed is targeting the funds rate directly. Hence, if the market interprets a discount rate change as a signal of change in the funds rate target, one should expect a delay in the market's response to a change in the discount rate when the Fed is indirectly targeting the funds rate using a non-borrowed reserves or a borrowed reserves operating procedure.

To test this hypothesis, the sample period was divided into "direct peg" and "fuzzy peg" periods. The direct-peg period is from the beginning of the sample to just prior to the Fed's switch to a non-borrowed reserve operating procedure in October 1979. The fuzzy-peg period is from just after the October 1979 switch in operating procedure to October 1987. The Federal Reserve was directly targeting the federal funds rate in a very narrow band during the first sub-period, while it was targeting either non-borrowed or borrowed reserves in the latter sub-period.[13] The discount rate change associated with the October 1979 change in operating procedures was not included in either sub-sample because it was qualitatively very important since the Fed simultaneously announced a change in operating procedure.[14] The second sub-sample ended in September 3, 1987 because Feinman (1990) has shown that Fed was targeting the funds

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13. See Goodfriend (1991) and Cook and Hahn (1989).

14. Thornton (1991).

rate in a very narrow band by October 1987, despite the fact that, officially, it continued on a borrowed reserves operating procedure. There were 14 non-technical discount rate changes during the first period and 15 during the second.

Estimates of Equation 5 for the "direct peg" and "fuzzy peg" periods are presented in Table 5. The results are at odds with Goodfriend's conjecture and with Cook and Hahn's view of how the market interprets non-technical discount rate changes. Consistent with the previous results, the evidence indicates that the T-bill rates respond simultaneously and completely to announcements of discount rate changes during both the direct peg and fuzzy peg periods. These results are consistent with an efficient markets view that market interest rate incorporate all new information completely and immediately. If the markets were uncertain of the information content of the announcement of a discount rate change, there should be some lag in the response of interest rates, but this is not the case.[15]

Moreover, the responses of the T-bill rates are smaller during the direct-peg period. Certainly, if the Fed is directly pegging the funds rate and if the market interprets a non-technical discount rate change as a "signal" that the Fed is permanently changing its target for the *level* of the funds rate, one would think that the response should be proportionately larger during this period. That it is not and that the response is immediate in both periods does not bode well for the "standard view" of the effects of discount rate changes on short-term interest

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15. These results are also at odds with the results of Cook and Hahn (1989). There they find a lag in the response of the T-bill rate to changes in the Fed's target for the federal funds rate.

rates. By implication, it also casts some doubt on the standard view of the role of the federal funds rate in the evolution of short-term interest rates.

3.5 *The Effects of a Discount Rate Change on the Structure of Interest Rates*

A test of the effect of changes in the discount rate on the structure of interest rates is obtained by first testing whether the federal funds rate and T-bill rates are cointegrated. Estimates of the cointegrating vector are made following what Pagan (1991) calls a structural approach and using the fully modified Phillips-Hansen (1990) estimator. The estimated cointegrating vectors and simple and augmented Dickey-Fuller tests of the residuals are presented in Table 6.[16] Formal tests suggest that the federal funds and T-bill rates are cointegrated. Nevertheless, the persistence in the cointegrating relationship is substantial, suggesting that the relationships are very close to integrated processes.

Nevertheless, because the formal test results indicate that a stationary relationship between the two rates exists, the hypothesis that changes in the discount rate alter the structural relationship between the federal funds and T-bill rates is tested by estimating Equation 8. The equation was estimated under the assumption that v_t is generated by an ARMA(1,1) and that $\gamma(L)$ is of order 1. The estimated equation includes a

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16. Settlement Wednesdays and all days when there were non-technical changes in the discount rate were deleted estimating the cointegrating vector. Settlement Wednesdays were removed because it is well-known that the federal funds rate often behaves unusually when depository institutions are force balance their reserve positions. Days when non-technical discount rate changes were made were removed because the hypothesis is that the such changes alter the "normal" structural relationship between these rates, hence, it would be inappropriate to those observations in determining the "normal" structural relationship between these rates.

constant term, μ, and because we are primarily interested in estimating the initial response to a change in the discount rate, only the contemporaneous and two lagged values of the change in the discount rate are included.

Estimates of this equation for each of the three T-bill rates are presented in Table 7. In each case the estimated coefficient on the contemporaneous change in the discount rate is negative. However, in no case is the coefficient statistically significant, suggesting that non-technical discount rate changes do not effect the structure of interest rates. These results are consistent with the idea that the markets respond simultaneously and completely to the information contained in a discount rate announcement.[17] In any event, the results presented here are not favorable to the hypothesis that discount rate changes are transmitted to the T-bill rates though their effect on the market's expectation of change in the Fed's target for the federal funds rate.[18] Nor do they support the "standard view" of the importance of the funds rate in the evolution of other short-term interest rates.

4. *CONCLUSIONS*

Market analysts have been aware for some time that market interest rates respond to announcements of changes in the Federal Reserve's discount rate, and it has been firmly established that markets only

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17. It is arguably the case that because of the high degree of persistence in the estimated cointegrating vectors, these tests are not too different from the previous ones.

18. It should be noted that recent evidence on the expectations theory of the term structure of interest rates [Fama (1986), Mankiw and Miron (1986) and Shiller, Campbell and Schoenholtz (1983)] finds little evidence to support the expectations theory.

respond to discount rate changes that the Fed announces are made for reasons other than to simply keep the discount rate "in line" with market interest rates. What is far less clear is the reason for the response.

This paper investigates the hypothesis that T-bill rates respond to discount rate changes because the market interprets changes in the discount rate as a signal of a change in the Federal Reserve's target for the federal funds rate. I find that the federal funds and 3-, 6-, and 12-month T-bill rates respond immediately and simultaneously to the information contained in announcements of non-technical discount rate changes. The evidence indicates that there is simply no way to differentiate this hypothesis from several other hypotheses of why T-bill rates respond to announcements of discount rate changes: the simultaneous response of interest rates to new information provides no insight about the reason for the market's response.

The hypothesis was tested further by investigating the assertion that non-technical discount rate changes signal a change in the target for the federal funds rate. Specifically, I tested whether there was a lag in the response of the T-bill rate to changes in the discount rate during periods when the Fed was targeting the federal funds rate indirectly, and found an immediate response of the T-bill rate to changes in the discount rate even during periods when the Fed's federal funds rate target was "fuzzy." These results run counter to the assertion that discount rate changes are merely taken as a signal of a change in the Fed's target for the funds rate. Moreover, they cast doubt on what Goodfriend calls the "standard view," that the Fed asserts it influence over longer-term interest rates by altering the market's expectation for the level of interest rates by changing its target for the federal funds rate.

The results suggest that financial markets do no simply interpret discount rate changes as a signal that the Fed has changed its target for the federal funds rate, and that the markets do not respond in the mechanical way suggested by Cook and Hahn's hypothesis. Furthermore, they are consistent with a recent investigation [Thornton (1991)] of alternative explanations of the market's response to discount rate changes, which suggests that the markets do not respond to the change in the discount rate per se, but to the new information provided by the "announcement" itself. Because the exact nature and anticipated usefulness of the information contained in the announcement varies from announcement to announcement, the market's reaction varies with the particular circumstances at the time.

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Table 1

Dates and Size of Non-Technical Discount Rate Changes

Date	Size of Change	Date	Size of Change	Date	Size of Change
Mon, Feb 26, 1973	0.5	Wed, Nov 1, 1978	1	Mon, Aug 16, 1982	-0.5
Mon, Jun 11, 1973	0.5	Fri, Jul 20, 1979	0.5	Mon, Nov 22, 1982	-0.5
Mon, Jul 2, 1973	0.5	Fri, Aug 17, 1979	0.5	Tue, Dec 14, 1982	-0.5
Thu, Apr 25, 1974	0.5	Tue, Oct 9, 1979	1	Fri, Nov 23, 1984	-0.5
Mon, Dec 9, 1974	-0.25	Fri, Feb 15, 1980	1	Mon, Dec 24, 1984	-0.5
Mon, Jan 6, 1975	-0.5	Fri, Sep 26, 1980	1	Mon, May 20, 1985	-0.5
Mon, Mar 10, 1975	-0.5	Mon, Nov 17, 1980	1	Fri, Mar 7, 1986	-0.5
Mon, Jan 9, 1978	0.5	Fri, Dec 5, 1980	1	Thu, Aug 21, 1986	-0.5
Mon, Aug 21, 1978	0.5	Tue, May 5, 1981	1	Fri, Sep 4, 1987	0.5
Fri, Sep 22, 1978	0.25	Tue, Jul 20, 1982	-0.5	Tue, Aug 9, 1988	0.5
Mon, Oct 16, 1978	0.5	Mon, Aug 2, 1982	-0.5	Fri, Feb 24, 1989	0.5

Table 2
Tests for a Unit Root

Interest Rate	Dickey-Fuller Test					
	without intercept		with intercept		augmented	
	α	t	α	t	α	t
FFR	.9986	-1.65	.9879	-5.24*	.9928	-3.25*
TBR3	.9999	-0.30	.9983	-2.12	.9738	-2.30
TBR6	.9999	-0.24	.9985	-2.02	.9984	-2.20
TBR12	.9999	-0.11	.9985	-2.08	.9984	-2.24

* indicates a rejection of the null hypothesis α=1 at the 5 percent significance level.

Table 3

Estimates of the Immediate and Lagged Response to Non-Technical Changes in the Discount Rate

Time Horizon of Dependent Variable	FFR	TBR3	TBR6	TBR12
91-day	1.268*	0.699*	.571*	.451*
	(5.40)	(4.28)	(3.90)	(3.41)
182-day	.851*	0.429	.337	.274
	(2.50)	(1.83)	(1.55)	(1.46)
1-day	.844*	0.542*	.457*	.389*
	(5.22)	(6.71)	(8.37)	(6.57)
90-day	.437*	0.161	0.116	0.064
	(2.18)	(0.96)	(0.90)	(0.54)
181-day	.017	-0.111	-0.119	-0.114
	(0.06)	(0.46)	(0.57)	(0.62)

* indicates statistical significance at the 5 percent level.

Table 4

Estimates of Equation 5

Coefficient	FFR	TBR3	TBR6	TBR12
Const.	-.001	-.000	-.000	-.000
	(0.13)	(0.10)	(0.09)	(0.02)
β_0	.865*	.510*	.432*	.355*
	(4.33)	(6.61)	(7.14)	(5.91)
θ	1.876*	.660*	.507*	.374*
	(3.20)	(3.04)	(3.32)	(2.55)
Γ_1	1.011	.150	.075	.019
	(1.82)	(0.81)	(0.50)	(0.14)
$\bar{R}^2$	.049	.056	.049	.049

* indicates a statistical significance at the 5 percent level.

Table 5

Estimates of Equation 5 During "Direct" and "Fuzzy" Federal Funds Rate Pegs

	TBR3		TBR6		TBR12	
	direct peg	fuzzy peg	direct peg	fuzzy peg	direct peg	fuzzy peg
Const.	.003	-.003	.002	-.002	.002	-.002
	(1.19)	(0.62)	(1.03)	(0.55)	(1.16)	(0.51)
β_0	.232*	.606*	.234*	.484*	.173*	.406*
	(3.39)	(8.11)	(3.18)	(8.46)	(2.64)	(7.59)
θ	.177	.813*	.222	.567*	.156	.438*
	(0.79)	(2.81)	(1.40)	(2.41)	(1.17)	(2.11)
Γ	-.009	.207	-.011	.093	-.017	.032
	(0.04)	(0.75)	(0.08)	(0.41)	(0.15)	(0.16)
$\bar{R}^2$	.047	.055	.039	.044	.037	.048

* indicates statistical significance at the 5 percent level.

Table 6
Estimated Cointegrating Vectors and Dickey-Fuller Tests

Variables	TBR3	TBR6	TBR12
Const.	.988*	1.527*	2.251*
	(27.14)	(42.86)	(58.17)
δ	.770*	.729*	.649*
	(223.82)	(208.49)	(166.80)

Dickey-Fuller Tests

Variable	without intercept		augmented	
	α	t	α	t
TBR3	.9271	-11.62*	.9484	-8.01*
TBR6	.9409	-10.43*	.9593	-7.08*
TBR12	.9617	-8.37*	.9732	-5.81*

* indicates statistical significance at the 5 percent level.

Table 7

Estimates of Equation 8

	TBR3	TBR6	TBR12
μ	.011	.002	-.059
	(0.20)	(0.03)	(0.67)
ΔDR_t	-.070	-.052	-.055
	(0.93)	(0.75)	(0.88)
ΔDR_{t-1}	.054	.051	.054
	(0.49)	(0.45)	(0.61)
ΔDR_{t-2}	.039	.008	.046
	(0.46)	(0.11)	(0.70)
γ	-.628	-.996	-.593
	(0.70)	(150.60)	(0.73)
AR	.928*	.944*	.965*
	(142.97)	(168.16)	(225.71)
MA	.295*	.331*	.352*
	(17.73)	(20.62)	(23.03)

* indicates a statistical significance at the 5 percent level.