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Federal Reserve interest rate targeting, rational expectations, and the term structure

Glenn D. Rudebusch

Economic Research Department, Federal Reserve Bank of San Francisco, San Francisco, CA 94105, USA

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Abstract

The amount of information in the yield curve for forecasting future changes in short rates varies with the maturity of the rates involved. Indeed, spreads between certain long and short rates appear unrelated to future changes in the short rate – contrary to the rational expectations hypothesis of the term structure. This paper estimates a daily model of Federal Reserve interest rate targeting behavior, which, accompanied by the maintained hypothesis of rational expectations, explains the varying predictive ability of the yield curve and elucidates the link between Fed policy and the term structure.

Key words: Term structure; Rational expectations; Federal Reserve

JEL classification: E42; E43; E52

1. Introduction

The rational expectations theory of the term structure implies that the current long-term interest rate should equal the market expectation of the average level of current and future short-term rates. As a result, it would seem that the spread between current long and short rates should predict future changes in the short rate. However, many researchers have tested this proposition using postwar

I presented the theoretical essence of this paper at a Federal Reserve conference in St. Louis, June 18–19, 1992 (see Rudebusch, 1993b). I thank participants at that conference as well as many colleagues in the Federal Reserve System for their comments; however, the views expressed herein are my own and are not necessarily shared by anyone else in the Federal Reserve System.

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data on the spread between yields on three-month and six-month Treasury bills, and they have found essentially no information in this spread for forecasting future changes in the three-month rate. After providing such evidence, Shiller, Campbell, and Schoenholtz (1983) concluded (p. 215): 'The simple theory that the slope of the term structure can be used to forecast the direction of future changes in the interest rate seems worthless.' Indeed, the absence of predictive information in the three-month and six-month yield spread has been widely interpreted as a rejection of the rational expectations theory of the term structure.

Mankiw and Miron (1986) provided an alternative explanation for the term structure evidence that was consistent with rational expectations. In contrast to the earlier results based on postwar data, they showed that the three-month and six-month yield spread did significantly help to predict future changes in the three-month rate from 1890 to 1914, a period that predated the founding of the Federal Reserve System. Mankiw and Miron argued that the negligible predictive power of the spread after the founding of the Fed did not reflect a failure of the expectations theory. Instead, they suggested that the Fed 'stabilized' short-term rates, such as the three-month rate, by inducing a random-walk behavior that eliminated any predictable variation.[1] Thus, to a first approximation, expected future short rates have equaled current short rates since the founding of the Fed. In such a situation, even if the rational expectations theory holds, supporting empirical evidence cannot be obtained from the forecasting ability of the slope of the yield curve because there is no predictable variation in future short rates to incorporate into yield spreads. In essence, Mankiw and Miron argued that the absence of predictive information in the term structure for future short rates reflects the manner in which the Fed controls interest rates and is not a rejection of the rational expectations theory of the term structure.

Although the Mankiw–Miron interpretation of the evidence is plausible, there has been no formalization of their argument. Furthermore, there has been a host of empirical research using postwar data on bills and bonds with maturities other than three and six months that has contradicted the postwar results of Shiller, Campbell, and Schoenholtz as well as Mankiw and Miron. Such research has found yield spreads that *do* help predict future rates. Notably, Fama (1984), Mishkin (1988), and Hardouvelis (1988) found predictive information at the very short end of the yield curve; for example, the spread between one-month and two-month rates helped predict the future change in the one-month rate. Similarly, Fama and Bliss (1987) found significant information in the long end of the term structure for predicting movements in short rates several years into the future. Finally, Simon (1990) provided evidence that the

[1] One type of predictable variation apparently eliminated was seasonal fluctuations; only in the pre-Fed period was there pronounced seasonality in interest rates (Mankiw and Miron, 1991).

spread between the three-month bill rate and an overnight rate had predictive power for future changes in the overnight rate.

In this paper, I attempt to explain these disparate pieces of evidence on the predictive content of the yield curve with an explicit model relating the term structure to the behavior of the Fed. In the next section, I briefly survey the term structure results. Section 3 then estimates a formal model of the Fed's interest rate targeting behavior. This model exhibits three key attributes: (1) daily deviations of the spot Fed funds rate from its target, (2) gradual adjustment of the target, and (3) persistent targets. This model is inspired, in part, by the suggestions of Cook and Hahn (1989a, 1990) and Goodfriend (1991); here, however, an explicit model is fit to actual data on Federal Reserve interest rate targets. Section 4 demonstrates how this empirical model of interest rate targeting, even with the maintained hypothesis of rational expectations, can explain the evidence on the varying predictive power of the yield curve. This explanation is, in essence, a rigorous empirical generalization of Mankiw and Miron (1986). The demonstration of the link between Fed behavior and the predictive content of the term structure is based on synthetic interest rate data generated from the model. Estimating the standard term structure regressions with this synthetic data allows me to replicate the various results obtained with actual data and, more importantly, to determine the source of these results. Finally, Section 5 concludes with speculation on rationales for the Fed's targeting behavior.

The empirical, model-based approach linking Fed policy and the term structure taken in this paper is similar in spirit to other recent work by Balduzzi, Bertola, and Foresi (1993) and by Dotsey and Otrok (1995), though, as noted below, our analyses differ in many specifics. Also, McCallum (1994) has proposed a related, though somewhat contrasting, theoretical explanation for the term structure evidence based on the assumption, which is not clearly supported in the data, that the Fed changes the target rate in response to movements in the term spread.

2. The predictive ability of the term structure

Numerous studies have provided evidence on the proposition that spreads between long and short rates should predict future changes in short rates. For ease of exposition, I limit my discussion to two types of evidence: first, evidence on the predictive ability of spreads between the yields of two securities where the maturity of the longer-term security is exactly twice that of the shorter-term one, and second, evidence on the ability of spreads between an overnight rate and a one-month or three-month rate to predict future changes in the overnight rate.[2]

[2] These two types of evidence encompass much but not all of the relevant empirical work; for comprehensive discussions, see Cook and Hahn (1990) and Campbell and Shiller (1991).

2.1. Evidence from spreads between one-period and two-period yields

The standard equation estimated in empirical work on the expectations hypothesis of the term structure can be easily obtained. Let $r(1)_t$ and $r(2)_t$ be the yields on one- and two-period (zero-coupon) bonds, respectively. Then, the expectations hypothesis with a constant term premium, $\pi(2)$, implies (to a close approximation)

$$r(2)_t = 1/2[r(1)_t + \mathrm{E}_t r(1)_{t+1}] + \pi(2); \tag{1}$$

that is, the current two-period yield equals the average of the actual and expected one-period yields plus a term premium. Assuming rational expectations,

$$r(1)_{t+1} = \mathrm{E}_t r(1)_{t+1} + \varepsilon_{t+1}, \tag{2}$$

where ε_{t+1} is a forecast error orthogonal to information available at time t. Substituting (2) into (1) and rearranging provides

$$1/2[r(1)_{t+1} - r(1)_t] = \alpha + \beta[r(2)_t - r(1)_t] + v_{t+1}. \tag{3}$$

Under the expectations hypothesis of the term structure, $\beta = 1$ and $\alpha = -\pi(2)$; that is, after taking expectations of both sides of (3), one-half the optimal forecast of the change in the short rate should equal the spread between the long rate and short rate (minus a term premium). The error term is orthogonal to the right-hand-side regressors ($v_{t+1} = \varepsilon_{t+1}/2$), so ordinary least squares provides consistent coefficient estimates.

Table 1 collects estimates of β from twelve studies that have estimated Eq. (3) using securities of various maturities.[3] These point estimates, along with their standard errors and t-statistics for the hypothesis $\beta = 0$, are arrayed according to the term of the one-period security, which ranges from two weeks to five years. For example, at the three-month maturity, the $\hat{\beta}$ equal to 0.23 (reported in Mankiw and Miron, 1986) is from a regression of the change in the three-month yield on the spread between six-month and three-month rates.

Many of the $\hat{\beta}$'s in Table 1 are less than one; indeed, many are insignificantly different from zero. There is a clear dependence of the size and statistical significance of the $\hat{\beta}$'s on the maturity of the securities. This dependence is illustrated in Fig. 1, which plots the point estimates (as dots) as a function of the maturity of the one-period security. The shaded band in Fig. 1 provides an informal summary of the central tendency of the size and statistical significance of the $\hat{\beta}$'s. The ability of the term structure to predict changes in short rates is quite good for forecast horizons (i.e., the maturities of the one-period security)

[3] Eq. (3) does not describe the frequency of observation; typically, overlapping observations that are separated by less than the maturity of the short bond have been used.

Table 1
Estimates of the predictive power of the spread between one-period and two-period rates at various maturities

Maturity of one-period rate	$\hat{\beta}$	s.e.($\hat{\beta}$)	tstat($\hat{\beta}$)	Source; table number; sample period
2 weeks	0.61[a]	0.15	4.12	Hardouvelis, 1988; 2; 1972–79
2 weeks	0.85[a]	0.09	9.63	Hardouvelis, 1988; 2; 1979–82
2 weeks	0.76[a]	0.05	15.55	Hardouvelis, 1988; 2; 1982–85
1 month	0.50[a]	0.12	4.21	Campbell and Shiller, 1991; 2; 1952–87
1 month	0.46[a]	0.07	6.57	Fama, 1984; 4; 1959–82
1 month	0.69[a]	0.17	4.06	Mishkin, 1988; 1; 1974–79
1 month	0.40[a]	0.09	4.44	Mishkin, 1988; 1; 1959–86
2 months	0.20	0.28	0.69	Campbell and Shiller, 1991; 2; 1952–87
3 months	– 0.15	0.20	– 0.74	Campbell and Shiller, 1991; 2; 1952–87
3 months	0.06	0.24	0.25	Froot, 1989; 1; 1969–86
3 months	0.23	0.19	1.24	Mankiw and Miron, 1986; 1; 1959–79
3 months	0.44	0.37	1.17	Roberds et al., 1994; 8; 1975–79
3 months	– 0.01	0.03	– 0.29	Roberds et al., 1994; 8; 1984–91
3 months	– 0.21	0.26	– 0.81	Shiller et al., 1983; 3; 1959–82
3 months	0.29	0.16	1.83	Shiller et al., 1983; 3; 1959–79
3 months	0.02	0.22	0.09	Simon, 1989; 1; 1961–88
6 months	0.04	0.33	0.13	Campbell and Shiller, 1991; 2; 1952–87
1 year	– 0.13	0.27	– 0.48	Blough, 1994; 3; 1949–89
1 year	– 0.02	0.37	– 0.05	Campbell and Shiller, 1991; 2; 1952–87
1 year	0.38	0.27	1.41	Cook and Hahn, 1990; 3; 1952–83
1 year	0.09	0.28	0.32	Fama and Bliss, 1987; 3; 1965–85
2 years	0.14	0.62	0.22	Campbell and Shiller, 1991; 2; 1952–87
5 years	2.79[a]	0.96	2.90	Campbell and Shiller, 1991; 2; 1952–87

The tstat($\hat{\beta}$) entries are t-statistics for the hypothesis that $\beta = 0$ in Eq. (3). All rates are based on discount or zero-coupon yields for U.S. Treasury securities.

[a]Significant at the 1 percent level.

that are no longer than about a month. As the forecast horizon increases, the predictive power disappears, and the $\hat{\beta}$'s are insignificantly different from zero from three months to one year. However, at horizons longer than one or two years, there is some evidence that predictive power appears to improve.[4] This

[4] In Table 1 and Fig. 1, evidence for significant predictive power at long horizons is limited to essentially one observation at the five-year horizon because only spreads between one- and two-period bonds are used. Further supporting evidence is provided in Fama and Bliss (1987) and Campbell and Shiller (1991), who find, for example, that the spread between four-year and five-year bonds has significant predictive power for the one-year rate four years ahead.

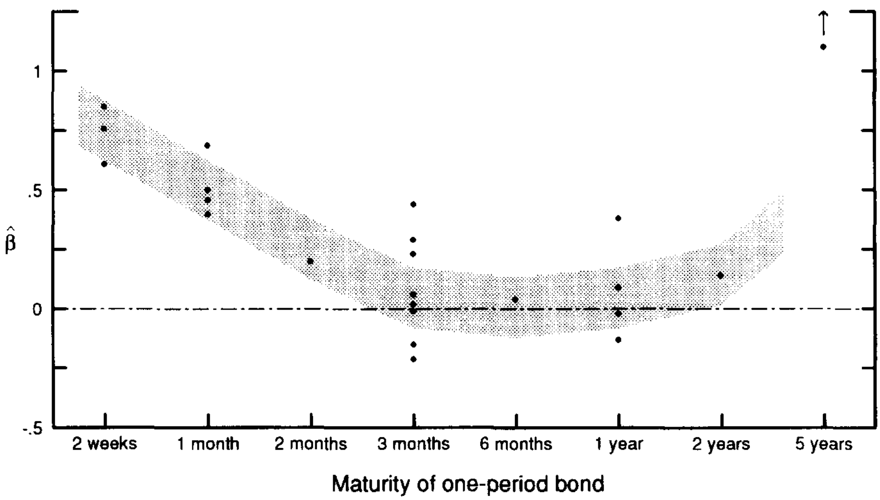

Fig. 1. Estimates of the predictive power of the spread between one-period and two-period rates at various maturities.

'U-shaped' pattern of the predictive ability of the yield curve traces out some of the results this paper will try to explain.

2.2. Evidence from spreads between overnight and monthly yields

Researchers have also investigated the forecasting ability of spreads between the overnight (one-day) Fed funds rate and longer rates. Let the length of a period be a day and define r_t as the overnight Fed funds rate and $r(n)_t$ as the yield [and $\pi(n)$ as the constant term premium] of an n-day bill; then the rational expectations theory of the term structure implies that

$$r(n)_t = 1/n\left[r_t + \mathrm{E}_t \sum_{i=1}^{n-1} r_{t+i}\right] + \pi(n). \tag{4}$$

After rearrangement, the term structure regression for empirical investigations [the analog to Eq. (3)] is

$$1/n\left[\sum_{i=0}^{n-1} r_{t+i}\right] - r_t = \alpha + \beta[r(n)_t - r_t] + v_{t+n-1}. \tag{5}$$

Under the rational expectations null hypothesis, $\beta = 1$; that is, the deviation of today's Fed funds rate from its expected average level over the next n days should equal the spread between the current n-day and one-day rates (minus a term premium).

Table 2 collects four estimates of β in Eq. (5) from the literature with n equal to 30 or 91 (that is, a one-month or three-month bill). All four $\hat{\beta}$'s are significant,

Table 2
Estimates of the predictive power of the spread between 30-day or 91-day rates and the Federal funds rate

Maturity of multi-day rate	$\hat{\beta}$	s.e.($\hat{\beta}$)	tstat($\hat{\beta}$)	Source; table number; sample period
30 days	0.66[a]	0.13	4.91	Roberds et al., 1994; 6; 1979–82
30 days	0.71[a]	0.09	8.51	Roberds et al., 1994; 6; 1984–91
91 days	0.58[a]	0.18	3.16	Balduzzi et al., 1993; 2; 1987–90
91 days	0.50[a]	0.17	2.94	Simon, 1990; 1; 1972–87

The tstat($\hat{\beta}$) entries are t-statistics for the hypothesis that $\beta = 0$ in Eq. (5). The multi-day rate is either a term Fed funds rate or, in the case of Simon (1990), a three-month Treasury bill rate.

[a]Significant at the 1 percent level.

which indicates that spreads between the overnight rate and longer yields have high predictive power for future changes in the funds rate.

2.3. Summary of term structure results

I summarize the above results on the forecasting ability of various yield spreads with four propositions about the term structure:

TS1 *Overnight Spreads.* Spreads between the overnight Fed funds rate and one-month or three-month rates are good predictors of the change from the current daily rate to the average daily rate that will prevail over the next one or three months.

TS2 *Short-Term Spreads.* Spreads between very-short-term bills – for example, 30-day and 60-day bills – are able to predict future changes in short rates at horizons of no more than one month.

TS3 *Medium-Term Spreads.* Yield spreads involving bills with maturities between three and twelve months have essentially no predictive information for future changes in these rates.

TS4 *Long-Term Spreads.* Spreads involving long-term bonds – specifically, for maturities longer than one or two years – appear to have some predictive content for movements in future interest rates.

3. Federal Reserve targeting of interest rates

Propositions TS1–TS4 describe the usefulness of term spreads for forecasting future interest rates. As noted in the introduction, Mankiw and Miron have suggested that the interest rate targeting behavior of the Federal Reserve is responsible for TS3. To investigate this suggestion, especially in light of TS1, TS2, and TS4, this section constructs an empirical model describing the Fed's targeting behavior. The model is estimated with a sample that runs from September 1974 to September 1979 and from March 1984 to September 1992 – two recent periods when the Fed funds rate targets were quite explicit. The intervening years are excluded because, as noted below, the Fed's nonborrowed reserves operating procedure during that period makes the analysis of any interest rate targets very difficult.

3.1. Transitory deviations from targets

Tables 3a and 3b provide the raw material for my analysis of Fed targeting behavior. They include – for the periods from 1974–1979 and 1984–1992, respectively – the dates on which Fed funds rate targets were changed, the level of the new target, the size of the target change, and the number of business days since the previous target change. The primary source for the target Fed funds rate series was the Federal Reserve Bank of New York's (FRBNY) internal 'Report of Open Market Operations and Money Market Conditions', which was prepared weekly by the FRBNY Trading Desk. Some judgement is required to obtain a single target series from these written accounts. For a few target changes, the exact date that the Desk began to enforce the new target could have been a day or two sooner or later than the one that I have designated. In addition, a target *range* of about a quarter of a percentage point in size was sometimes specified rather than a precise level; in these cases, the midpoint of the range was considered the new target. For my purposes, however, the amount of ambiguity in specifying the target series is small.[5]

Figs. 2a, 2b, and 2c display daily data on the Fed funds rate – the target rate as a solid line and the actual spot rate as a dotted line.[6] Wide deviations of the spot rate from the target are apparent on a daily basis because the Fed would usually enter the market to influence the spot rate only once, or possibly twice, each day.[7]

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[5] My target series is consistent with those obtained by others. For the period 1974–1979, Cook and Hahn (1989b) derive a very similar target series; in addition, both of our target series generally accord with the market perceptions of the target reported in Cook and Hahn (1989a). For the period 1985–1992, my target series matches the expected Fed funds rate series supplied publicly by the FRBNY.

[6] The actual rate is a volume-weighted average of quoted rates on trades through New York brokers during the day.

[7] Further institutional details about Fed targeting are given in Meulendyke (1990, pp. 38–43, 47).

I model the funds rate (r_t) as the sum of the target rate ($\bar{r}_t$) and a deviation (u_t): $r_t = \bar{r}_t + u_t$. In the daily data in Figs. 2, the mean absolute value of u_t is 0.174, or about 17 basis points. Because of obvious outliers, I used various robust regression techniques to estimate an autoregressive process for u_t. These techniques recommended fairly similar first-order autoregressive models. The one that I use is

$$u_t = 0.017 + 0.384 * u_{t-1} + e_t, \tag{6}$$

which was estimated by minimizing the mean absolute value of the residuals.[8] The small estimated coefficient in (6) indicates that daily deviations were generally transitory; for example, if the funds rate were 20 basis points above the target today, it would, on average, be only 7 basis points above target tomorrow and 3 basis points above target on the next day. Thus, although the funds rate was not pegged to the target on a daily basis, the Fed appears to have enforced the targets over the course of a few days.

3.2. The size of target changes

I define changes in the daily target rate as $\delta_t \equiv \bar{r}_t - \bar{r}_{t-1}$. Most of the δ_t are zero because the target is rarely changed; indeed, during the 3,427 business days in the sample, there were 199 nonzero δ_t. The frequency distribution of the absolute value of these nonzero target changes is given in the top line of Table 4. This distribution is clustered around only a handful of values. Furthermore, this clustering is true regardless of sign; indeed, almost three-fourths of both positive and negative changes were in the range from one-eighth to one-quarter of a percentage point. As a broad characterization then, target changes were conducted in small, standardized steps with a rough equality in the size of target increases and decreases.[9]

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[8] A lag coefficient of 0.31 (with a standard error of 0.01) was estimated by ordinary least squares (OLS) with dummies for the four u_t greater than 400 basis points; a lag coefficient of 0.33 was estimated by minimizing the smallest 95 percent of the squared residuals (a least trimmed squares regression). (For comparison, the OLS lag coefficient was 0.46.) Additional lags did not appear to be significant. For an analysis that incorporates day-of-week effects and other subtle daily fluctuations, see Hamilton (1994).

[9] The mean negative change (24 basis points) is about 7 basis points larger than the mean positive target change (17 basis points). This difference is probably not economically significant; certainly from the policy record, there is no indication that the Fed perceives any difference. Strictly speaking, a chi-squared test based on the observed frequencies of sign and size in the two lower lines of Table 4 rejects symmetry. However, this is an exacting test that distinguishes, for example, between target changes of five-sixteenths and three-eighths. When target changes are simply grouped into large and small ones (specifically, those greater than 0.25 and those not), there is little evidence against the hypothesis of symmetry.

Table 3a
Changes in the Federal funds rate target, 1974–1979

Date of change	New target	Size of change	Days since previous change	Date of change	New target	Size of change	Days since previous change
Sep 13–74	11.5	− 0.25	—	Jul 09–76	5.25	− 0.125	4
Sep 20–74	11.125	− 0.375	5	Oct 01–76	5.1875	− 0.0625	59
Sep 27–74	11	− 0.125	5	Oct 08–76	5	− 0.1875	5
Oct 04–74	10.625	− 0.375	5	Nov 19–76	4.875	− 0.125	27
Oct 11–74	10.25	− 0.375	5	Nov 26–76	4.75	− 0.125	4
Oct 18–74	9.75	− 0.5	4	Dec 10–76	4.6875	− 0.0625	10
Nov 01–74	9.5	− 0.25	10	Dec 17–76	4.625	− 0.0625	5
Nov 25–74	9.25	− 0.25	15	Jan 19–77	4.6875	0.0625	23
Nov 29–74	9.125	− 0.125	3	Apr 15–77	4.75	0.0625	61
Dec 09–74	8.875	− 0.25	6	Apr 29–77	5	0.25	10
Dec 13–74	8.75	− 0.125	4	May 05–77	5.25	0.25	4
Dec 20–74	8.25	− 0.5	5	May 18–77	5.375	0.125	9
Dec 27–74	8	− 0.25	4	Jul 27–77	5.5	0.125	47
Jan 03–75	7.5	− 0.5	4	Jul 28–77	5.625	0.125	1
Jan 10–75	7.25	− 0.25	5	Aug 01–77	5.75	0.125	2
Jan 17–75	7.125	− 0.125	5	Aug 09–77	5.875	0.125	6
Jan 24–75	6.875	− 0.25	5	Aug 12–77	6	0.125	3
Jan 31–75	6.5	− 0.375	5	Sep 09–77	6.125	0.125	19
Feb 07–75	6.25	− 0.25	5	Sep 21–77	6.25	0.125	8
Feb 21–75	6.0	− 0.25	9	Sep 30–77	6.375	0.125	7
Mar 07–75	5.75	− 0.25	10	Oct 03–77	6.4375	0.0625	1
Mar 21–75	5.5	− 0.25	10	Oct 07–77	6.5	0.0625	4

May 02–75	5.25	– 0.25	30	Oct 28–77	6.5625	0.0625	14
May 08–75	5.125	– 0.125	4	Nov 04–77	6.5	– 0.0625	5
Jun 06–75	5.25	0.125	20	Jan 09–78	6.75	0.25	42
Jun 18–75	5.5	0.25	8	Apr 19–78	7	0.25	71
Jun 20–75	5.75	0.25	2	Apr 26–78	7.125	0.125	5
Jun 27–75	6.0	0.25	5	Apr 27–78	7.25	0.125	1
Jul 18–75	6.1875	0.1875	14	May 17–78	7.5	0.25	14
Sep 19–75	6.375	0.1875	44	Jun 21–78	7.75	0.25	25
Sep 26–75	6.25	– 0.125	5	Jul 19–78	7.875	0.125	19
Oct 03–75	6	– 0.25	5	Aug 16–78	8	0.125	20
Oct 10–75	5.75	– 0.25	5	Aug 18–78	8.125	0.125	2
Oct 24–75	5.625	– 0.125	9	Aug 25–78	8.25	0.125	5
Oct 31–75	5.5	– 0.125	5	Sep 08–78	8.375	0.125	9
Nov 07–75	5.25	– 0.25	5	Sep 20–78	8.5	0.125	8
Dec 26–75	5.125	– 0.125	32	Sep 22–78	8.625	0.125	2
Jan 02–76	5	– 0.125	4	Sep 28–78	8.75	0.125	4
Jan 09–76	4.875	– 0.125	5	Oct 18–78	9	0.25	13
Jan 12–76	4.75	– 0.125	1	Oct 31–78	9.625	0.625	9
Feb 27–76	4.8125	0.0625	33	Nov 21–78	9.875	0.25	15
Mar 20–76	4.75	– 0.0625	8	Dec 10–78	10.0625	0.1875	19
Apr 21–76	4.875	0.125	30	Apr 27–79	10.25	0.1875	90
Apr 30–76	5	0.125	7	Jul 20–79	10.5	0.25	59
May 11–76	5.125	0.125	7	Jul 27–79	10.625	0.125	5
May 14–76	5.25	0.125	3	Aug 15–79	11	0.375	13
May 19–76	5.375	0.125	3	Aug 24–79	11.25	0.25	7
May 21–76	5.4375	0.0625	2	Aug 31–79	11.375	0.125	5
May 28–76	5.5	0.0625	5	Sep 19–79	11.5	0.125	12
Jul 02–76	5.375	– 0.125	24				

Table 3b
Changes in the Federal funds rate target, 1984–1992

Date of change	New target	Size of change	Days since previous change	Date of change	New target	Size of change	Days since previous change
Mar 01–84	9.5	0.125	—	Sep 04–87	7.25	0.375	1
Mar 15–84	9.875	0.375	10	Sep 24–87	7.3125	0.0625	13
Mar 22–84	10	0.125	5	Oct 22–87	7.125	− 0.1875	19
Mar 29–84	10.25	0.25	5	Oct 28–87	7	− 0.125	4
Apr 05–84	10.5	0.25	5	Nov 04–87	6.8125	− 0.1875	5
Jun 14–84	10.625	0.125	49	Jan 28–88	6.625	− 0.1875	56
Jun 21–84	11	0.375	5	Feb 11–88	6.5	− 0.125	10
Jul 19–84	11.25	0.25	19	Mar 30–88	6.75	0.25	33
Aug 09–84	11.5625	0.3125	15	May 09–88	7	0.25	28
Aug 30–84	11.4375	− 0.125	15	May 25–88	7.25	0.25	12
Sep 20–84	11.25	− 0.1875	14	Jun 22–88	7.5	0.25	19
Sep 27–84	11	− 0.25	5	Jul 19–88	7.6875	0.1875	18
Oct 04–84	10.5625	− 0.4375	5	Aug 08–88	7.75	0.0625	14
Oct 11–84	10.5	− 0.0625	4	Aug 09–88	8.125	0.375	1
Oct 18–84	10	− 0.5	5	Oct 20–88	8.25	0.125	50
Nov 08–84	9.5	− 0.5	15	Nov 17–88	8.3125	0.0625	19
Nov 23–84	9	− 0.5	9	Nov 22–88	8.375	0.0625	3
Dec 06–84	8.75	− 0.25	9	Dec 15–88	8.6875	0.3125	16
Dec 20–84	8.5	− 0.25	10	Dec 29–88	8.75	0.0625	9
Dec 27–84	8.125	− 0.375	4	Jan 05–89	9	0.25	4
Jan 24–85	8.25	0.125	19	Feb 09–89	9.0625	0.0625	24
Feb 14–85	8.375	0.125	15	Feb 14–89	9.3125	0.25	3

Feb 21–85	8.5	0.125	4	Feb 23–89	9.5625	0.25	6
Mar 21–85	8.625	0.125	20	Feb 24–89	9.75	0.1875	1
Mar 28–85	8.5	−0.125	5	May 04–89	9.8125	0.0625	49
Apr 18–85	8.375	−0.125	15	Jun 06–89	9.5625	−0.25	22
Apr 25–85	8.25	−0.125	5	Jul 07–89	9.3125	−0.25	22
May 16–85	8.125	−0.125	15	Jul 27–89	9.0625	−0.25	14
May 20–85	7.75	−0.375	2	Aug 10–89	9	−0.0625	10
Jul 11–85	7.6875	−0.0625	36	Oct 18–89	8.75	−0.25	47
Jul 25–85	7.75	0.0625	10	Nov 06–89	8.5	−0.25	13
Aug 22–85	7.8125	0.0625	20	Dec 20–89	8.25	−0.25	31
Aug 29–85	7.875	0.0625	5	Jul 13–90	8	−0.25	141
Sep 06–85	8	0.125	5	Oct 29–90	7.75	−0.25	74
Dec 18–85	7.75	−0.25	70	Nov 14–90	7.5	−0.25	11
Mar 07–86	7.25	−0.5	53	Dec 07–90	7.25	−0.25	16
Mar 10–86	7.125	−0.125	24	Dec 19–90	7	−0.25	8
Apr 17–86	7	−0.125	5	Jan 09–91	6.75	−0.25	13
Apr 24–86	6.75	−0.25	5	Feb 01–91	6.25	−0.5	16
May 22–86	6.8125	0.0625	20	Mar 08–91	6	−0.25	24
Jun 05–86	6.875	0.0625	9	Apr 30–91	5.75	−0.25	37
Jul 11–86	6.375	−0.5	25	Aug 06–91	5.5	−0.25	68
Aug 14–86	6.3125	−0.0625	24	Sep 13–91	5.25	−0.25	27
Aug 21–86	5.875	−0.4375	5	Oct 31–91	5	−0.25	33
Dec 04–86	6	0.125	71	Nov 06–91	4.75	−0.25	4
Apr 30–87	6.5	0.500	101	Dec 06–91	4.5	−0.25	20
May 21–87	6.75	0.25	15	Dec 20–91	4	−0.5	10
Jul 02–87	6.625	−0.125	29	Apr 09–92	3.75	−0.25	75
Aug 27–87	6.75	0.125	40	Jul 02–92	3.25	−0.5	59
Sep 03–87	6.875	0.125	5	Sep 04–92	3	−0.25	46

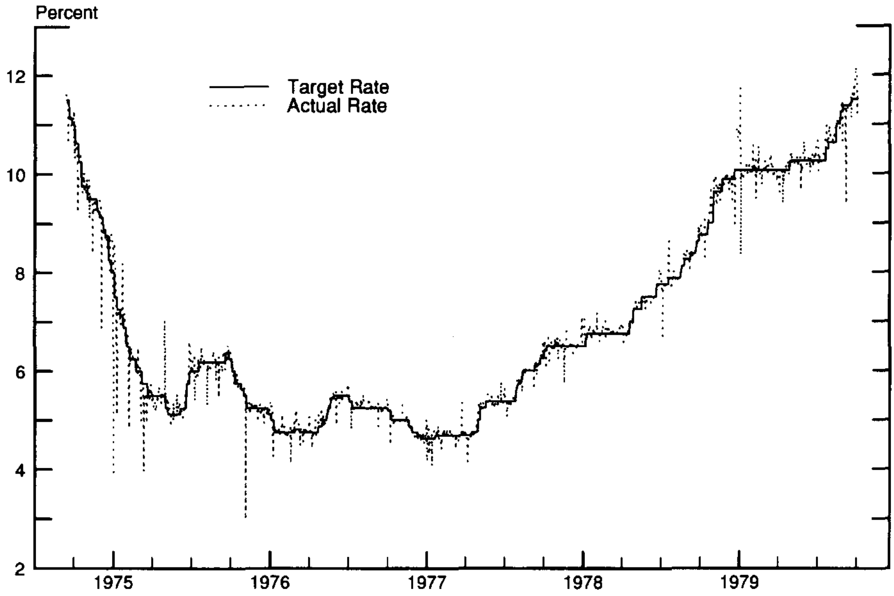

Fig. 2a. Actual and target Federal funds rate (September 1974 to September 1979).

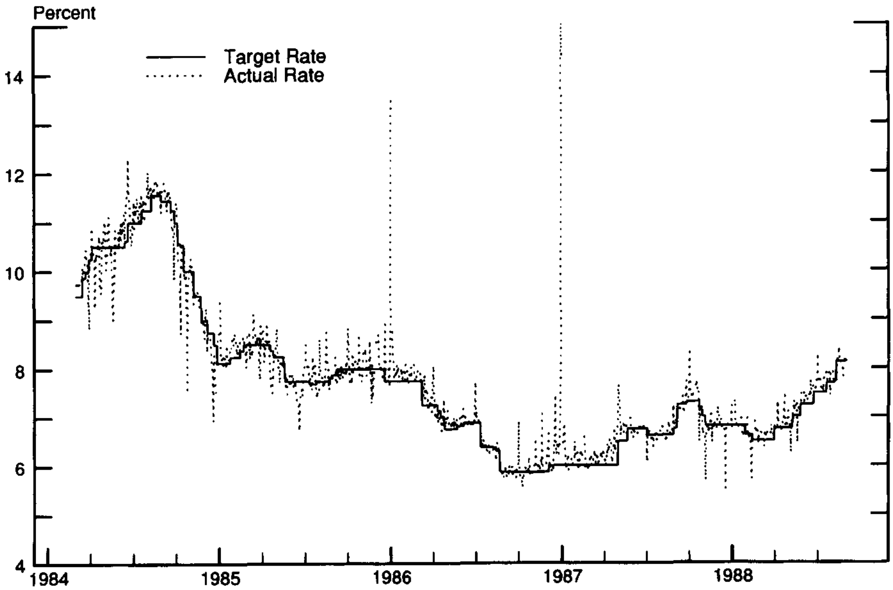

Fig. 2b. Actual and target Federal funds rate (January 1984 to August 1988).

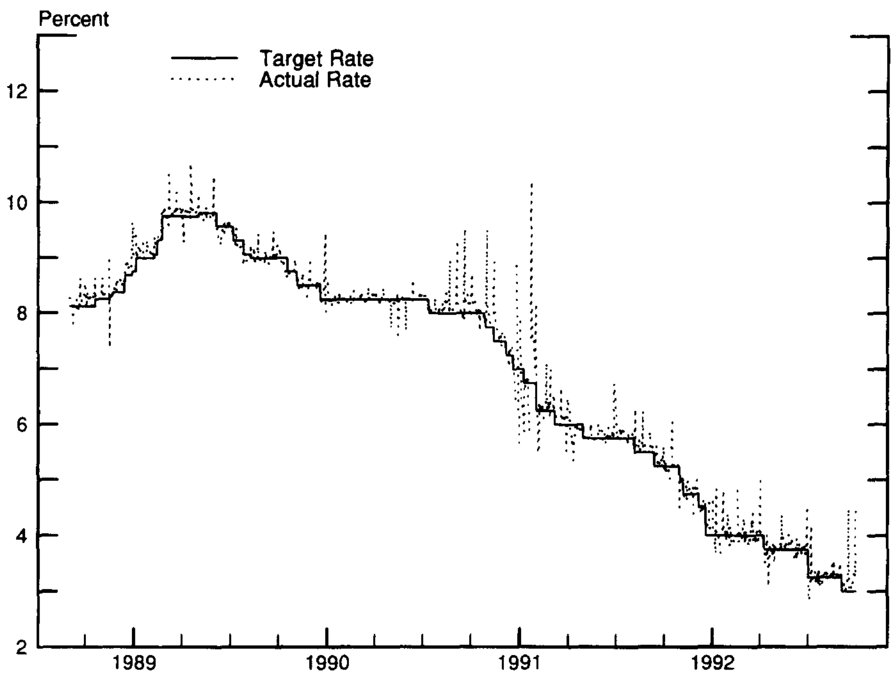

Fig. 2c. Actual and target Federal funds rate (September 1988 to September 1992).

Table 4
Frequency distribution of the absolute value of target changes

Changes	Absolute value of target change									Total number
	0.0625	0.125	0.1875	0.25	0.3125	0.375	0.4375	0.5	0.625	
All changes	29	66	11	65	2	11	2	12	1	199
Positive	20	40	6	24	2	5	0	1	1	99
Negative	9	26	5	41	0	6	2	11	0	100

Each entry shows the number of target changes of a given size.

Assuming a symmetric size for positive and negative changes in the target rate, I model the probability generating process for the δ_t as

$$\delta_t = \begin{cases} \eta & \text{with probability} \quad P_t^+, \\ 0 & \text{with probability} \quad 1 - P_t^+ - P_t^-, \\ -\eta & \text{with probability} \quad P_t^-, \end{cases} \tag{7}$$

where η is a *positive* random variable drawn from the probability density $f(\eta)$ for the absolute size of a target change, and P_t^+ and P_t^- are the probabilities of positive and negative target changes, respectively.

3.3. The timing of target changes

The relative sizes of the probabilities of target increases and decreases, P_t^+ and P_t^-, which determine the timing of target changes, are of particular interest. If P_t^+ is greater (less) than P_t^-, then the expected value $\mathrm{E}_{t-1}(\bar{r}_t)$ is larger (smaller) than $\bar{r}_{t-1}$ [$\mathrm{E}_{t-1}(\bar{r}_t) = \bar{r}_{t-1} + P_t^+ \mathrm{E}(\eta) - P_t^- \mathrm{E}(\eta)$]. Thus, if Mankiw and Miron's (1986) supposition is correct that the Fed induces a random walk in the target rate, it must be the case that $P_t^+ = P_t^-$ at each date t.

From Figs. 2, it appears unlikely that P_t^+ is always equal to P_t^-. The target rate displays sustained movements of many small steps in the same direction; apparently, a change of a given sign is unlikely to be followed by a change of the opposite sign. This dependence is exhibited in Table 5. Of the positive target changes, 87 were directly followed by another increase while 11 were followed by a decrease; likewise, negative changes usually followed negative changes. Not surprisingly, the p-value from a chi-squared test of the hypothesis of no association between the signs of successive nonzero target changes is essentially zero. This evidence of dependence between the signs of successive nonzero target changes suggests that the random-walk characterization of the behavior of the target rate is, strictly speaking, incorrect. After a target change, there is a greater likelihood of another target change in the same direction, so $\mathrm{E}_t\bar{r}_{t+1} \neq \bar{r}_t$.

Incorporating the evidence thus far, I can provide a preliminary description of P_t^+ and P_t^-. Let $t - \tau$ be the date of the last nonzero target change before time t; that is, $\delta_{t-\tau} \neq 0$, but $\delta_{t-\tau+k} = 0$, for $k = 1, \ldots, \tau - 1$. Then, at time t,

$$P_t^+ = \begin{cases} P^{-+} & \text{if } \delta_{t-\tau} < 0 \\ P^{++} & \text{if } \delta_{t-\tau} > 0 \end{cases} \quad \text{and} \quad P_t^- = \begin{cases} P^{--} & \text{if } \delta_{t-\tau} < 0, \\ P^{+-} & \text{if } \delta_{t-\tau} > 0, \end{cases} \tag{8}$$

where P^{--} and P^{++} are the probabilities of successive changes in the same direction (both changes down and both changes up, respectively) and P^{-+} and

Table 5
Contingency table of signs of successive target changes

	Sign of second change	
Sign of first change	Positive	Negative
Positive	87	11
Negative	11	88

Table 6
Tests of the equality of various duration distributions

Sample (1)	Sample (2)	Sample sizes (1)	(2)	Wilcoxon p-value	M–H p-value
All durations					
Durations between two pos. changes	Durations between two neg. changes	87	88	0.53	0.48
Durations between pos. & neg. changes	Durations between neg. & pos. changes	11	11	0.06	0.10
Durations between same-sign changes	Durations between diff.-sign changes	175	22	0.00	0.03
Only durations longer than 24 days					
Durations between same-sign changes	Durations between diff.-sign changes	30	9	0.16	0.14

The p-values test the null hypothesis that the distributions of samples (1) and (2) are equal against a two-sided alternative.

P^{+-} are the probabilities of successive changes in different directions (moving down and then up and moving up and then down, respectively).

The evidence in Table 5 indicates that $P^{--} \neq P^{+-}$ and $P^{++} \neq P^{-+}$. Further information about these probabilities can be obtained by examining the number of business days separating the nonzero target changes (as shown in Table 3). The crucial insight is that the number of days separating target changes can be interpreted as duration data and the probabilities of target changes can be interpreted as hazard rates; therefore, all of the tools of duration analysis can be employed.[10] Specifically, the distribution of durations gives direct information about the hazard rate probabilities of nonzero target changes. Table 6 gives results of two nonparametric tests – the Wilcoxon and Mantel–Haenszel (M–H) tests – that examine these durations.[11] The first line tests the hypothesis that durations between two positive target changes have the same distribution as durations between two negative target changes. The p-values for this hypothesis are quite high (0.53 and 0.48), which implies that $P^{--} = P^{++} \equiv P^{S}$. Similarly, the second line tests whether durations separating a negative change from

[10] See Diebold and Rudebusch (1990) for an introduction to the literature analyzing duration data.

[11] Both of these tests are based on the relative ranks of the durations in the samples. Diebold and Rudebusch (1992) describe the Wilcoxon test, which is essentially a nonparametric t-test that does not depend on the assumption of normality. Harrington and Fleming (1982) describe the Mantel–Haenszel (or log-rank) test.

a succeeding positive change have the same distribution as durations separating a positive change from a succeeding negative change. Here, both p-values are again not significant (at the 5 percent level), which implies that $P^{+-} = P^{-+} \equiv P^{d}$. Incorporating this symmetry *in timing* between positive and negative changes, (8) becomes

$$P_t^+ = \begin{cases} P^{d} & \text{if} \quad \delta_{t-\tau} < 0 \\ P^{S} & \text{if} \quad \delta_{t-\tau} > 0 \end{cases} \quad \text{and} \quad P_t^- = \begin{cases} P^{S} & \text{if} \quad \delta_{t-\tau} < 0, \\ P^{d} & \text{if} \quad \delta_{t-\tau} > 0, \end{cases} \tag{9}$$

where P^{S} and P^{d} are probabilities of a target change in the *same* and in a *different* direction, respectively. Finally, the third line in Table 6 indicates that durations between changes of the same sign (whether positive or negative) are drawn from a different distribution than the durations separating changes of different signs. This confirms that $P^{S} \neq P^{d}$, which is consistent with Table 5.

Now I consider variation over time in P^{d} and P^{S}. In particular, I let these probabilities depend on τ, the number of business days since the previous target change. One question of interest is whether the resulting hazard functions $P^{S}(\tau)$ and $P^{d}(\tau)$ display duration dependence – that is, whether $\partial P^{S}(\tau)/\partial\tau$ and $\partial P^{d}(\tau)/\partial\tau$ are nonzero. Some initial evidence is provided in the last line of Table 6, which is identical to the third line but only includes those target changes that are separated by at least five weeks (25 business days) from another target change. For such changes, the p-values are 0.16 and 0.14, which suggests identical distributions; that is, for $\tau \geq 25$, $P^{S}(\tau) = P^{d}(\tau)$. Taken together, Tables 5 and 6 suggest that during the first five weeks after a target change there is a higher probability that the target rate will change again in the same direction than in a different direction; however, after five weeks have past, there is no greater likelihood of a change in the same direction as a change in a different direction.

Rigorous estimates of the hazard functions $P^{S}(\tau)$ and $P^{d}(\tau)$ are given in Fig. 3. These estimates were obtained from the nonparametric hazard rate estimator using kernel functions and quasi-likelihoods described in Tanner and Wong (1984).[12] The hazard function $P^{S}(\tau)$, shown as the dotted line, was estimated using all of the observations, but treating the 22 observations where the target change was in a different direction than the previous one as censored observations. Similarly, the hazard function $P^{d}(\tau)$, shown as the dashed line, was estimated using all of the observations, but treating the 175 observations where the target change was in the same direction as the previous one as censored observations.

The estimated hazard functions in Fig. 3 are consistent with the earlier evidence. The dashed line indicates that in the first few weeks after a target

[12] These estimates were obtained with the HAZRD subroutine in IMSL.

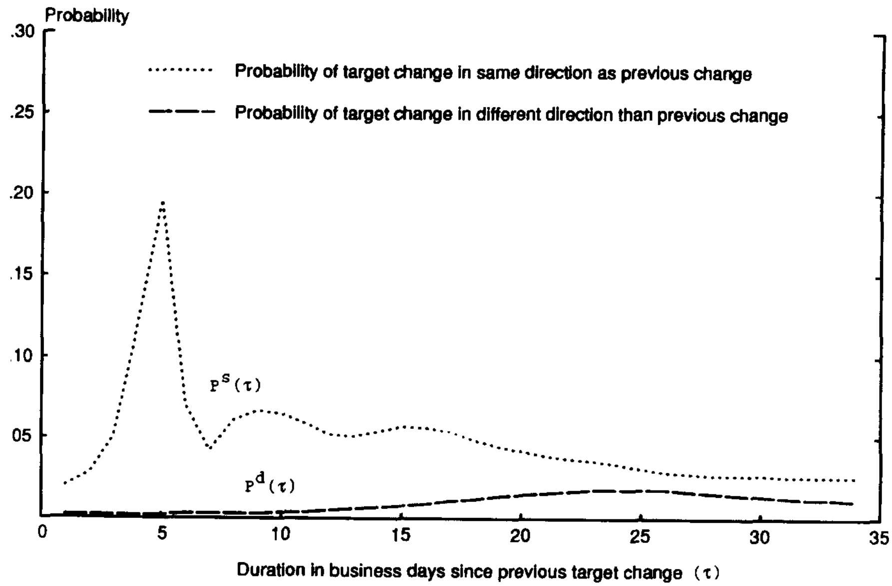

Fig. 3. Hazard functions for changes in the Federal funds rate target (data-based nonparametric kernel estimates).

change, the Fed is unlikely to reverse course by changing the target in the opposite direction. The dotted line indicates that in the first few weeks after a target change, the Fed is fairly likely to change the target again in the same direction. However, after five weeks ($\tau \geq 25$), the estimated hazard functions are essentially identical. This is consistent with the evidence in Table 6 that for $\tau \geq 25$, $P^{\mathrm{s}}(\tau) = P^{\mathrm{d}}(\tau)$, and there is equal likelihood of a decrease or increase in the target rate. Thus, four weeks after a target change, the random-walk nature of the funds rate target asserts itself; for $\tau \geq 25$, $\mathrm{E}_t\bar{r}_{t+1} = \bar{r}_t$.

Finally, note that the hazard functions also are essentially flat after 24 business days; that is, they show no duration dependence. A formal non-parametric test of the null hypothesis of no duration dependence calculated for the 39 durations greater than 24 days has a p-value of 0.88.[13] Assuming no duration dependence, the maximum likelihood estimate of the constant hazard rate for all durations greater than 24 days is $P^{\mathrm{s}}(\tau) = P^{\mathrm{d}}(\tau) = 0.020$; that is, after four weeks, there is a 2 percent probability of an increase in the target rate and an equal probability of a decrease.

[13] This test is based on the Brain and Shapiro Z-statistic, which is described in Diebold and Rudebusch (1990).

3.4. Summary and further interpretation of Fed behavior

As a qualitative summary of the above statistical description, I characterize the Fed's interest rate targeting behavior during the sample period with these three attributes:

FR1 *Transitory Daily Deviations.* Large deviations of the spot rate from the target rate are allowed on a daily basis. However, deviations from the target rate are transitory and are largely eliminated by the following day.

FR2 *Short-Term Interest Rate Smoothing.* Targets are adjusted in limited amounts at a restrained, deliberate pace, and target changes are seldom immediately reversed. Thus, a typical policy action is implemented over the course of several weeks with gradual increases or decreases (but not both) in the target rate.[14]

FR3 *Medium-Term Target Persistence.* Abstracting from short-term interest rate smoothing considerations (FR2), the target rate is set at a level the Fed expects to maintain. That is, beyond a horizon of about a month, there are no planned movements to react to information already known.[15]

In the next section, these attributes, which are based on an analysis of targets during 1974–1979 and 1984–1992, will be used to account for the term structure empirical results TS1–TS3, which were obtained, in part, from much longer postwar data samples.[16] To be completely convincing, this accounting requires that FR1–FR3 be broadly applicable to the entire postwar period. This requirement seems plausible. For example, it is consistent with the historical descriptions of monetary policy given in Goodfriend (1991, 1993). Goodfriend argues that during the past four decades the Fed has always taken an active interest in controlling the Fed funds rate (or its equivalent) and that the broad characteristics of its targeting procedures (like FR1–FR3) have remained constant. The one period that appears most unlike an interest rate targeting regime runs from

[14] Note the account in Meulendyke (1990, p. 41): 'During most of the 1970s, the [Fed] was reluctant to change the funds rate by large amounts at any one time . . . Part of that reluctance reflected a wish to avoid short-term reversals of the rate. Keeping each rate adjustment small minimized the risk of overdoing the rate changes and then having to reverse course.'

[15] This attribute is stated more broadly than the evidence given above can establish where the estimated hazard probabilities are conditioned only on the number of days since the previous target change and the sign of that change. As discussed below, I assume this attribute is true with regard to other information sets as well.

[16] Note, however, that several of the estimates in Tables 1 and 2 were obtained using data from only my sample period and that these estimates are not outliers.

late 1979 through late 1982, when the declared target was nonborrowed reserves. However, Cook (1989) shows that a majority of the policy actions during this period were conducted in order to adjust the level of the Fed funds rate, so this period could be characterized as simply indirect interest rate targeting following FR1–FR3 but with looser daily control and less smoothing than other periods.[17]

Finally, I should stress that the above model describing policy behavior is incomplete. The long-run determinant of the level of the Fed funds rate is the Fed's assessment of the fundamental goals of monetary policy. This is summarized by a fourth attribute:

FR4 *Long-Run Objectives.* Subject to FR1–FR3, the target rate is adjusted in a manner that the Fed expects will help achieve future goals for wage and price inflation, real output, employment, the exchange rate, credit market conditions, and the health of the financial system.

The specification of FR4 would let the probabilities P_t^+ and P_t^- be functions of the daily 'real-time' data that were available historically on each of the objectives of the Fed. The voluminous literature on the Fed's 'reaction function', which regresses a monetary policy instrument on some set of variables, is instructive in this regard. Khoury (1990) surveys 42 such studies published between 1963 and 1986 and finds essentially no consistency in terms of which variables are significant across studies.[18] Given this vast array of results (which is likely a consequence of the discretionary manner in which policy has been conducted), I make no attempt to incorporate FR4 into the model. However, I do assume, as reflected in FR3 and following Mankiw and Miron (1986), that such strategic policy actions are not based on lagged information in any systematic way that allows financial markets to predict interest rate movements at a horizon of three to twelve months.

4. Reconciling Fed behavior and term structure evidence

This section reconciles the evidence surveyed in Section 2 on the predictive power of the term structure with the evidence given in Section 3 on the Fed's interest rate targeting behavior. I first describe how the latter results on targeting can be used to construct a model that can generate simulated data on the actual and target Fed funds rates and on the term structure of rates. Estimating

[17] This is the essence of the argument of Poole (1982) as well.

[18] The modern version of the reaction function is the interest rate or money equation in a VAR as in, for example, Bernanke and Blinder (1992); again, no clear conclusions on the proper form of such an equation have been established in the literature.

the term structure regressions on synthetic data from this model, as well as from slight variations of it, provides insight about the link between Fed targeting behavior and the term structure results TS1–TS3.

4.2. Baseline interest rate targeting model

The model of interest rates that will serve as the baseline data-generating process for the simulations has four crucial elements:

1. *Deviations of funds rate* (r_t) *from target* ($\bar{r}_t$): These deviations are determined by

$$r_t = \bar{r}_t + u_t, \qquad u_t = 0.017 + 0.384 * u_{t-1} + \hat{e}_t, \tag{10}$$

where the $\hat{e}_t$ are drawn with equal probability from among the fitted residuals in Eq. (6) (i.e., a bootstrap).

2. *Size of target changes*: Targets are changed according to

$$\bar{r}_t = \bar{r}_{t-1} + \delta_t, \qquad \delta_t = \begin{cases} \eta & \text{with probability } P_t^+, \\ 0 & \text{with probability } 1 - P_t^+ - P_t^-, \\ -\eta & \text{with probability } P_t^-, \end{cases} \tag{11}$$

where η is a positive random number. Its distribution, $f(\eta)$, is determined by the historical empirical frequencies (Table 4); thus, $f(0.0625) = 0.146$, $f(0.125) = 0.332$, $f(0.1875) = 0.055$, $f(0.25) = 0.327$, $f(0.3125) = 0.010$, $f(0.375) = 0.055$, $f(0.4375) = 0.010$, $f(0.5) = 0.060$, and $f(0.625) = 0.005$.

3. *Timing of target changes*: The target change probabilities are given by

$$P_t^+ = \begin{cases} P^{\mathrm{d}}(\tau) & \text{if } \delta_{t-\tau} < 0 \\ P^{\mathrm{S}}(\tau) & \text{if } \delta_{t-\tau} > 0 \end{cases} \quad \text{and} \quad P_t^- = \begin{cases} P^{\mathrm{S}}(\tau) & \text{if } \delta_{t-\tau} < 0, \\ P^{\mathrm{d}}(\tau) & \text{if } \delta_{t-\tau} > 0, \end{cases} \tag{12}$$

where $t - \tau$ is the date of the last nonzero target change before time t and where $P^{\mathrm{S}}(\tau)$ and $P^{\mathrm{d}}(\tau)$ are given in Fig. 3 for $\tau < 25$ and are both equal to the constant 0.020 for $\tau \geq 25$.

4. *Long rates set with rational expectations*: Long rates are set according to the rational expectations hypothesis of the term structure (with no term premium):[19]

$$r(n)_t = 1/n\left[r_t + \mathrm{E}_t \sum_{i=1}^{n-1} r_{t+i}\right], \tag{13}$$

[19] A constant but nonzero term premium would not alter the results. The consequences of a time-varying term premium are discussed below.

where expectations of the future funds rate are rational, that is, consistent with the model (elements 1–3) given above.

Simulated data from this baseline model are obtained by sequential application of the following two steps at each point in time. In step 1, the actual and target Fed funds rates at time t are generated with four inputs from the past: the values of u_{t-1} and $\bar{r}_{t-1}$, the number of days since the previous nonzero target change τ, and the sign of the previous change $\delta_{t-\tau}$. The sign of the target change at time t, δ_t, depends on the random number v_t, which is uniformly distributed over the zero to one interval. If $v_t < P^{\mathrm{S}}(\tau)$, then δ_t has the same sign as $\delta_{t-\tau}$. If $P^{\mathrm{S}}(\tau) < v_t < P^{\mathrm{S}}(\tau) + P^{\mathrm{d}}(\tau)$, then δ_t has the opposite sign from $\delta_{t-\tau}$. In either case, the size of the nonzero target change is η, which is distributed randomly according to $f(\eta)$. For all other values of v_t, there is no target change, so $\delta_t = 0$ and $\bar{r}_t = \bar{r}_{t-1}$. Finally, given $\bar{r}_t$, a fitted residual from Eq. (6) is selected at random (with replacement), and the spot rate deviation u_t – and hence r_t – is determined.[20]

In step 2, the entire term structure of rates at time t is generated. To do this, step 1 is applied sequentially starting at date t to obtain one possible future path for the funds rate over the next six months (actually 24 weeks or 168 days). This procedure is repeated 200 times to provide 200 possible realizations on the sequence r_{t+i}, $i = 1, 2, \ldots, 168$, conditional on the past at time t. Then for each future date, $\mathrm{E}_t r_{t+i}$ is simply taken to be the mean of the 200 realizations on that date. This procedure provides the rational (model-consistent) expectations that are used to compute long rates at time t.

In such a fashion, I generate 4000 days of term structure data (which is a typical span of data underlying the results in Table 1). These data are sampled biweekly to obtain 279 regression observations. I estimate three regressions with the data: Eq. (5) using the spread between the overnight rate, r_t, and the three-month rate, $r(84)_t$; Eq. (3) using the spread between the one-month rate, $r(28)_t$, and the two-month rate, $r(56)_t$; and Eq. (3) using the spread between the three-month rate, $r(84)_t$, and the six-month rate, $r(168)_t$. These three regressions relate to TS1, TS2, and TS3, respectively, and I denote the estimated coefficients on the spread variables from these regressions as $\hat{\beta}_{\mathrm{TS1}}$, $\hat{\beta}_{\mathrm{TS2}}$, and $\hat{\beta}_{\mathrm{TS3}}$. Line 2 in Table 7 provides the t-statistics for these coefficients based on simulated data from the baseline model.[21] These are the average t-statistics from 50 samples of model data (each with 279 biweekly observations).

[20] One minor point, I define weekends every five business days as two-day periods when no rates change. Weekends are required for the correct computation of long rates, but do not affect the duration accounting, which is conducted in business days.

[21] With biweekly observations, each of these regressions has overlapping forecast horizons and thus serially correlated residuals. In computing the t-statistics, I use the standard Newey–West (1987) adjustment to obtain heteroskedasticity and autocorrelation consistent standard errors for the parameters.

Table 7
Representative term structure regression results

	Results using spreads between yields		
	Overnight & three-month	One-month & two-month	Three-month & six-month
Source of data	tstat ($\hat{\beta}_{TS1}$)	tstat ($\hat{\beta}_{TS2}$)	tstat ($\hat{\beta}_{TS3}$)
Actual data (based on Tables 1 and 2)	3.05[a]	4.82[a]	0.34
Results from model simulations			
Baseline model	28.50[a]	4.11[a]	0.73
No daily deviations (no FR1) [$u_t = 0.0$]	7.39[a]	3.90[a]	0.74
No near-term smoothing (no FR2) [$P^s(\tau) = P^d(\tau) = 0.03$]	31.82[a]	1.20	0.04
No med.-term persistence (no FR3) [$P^s(\tau) = 0.03$, $P^d(\tau) = 0.005$]	37.69[a]	4.90[a]	2.90[a]

Each column contains average t-statistics from a particular term structure regression. The first row gives averages of t-statistics reported in the literature. The remaining rows give averages of t-statistics obtained from model simulations.

[a]Significant at the 1 percent level.

In evaluating the adequacy of the model, I do not emphasize the precise values of the t-statistics, for the model is obviously incomplete.[22] However, I do hope to replicate the general pattern of significance levels describing the predictive ability of the term structure in the empirical propositions TS1–TS3. These results, as obtained from the actual historical data, are summarized in line 1 of Table 7; namely, the tstat ($\hat{\beta}_{TS1}$) equal to 3.05 is the average of the two t-statistics given in the bottom half of Table 2, while the tstat ($\hat{\beta}_{TS2}$) and tstat ($\hat{\beta}_{TS3}$) equal to 4.82 and 0.34, respectively, are the averages of the estimates given in Table 1 at the one-month and three-month forecast horizons. In accordance with propositions TS1–TS3, the first two of these t-statistics are significant while the third is not. Most importantly, note that the baseline model is able to replicate all three of these propositions about the predictive power of the term structure, as tstat ($\hat{\beta}_{TS1}$) and tstat ($\hat{\beta}_{TS2}$) are quite high but tstat ($\hat{\beta}_{TS3}$) is not.

[22]One of the reasons I focus on the t-statistics rather than on the coefficients is that the point estimates of β depend crucially on the variance of a time-varying term premium (see Mankiw and Miron, 1986), which for simplicity is not a feature of my model. One of the interesting aspects of the analysis of Dotsey and Ortok (1995) is their modeling of time-varying term premia.

4.2. Reconciling facts and attributes

I now try to determine which aspects of the model account for the various term structure results. A reasonable guess is that TS1 can be explained, at least in part, by the transitory daily deviations from the persistent target rate. As described by FR1, if today's spot rate is unusually high relative to the target, it can be expected that future daily rates will return to the target level. Thus, the current three-month rate is close to the target rate. In this way, the spread between the overnight funds rate and the three-month rate should be a very good predictor of the change from the current daily rate to the average daily rate that prevails over the next three months.[23]

Support for this reasoning can be obtained from examining simulated data from a modified version of the baseline targeting model that has no daily deviations of the spot rate from the target (that is, a model where $u_t = 0$). The third line of Table 7 shows the results of regressions TS1–TS3 estimated with such data. The removal of the transitory daily deviations does not significantly affect the average tstat ($\hat{\beta}_{TS2}$) or tstat ($\hat{\beta}_{TS3}$), which is not surprising because the associated spreads involve rates of at least one month in maturity. However, tstat ($\hat{\beta}_{TS1}$) is about one-fourth as large as its value from the baseline model. Thus, TS1 appears to be largely accounted for by FR1. The fact that tstat ($\hat{\beta}_{TS1}$) is significant event with $u_t = 0$ suggests that FR2 – the partial adjustment of the target – plays some role in accounting for TS1. It appears that the predictable short-run target changes of FR2 are also incorporated in the spread between overnight and three-month rates and boost tstat ($\hat{\beta}_{TS1}$). Indeed, only in a model with no daily deviations or short-term smoothing (no FR1 or FR2; not shown in Table 7) does an insignificant tstat ($\hat{\beta}_{TS1}$) result.

The predictive information described by TS2, which is available at the very short end of the term structure, likely reflects the gradual nature of policy actions. For example, suppose that a major piece of information arrives that clearly requires a large target change; according to FR2, the Fed accomplishes this change with a sequence of target adjustments conducted over the next several weeks. The gap in timing between the release of new information and the completion of the policy action will generate predictable changes in interest rates at very short horizons, which will be incorporated into yield spreads. This predictive power will result in a significant $\hat{\beta}_{TS2}$.[24]

[23] This interpretation is also suggested by the results of Roberds, Runkle, and Whiteman (1994). They find a very high tstat ($\hat{\beta}_{TS1}$) in a sample of just 'settlement' Wednesdays, which are at the end of bank reserve accounting periods and exhibit large transitory deviations in the daily funds rate from its target.

[24] Cook and Hahn (1990) suggest a related aspect of interest rate smoothing to explain TS2: Given an information threshold determining discrete target changes, small (below-threshold) amounts of news produce predictable target variation on average.

Support for this interpretation can be developed by comparing lines 2 and 4 of Table 7. The baseline model, which clearly exhibits TS2 in line 2, smooths interest rates by allowing the probabilities of positive and negative target changes to differ at times over short horizons (as in Fig. 3). These differences imply predictable movements in rates at short horizons, which induce substantial discrepancies between current one-month rates and the one-month forward rates one month ahead (and hence sizable yield spreads). In contrast, if a target increase or decrease is equally likely at each point in time, there can be no significant differences between current and forward rates. Results for this latter case are given in line 4, where the baseline model is modified to exhibit no short-term smoothing [specifically, $P^{\mathrm{S}}(\tau) = P^{\mathrm{d}}(\tau) = 0.03$], so at each date t, positive and negative target changes are equally probable. With such complete and immediate random-walk behavior of the target rate, tstat $(\hat{\beta}_{\mathrm{TS2}})$ is insignificant.[25]

The lack of predictive information in the three- to twelve-month range of the term structure noted in TS3 can likely be associated with the target persistence described in attribute FR3. As Mankiw and Miron (1986) argued, if market participants (rationally) expect the Fed to maintain the current Fed funds rate target, then the current spread will have no predictive power for actual future changes in interest rates.[26] Cook and Hahn (1989) suggest that this same reasoning holds if the funds target is expected to change in the near future (consistent with FR2) and then to persist at its new level. In essence, because an expected near-term target change is incorporated to about the same degree in all current longer-term rates, *spreads* between these rates are essentially unaffected.[27] In the baseline model, where tstat $(\hat{\beta}_{\mathrm{TS3}})$ is insignificant, the target rate is well-approximated by a random walk at a medium-term horizon [because $P^{\mathrm{S}}(\tau)$ and $P^{\mathrm{d}}(\tau)$ are equal for $\tau \geq 25$]. In contrast, in line 5 of Table 7, the baseline model is modified so that at each point in time there is a difference between the probabilities of positive and negative target changes [specifically, $P^{\mathrm{S}}(\tau) = 0.03$ and $P^{\mathrm{d}}(\tau) = 0.005$]. These differences induce predictable changes in

[25] Such a model for funds rate targets is closest to the one of Balduzzi, Bertola, and Foresi (1993), which is based on target data from 1987–1990 and assumes that the probabilities of positive and negative target changes are always constant and equal. However, they consider the model's implications only for the term structure regression that uses the spread between the overnight and three-month bill rates (TS1).

[26] Froot (1989) provides support for this interpretation. He shows that there is little information in survey data on interest rate expectations about future changes in short rates at the three- and six-month horizons.

[27] As an example, suppose the market is sure that the funds rate will be increased 50 basis points after five business days. This expectation induces only a 2 basis point difference between the current three- and six-month rates; however, it induces a 25 basis point difference between the current one- and two-week rates.

the target rate at a horizon of several months and give the six-month and three-month spread predictive power, which is reflected in the significant average tstat ($\hat{\beta}_{TS3}$).

Finally, for completeness, let me consider TS4. Since Fama and Bliss (1987), the proposition that spreads between long rates contain long-horizon forecasting information has been reduced to the issue of whether interest rates display a slow reversion to mean at long horizons.[28] My own view (following Rudebusch, 1992, 1993a) is that conclusions about the stationarity or nonstationarity of yields, and thus about even the validity of TS4, are likely to be *very* tenuous given the size of the available samples. In any case, TS4 is not a proposition that the daily targeting model estimated above can illuminate. However, as a statement about the postwar sample, TS4 probably reflects the fact that markets expected the Fed to restrain inflation (consistent with FR4) and that the Fed has indeed been successful in obtaining such restraint, at least at business-cycle frequencies. Coupled with a stationary real rate, the Fed's expected and actual containment of inflation during the sample has probably generated the significant coefficients associated with long-maturity nominal interest rate spreads.

5. Conclusion

Previous researchers have provided evidence about the varying ability of term spreads to forecast future interest rates at different horizons. This paper shows how these findings are consistent with the hypothesis of rational expectations and reflect the manner in which the Federal Reserve controls the Fed funds rate. An empirical model of Fed interest rate targeting that is estimated from actual data on target rates is employed. Simulations of this model, which is augmented with a rational expectations term structure equation, demonstrate how Fed targeting behavior accounts for the disparate term structure results.

In light of this analysis, an interesting area for future research is to understand why the Fed conducts policy in this manner. Some speculations are offered below.

The rationale for allowing daily transitory deviations from the target rate (FR1) may simply be that any benefit of eliminating such volatility for the conduct of monetary policy is modest, especially relative to the cost of having to intervene in the market several times each day to enforce targets. However, Meulendyke (1990, p. 43) goes even further and suggests that information about the market for reserves can be obtained by allowing transitory daily deviations from the target to develop. This information might help the Fed gauge reserve pressures and aid in the day-to-day operation of policy.

[28] The subsequent debate is summarized in Shea (1992).

The short-run smoothing of interest rates (FR2) evident in the gradual target adjustments of limited size in a single direction may be of much greater import. The Federal Reserve as well as the financial press appears to interpret the purpose of such smoothing to be the avoidance of 'undue stress' on financial markets. Thus, the *Wall Street Journal* (Wessel, 1994) quotes Fed Chairman Alan Greenspan as arguing that the central bank implemented 'measured and deliberate' increases in short-term rates in early 1994 'so as not to unsettle financial markets'.[29] Besides gradual adjustments, interest rate smoothing also discourages quick reversals of the direction of target changes. Such reversals are thought to 'whipsaw' the market and also contribute to disorder (see Footnote 14).

A similar rationale of stabilizing or steadying markets could also be given for the persistence described in attribute FR3. However, Goodfriend (1991) elucidates a more subtle reason why the Fed might impart random-walk behavior to the Fed funds rate. He argues that output and prices do not respond to daily fluctuations in the funds rate but only to rates of at least three- or six-months maturity. Thus, for the Fed to attain its macroeconomic goals, it must be able to manipulate these longer-term rates. However, such rates are determined by market expectations of future funds rates; thus, by presenting the markets with a clear path for the future funds rate, the Fed can influence the longer-term rates. A constant funds rate is the path that likely communicates policy intentions most clearly and perhaps most credibly to markets. Thus, the pursuit of macroeconomic stabilization may impart a high degree of persistence to the funds rate.

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[29] Also see, the *Washington Post* (Berry, 1994) article, entitled 'Fed Likely to Sit Tight on Rates: Officials Waiting Until Markets Calm'.

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Erratum

Glenn D. Rudebusch

Economic Research Department, Federal Reserve Bank of San Francisco, San Francisco, CA 94105, USA

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In Tables 3a and 3b, three of the dates listed for changes in the Federal funds rate target are incorrect. In Table 3a, the date of the target change 'Mar 20-76' should read 'Mar 10-76' and the date 'Dec 10-78' should read 'Dec 19-78'. In Table 3b, the date 'Mar 10-86' should read 'Apr 10-86'. All other columns in these tables are correct. In particular, the 'Days since previous change' column was calculated using the correct dates; therefore, none of the empirical analysis in the paper is affected.

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