Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market

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February 10, 2000

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Abstract

This paper estimates the impact of monetary policy actions on bill, note, and bond yields, using data from the futures market for Federal funds to separate changes in the target funds rate into anticipated and unanticipated components. Bond rates' response to anticipated changes is essentially zero, while their response to unanticipated movements is large and highly significant. Surprise policy actions have little effect on near-term expectations of future actions, which helps explain the failure of the expectations hypothesis on the short end of the yield curve.

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1 Introduction

How market interest rates respond to Federal Reserve actions is a topic of great interest to financial market participants and policymakers alike. Bondholders, naturally, are concerned with the effects of Fed policy on bond prices. And because the first link in the transmission of Federal Reserve policy is from the Fed funds target to other interest rates, the issue is an important one for assessing the likely effectiveness of monetary policy.

Conventional wisdom is that an increase in the target Fed funds rate leads to an immediate increase in market interest rates, and a fall in bond prices; yet evidence for this view is elusive. Cook and Hahn (1989) documented a strong response in the 1970s, but regressions using data from the 1980s and 1990s show little, if any, impact of Fed policy on interest rates. Roley and Sellon (1995), for example, conclude that "although casual observation suggests a close connection …, the relationship between Fed actions and long-term interest rates appears much looser and more variable." These studies did not distinguish between anticipated and unanticipated actions, however, and it turns out that the failure to do so accounts for the apparent lack of a close link.

Using Fed funds futures rates to disentangle expected from unexpected policy actions, this paper shows that interest rates' response to the "surprise" component of Fed policy is significantly stronger than the response to the change in the target itself; in fact, rates' response to the anticipated component of policy actions is minimal, consistent with the efficient markets hypothesis. The response of Fed funds futures rates themselves to unexpected policy actions is fairly uniform across the one- to five-month horizon, supporting the view that the short end of the term structure contains little information about future movements in short-term rates.

2 A brief review of earlier studies

The first paper to assess markets' reaction to monetary policy actions is Cook and Hahn (1989), who examined the one-day response of bond rates to changes in the target Fed funds rate from 1974 through 1979. Their procedure was to regress the change in the bill, note and bond rates (denoted ΔR^i) on the change in the target Fed funds rate (denoted $\Delta \tilde{r}$),

$$\Delta R_t^i = \alpha^i + \beta^i \Delta \tilde{r}_t + \varepsilon_t^i \,, \tag{1}$$

for a sample consisting of the 75 days on which the Fed changed the funds rate target.

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The response to target rate increases was positive and significant at all maturities, but smaller at the long end of the yield curve: a one percentage point increase in the Fed funds target led to an increase of 55 basis points in the three-month T-bill rate, but only a 10 basis point increase in the 30-year bond yield. Recognizing that some Fed actions may have been anticipated, Cook and Hahn also examined the relationship between changes in interest rates and *future* changes in the target. They found little evidence that the target rate changes were anticipated at a one- to two-day horizon, however.

Results for more recent periods show a much weaker relationship between target rate changes and other interest rates. For example, in applying the Cook and Hahn event-study approach to the 1987–1995 period, Roley and Sellon (1995) found that the bond rate rose a statistically insignificant four basis points for each percentage point change in the target funds rate. (They did, however, find some evidence that policy moves were anticipated in the latter period.) Similarly weak results for the 1989–1992 period were obtained by Radecki and Reinhart (1994).

More sophisticated econometric procedures have been used to estimate the market's reaction to Federal Reserve policy, focusing on the unanticipated element of the actions. Using a Vector Autoregression (VAR) to model monetary policy, for example, Edelberg and Marshall (1996) found a large, highly significant response of bill rates to policy shocks, but only a small, marginally significant response of bond rates. Other examples of the VAR approach include Evans and Marshall (1998) and Mehra (1996). In an effort to model the discrete nature of target rate changes, Demiralp and Jorda (1999) examined the response of interest rates using an autoregressive conditional hazard (ACH) model to forecast the timing of changes in the Fed funds target, and an ordered probit to predict the size of the change. These methods can be cumbersome, however, and there is some debate as to the reliability of VAR-based measures of policy shocks [e.g., Rudebusch (1998)].

3 Interest rates' one-day response to monetary policy

This section first revisits the basic relationship between target rate changes and market interest rates, and confirms its apparent deterioration in the 1990s. It then describes how Fed funds futures rates can be used to distinguish between anticipated and unanticipated changes in the Fed funds target, and documents the much stronger relationship between market rates and unanticipated changes in the funds rate target.

Table 1: The one-day response of interest rates to changes in the Fed funds target

Maturity	Intercept	Response	R^2	SE	DW
3 month	−3.0	23.8	0.49	7.6	2.13
	(2.4)	(6.2)			
6 month	−5.0	18.4	0.29	9.0	2.35
	(3.5)	(4.0)			
12 month	−5.5	21.6	0.32	9.8	1.80
	(3.4)	(4.3)			
2 year	−5.2	18.2	0.26	9.6	2.28
	(3.4)	(3.7)			
5 year	−4.5	10.4	0.10	9.8	2.40
	(2.9)	(2.1)			
10 year	−4.0	4.3	0.02	8.5	2.50
	(2.9)	(1.0)			
30 year	−3.6	0.1	0.00	6.9	2.47
	(3.2)	(0.0)			

Notes: The change in the target Fed funds rate is expressed in percent, and the interest rate changes are expressed in basis points. The sample contains 42 changes in the target Fed funds rate from June 6 1989 through February 2 2000. Parentheses contain t-statistics.

3.1 Cook and Hahn revisited

Table 1 summarizes the relationship between target rate changes and market interest rates over the past ten years, using a regression identical to that used in the Cook and Hahn (1989) analysis. The sample includes 42 changes in the target rate, with the first on June 6 1989, and the last on February 2 2000. The bill rate data are end-of-day secondary market yields from the Federal Reserve H.15 release. The note and bond data are the end-of-day yields of on-the-run Treasuries, obtained from Bloomberg.

The coefficients describing interest rates' reaction to target rate changes are uniformly smaller and less significant than those reported by Cook and Hahn. For the three-month T-bill, the response is 24 basis points, compared with 55 basis points in Cook and Hahn. That study also found a statistically significant 10 basis point response of the 30-year bond, while here it is essentially zero, and statistically insignificant.

One possible explanation for the lack of statistical significance is simply the smaller number of observations — 42 target rate changes, compared with 75 in the Cook-Hahn sample. This cannot explain the smaller magnitude of the response, however. Another pos-

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sibility is that traders were not aware of the policy actions.[1] This is implausible, however, as since the late 1980s the target (or "intended") rate was generally apparent to market participants, even prior to the FOMC's practice of announcing its decisions, which began in 1994 [Meulendyke (1998)].

A more likely explanation is that target rate changes have been more widely anticipated in recent years, and this squares with the Roley and Sellon (1995) observation that interest rates rose somewhat in advance of target rate increases. Bond prices set in forward-looking markets should respond only to the surprise element of monetary policy actions, and not to anticipated movements in the funds rate. In assessing the market response to monetary policy, therefore, it makes sense to focus on the surprise component; to the extent that the target rate change itself is a "noisy" measure of the policy surprise, using it as a regressor would lead to attenuated estimates of interest rates' response.

3.2 Using futures rates to gauge policy expectations

Expectations of Fed policy actions are not directly observable, of course, but Fed funds futures prices are a natural, market-based proxy for those expectations. The market was established in 1989 at the Chicago Board of Trade, and contracts based on one- through five-month Fed funds are currently traded, along with a "spot month" contract based on the current month's funds rate. Krueger and Kuttner (1996) found that funds rate forecasts based on the futures price are "efficient," in that the forecast errors are not significantly correlated with other variables known when the contract was priced.

Using futures data as a measure of expected Fed policy has a number of advantages over statistical proxies. First, there is no issue of model selection; second, the vintage of the data used to produce the forecast is not an issue; and third, there are no generated-regressor problems. The main disadvantage, of course, is that it limits the analysis to the post-1989 period.

As it embodies near-term expectations of the Fed funds rate, the rate from the spot month contract offers a promising way to measure the surprise element of specific Fed actions. Two factors complicate the use of futures data for this purpose, however.

One complication is that the Fed funds futures contract's settlement price is based on the *average* of the relevant month's effective overnight Fed funds rate, rather than the rate

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[1]This would be consistent with Thornton (1999), who found that the Cook and Hahn results are attributable to the *announcement* of a policy change, rather than the action itself.

on any specific day.[2] Consequently, the time-averaging must somehow be undone to get a correct measure of the expected funds rate.

A second complication is that the futures contracts are based not on the target Fed funds rate, but on the effective market rate. In monthly averages, the two are very close — usually within a few basis points. At a daily frequency, however, the discrepancy between the market rate and the Fed's target is often too large to be ignored.

The question, then, is how best to extract a measure of the unexpected change in the target rate on date τ, relative to the forecast made on date $\tau - 1$,

$$\tilde{r}_\tau - E_{\tau-1}\tilde{r}_\tau \ ,$$

in light of these complications. To understand how the calculations are affected, it is useful to write out exactly what the futures rate represents. The spot futures rate on day τ of month s, $f^0_{s,\tau}$ can be interpreted as the conditional expectation of the average funds rate, r_t, for month s,

$$f^0_{s,\tau} = E_\tau \frac{1}{m_s} \sum_{t \in s} r_t + \mu_t \ ,$$

where m_s is the number of days in month s. In an efficient, frictionless market with risk-neutral investors, μ_t would be zero; otherwise, a non-zero and potentially time-varying premium may be present. The realized funds rate, r_t, can be thought of as the target rate plus noise, $\tilde{r}_t + \eta_t$, the error coming from unanticipated movements in reserve supply or demand.

Suppose that on date $\tau - 1$, futures market participants expected the Fed to change the Fed funds target rate on date τ, and that no further changes were expected within the month. The futures rate on date $\tau - 1$ would embody the average of realized funds rates through that date, and expectations about the rates prevailing after that date:

$$f^0_{s,\tau-1} = \frac{\tau}{m_s} \left[\tilde{r}_{\tau-1} + \bar{\eta}_{t<\tau} \right] + \frac{m_s - \tau}{m_s} \left[E_{\tau-1} \left(\tilde{r}_\tau + \bar{\eta}_{t\geq\tau} \right) \right] + \mu_t \ ,$$

where $\bar{\eta}$ is the average targeting error over the relevant portion of the month.

An obvious way to reconstruct the surprise change in the target is to look at the difference between the average funds rate and the spot month rate on the day prior to the change, scaled up to reflect the number of days affected by the change:

$$\frac{m_s}{m_s - \tau} \left(\bar{r} - f^0_{s,\tau-1} \right) \ ,$$

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[2]The futures rate is defined as 100 minus the contract's price. An additional twist is that the average is computed over every day in the month, with rates for weekends and holidays carried over from the previous business day.

where $\bar{r}$ is simply the effective funds rate averaged over the entire month. Substituting from above yields:

$$\left(\tilde{r}_\tau - E_{\tau-1}\tilde{r}_\tau\right) + \left(\bar{\eta}_{t\geq\tau} - E_{\tau-1}\bar{\eta}_{t\geq\tau}\right) - \frac{m_s}{m_s - \tau}\mu_t \;.$$

The surprise computed in this way, therefore, is equal to the "true" surprise, plus the average targeting errors made later in the month, minus the scaled-up premium. The first of these may introduce some noise (especially if an unusually volatile settlement period occurs late in the month), but its magnitude is likely to be no more than a few basis points.

The term involving μ_t is a more serious problem, however, as the scaling magnifies it and introduces time variation. The problem is especially severe towards the end of the month. With two days remaining in the month, for example, a one basis point premium would become a 15 basis point error; with one day left, the error would be 30 basis points. The problem could be solved by subtracting the premium from the forward rate, but this only works if μ_t is a known constant. Replacing the average realized funds rate with a weighted average of past realized funds rates and future target rates eliminates the average future targeting error, but the scaled-up forward premium remains.

How serious is this problem? As shown in the top panel of Figure 1, the spot-month futures rate does tend to converge to the average funds rate as the month progresses. But the expected next-day change in the Fed funds target from the procedure described above, shown in the bottom panel, becomes much more volatile towards the end of the month. (Much, but not all, of the volatility comes in December, apparently associated with year-end effects in the funds market.) If μ_t were a constant or a deterministic function of the day of the month, one would see a systematic bias in the predicted change; that the predictions' *volatility* increases suggests a random, time-varying μ_t.

A policy surprise measure less susceptible to this problem can be computed from the one-day change in the spot-month futures rate.[3] The key insight is that the day $\tau - 1$ futures rate embodies the expected change on (or after) date τ; if the change occurs as expected, then the spot rate will remain unchanged. Any deviation from the expected rate will result in a change in the futures rate, by an amount proportional to the number of days affected by the change. The one-day surprise computed in this way would be:

$$\Delta\tilde{r}_\tau^u = \frac{m_s}{m_s - \tau}\left(f_{s,\tau}^0 - f_{s,\tau-1}^0\right)$$

for all but the first and last days of the month. When the change comes on the first day of the month, its expectation would have been reflected in the prior month's spot rate, so the

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[3]Evans and Kuttner (1998) used a similar procedure to gauge the size of monetary shocks.

Figure 1: End-of-month behavior of the futures rate and implied target rate changes
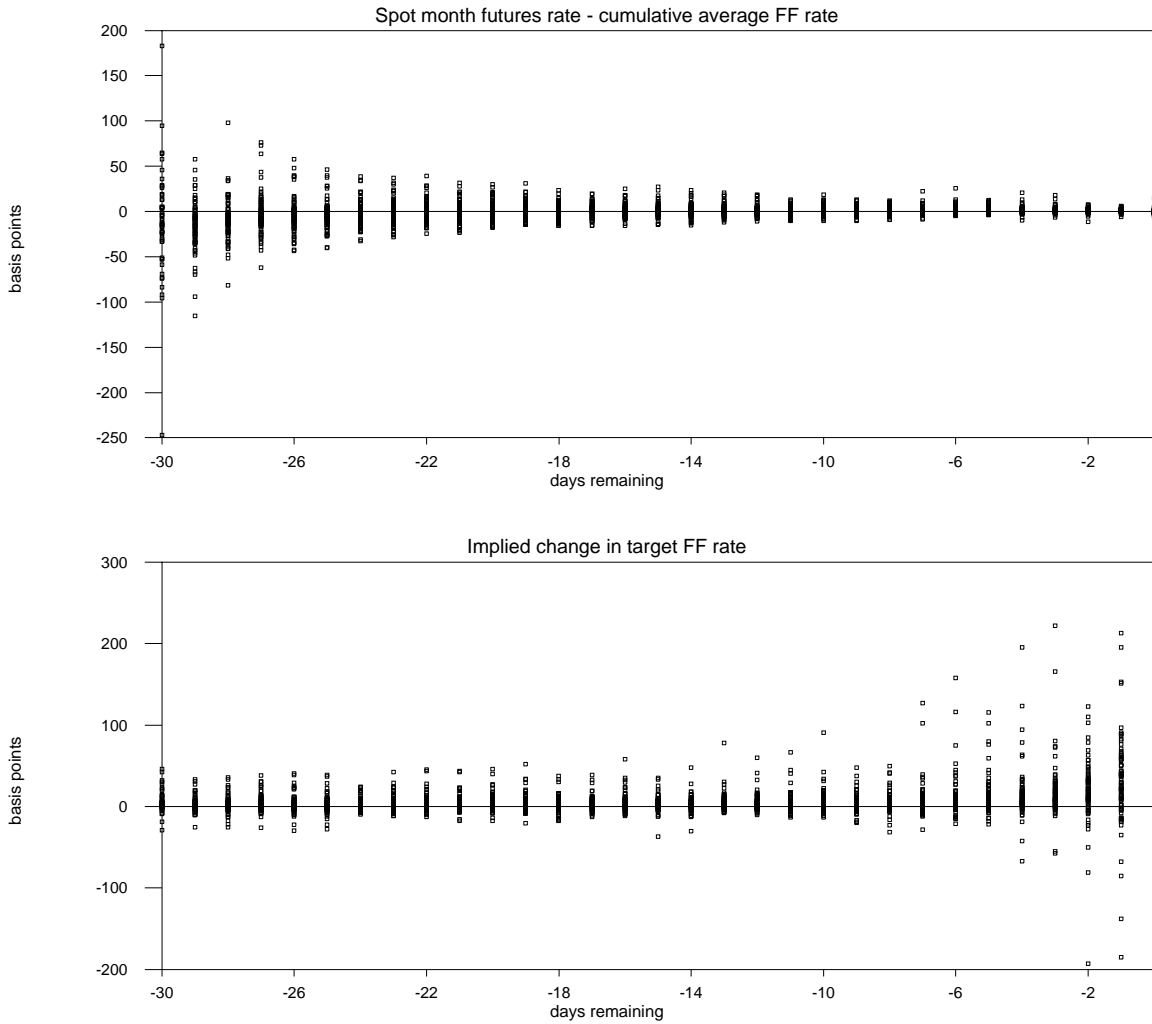
Notes: The top panel plots the difference between the spot-month futures rate on day t and the average through day t of the effective Fed funds rate: $f_{s,t}^0 - (1/t)\sum_{i=1}^{t} r_i$. The bottom panel plots the a measure of the expected target rate change, if that change were to take place on day $t+1$, based on the scaled-up futures rate and the average funds rate through day t: $[m/(m-t)]f_{s,t}^0 - \{[t/(m-t)](1/t)\sum_{i=1}^{t} r_i\} - \tilde{r}_t$.

one-month futures rate on the last day of the previous month, $f^1_{s-1,m_{s-1}}$ is used instead of $f^0_{s,\tau-1}$. Similarly, since the market Fed funds rate doesn't change until the day following the target change, when the change comes on the last day of the month it would have no effect on that month's spot rate. In this case, the difference in one-month futures rates must be used instead.

Under the assumption that no further changes are expected within the month (i.e., that $E_\tau \tilde{r}_{\tau+1} = \tilde{r}_\tau$ for $\tau \in s$), this method delivers a nearly pure measure of the one-day surprise target change.[4] As it involves only differences in the futures rate, the forward premium disappears, providing it doesn't change too much from one day to the next. The only contamination is the day τ targeting error, and the revision in the expectation of future targeting errors.[5] The expected component of the change is simply calculated as the actual minus the unexpected,

$$\Delta \tilde{r}^e_t = \Delta \tilde{r}_t - \Delta r^u_t \ .$$

A final issue concerns the timing of the data. The target rate changes are dated according to the day on which they became known. Up until 1994, this corresponded to the day after the FOMC's vote, when the new target rate became effective. In February 1994, the Federal Reserve began announcing its decision following each FOMC meeting. After the adoption of this procedure, target changes are assigned to the dates of the announcements, which usually come at 2:15 p.m. Eastern time. Since trading in Fed funds futures ends at 3:00 Eastern time (2:00 Central), the closing futures price used in the analysis typically will have incorporated the news of the FOMC's decision.

The sample contains two important deviations from this chronology, however. The first occurred on December 18 1990, when the Federal Reserve took the unusual step of announcing a 50 basis point cut in the discount rate immediately following the FOMC meeting. The action, which was made public at 3:30 p.m., after the close of the futures market, was correctly interpreted as signaling that the Fed had also cut the funds rate 25 basis points.[6] Stock and bond markets, which were still open when the announcement was made, reacted euphorically to the news, even though the change would not affect the Fed funds spot and futures markets until the following day. To deal with this timing mismatch,

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[4]This assumption is not entirely justified, as since 1989, three months have had two target rate changes.

[5]These errors are occasionally non-trivial, so the change in the one-month futures rate is used when the target rate change occurs within three days of the end of the month, which was the case for five of the 42 changes in the sample.

[6]In its reporting on the move, the Wall Street Journal stated: "The committee is believed to have authorized an immediate reduction of one quarter percentage point in the key federal funds rate," Wessel (1990).

the December 19 move is treated as if it occurred on the 18th, and the difference between closing futures rate on the 18th and the opening rate on the 19th is used to measure the surprise element of the action.[7]

A similar episode occurred on October 15 1998, when the Fed surprised the markets by changing its Fed funds target between FOMC meetings — something it had not done since April 1994. The move was announced at 3:15 p.m. Eastern time, after the futures market in Chicago had closed. Consequently, although the announced change in the target Fed funds rate took place on the 15th, the futures market did not register the change until the following day. In this case, a better measure of the policy surprise would involve the difference between the closing futures rate on the 15th and the opening rate on the 16th.

Table 2 lists the 42 target rate changes contained in the sample, and their futures-based decomposition into expected and unexpected components.[8] Breaking the changes out in this way reveals some interesting patterns. For example, the rate cuts in 1989 appear to have been largely anticipated, as was the runup of rates in 1994–95. Many of the final round of rate cuts in late 1991 and 1992 seem to have taken the market by surprise, however.

3.3   Results

Having used the futures rates to distinguish between anticipated and unanticipated changes in the funds rate target, the natural question to ask is whether the response of bill and bond rates to the two components differs — or indeed whether rates respond at all to predictable changes. This can be done within the Cook and Hahn-style analysis by regressing the change in the interest rate on the two components of the target rate change,

$$\Delta R_t^i = \alpha^i + \beta_1^i \Delta \tilde{r}_t^e + \beta_2^i \Delta \tilde{r}_t^u + \varepsilon_t^i \ , \tag{2}$$

where R^i again represents the yields on 3- 6- and 12-month bills, 2- 5- and 10-year notes, and 30-year bonds. The results appear in Table 3.

Two main conclusions emerge from the table. The first is that the coefficient on the anticipated portion of the target Fed funds change is small, and except for the three-month bill, statistically insignificant, consistent with the view that market rates respond only to new information.

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[7]Thanks to Jason Bram for suggesting this modification.

[8]The target rate changes correspond to those in Rudebusch (1995), except for the six-basis point adjustment on August 10 1989, which is omitted from the analysis, and the 50 basis point rate cut on December 19 1990, which is assigned to the 18th instead.

Table 2: Actual, expected and unexpected changes in the Fed funds target (bp)

	Date	Actual	Expected	Unexpected
1989	6/6	-25	-24	-1
	7/7	-25	-22	-3
	7/27	-25	-25	0
	10/18	-25	-25	0
	11/6	-25	-29	+4
	12/20	-25	-8	-17
1990	7/13	-25	-11	-14
	10/29	-25	+6	-31
	11/14	-25	-29	+4
	12/7	-25	+2	-27
	12/18	-25	-4	-21
1991	1/8	-25	-7	-18
	2/1	-50	-25	-25
	3/8	-25	-9	-16
	4/30	-25	-8	-17
	8/6	-25	-10	-15
	9/13	-25	-20	-5
	10/31	-25	-20	-5
	11/6	-25	-13	-12
	12/6	-25	-16	-9
	12/20	-50	-22	-28
1992	4/9	-25	-1	-24
	7/2	-50	-14	-36
	9/4	-25	-3	-22
1994	2/4	+25	+13	+12
	3/22	+25	+28	-3
	4/18	+25	+15	+10
	5/17	+50	+37	+13
	8/16	+50	+36	+14
	11/15	+75	+61	+14
1995	2/1	+50	+45	+5
	7/6	-25	-24	-1
	12/19	-25	-15	-10
1996	1/31	-25	-18	-7
1997	3/25	+25	+22	+3
1998	9/29	-25	-25	0
	10/15	-25	+1	-26
	11/17	-25	-19	-6
1999	6/30	+25	+29	-4
	8/24	+25	+23	+2
	11/16	+25	+16	+9
2000	2/2	+25	+30	-5

Table 3: The one-day response of interest rates to Fed funds surprises

| Maturity | Intercept | Response to target change: | | R^2 | SE | DW |
		anticipated	unanticipated			
3 month	−1.5	12.3	50.4	0.60	6.8	2.24
	(1.2)	(2.5)	(5.7)			
6 month	−2.9	2.1	56.3	0.51	7.6	2.41
	(2.2)	(0.4)	(5.7)			
12 month	−2.6	−0.3	72.7	0.63	7.3	2.15
	(2.0)	(0.1)	(7.6)			
2 year	−2.8	−0.4	61.4	0.52	7.8	2.25
	(2.0)	(0.1)	(6.0)			
5 year	−2.4	−5.8	48.1	0.33	8.6	2.37
	(1.6)	(0.9)	(4.3)			
10 year	−2.4	−7.4	31.5	0.19	7.8	2.37
	(1.8)	(1.3)	(3.1)			
30 year	−2.5	−8.2	19.4	0.13	6.5	2.46
	(2.2)	(1.7)	(2.3)			

Notes: Anticipated and unanticipated changes in the Fed funds target are computed from Fed funds futures rates, as described in the text. Parentheses contain t-statistics. See also notes to Table 1.

Table 4: The one-day response of interest rates to the lagged Fed funds rate

| Maturity | Lagged target change | | Lagged surprise change | |
	Response	R^2	Response	R^2
3 month	−1.4	0.00	4.1	0.01
	(0.4)		(0.5)	
6 month	1.1	0.00	−1.6	0.00
	(0.3)		(0.2)	
12 month	1.3	0.01	−3.7	0.01
	(0.5)		(0.6)	
2 year	3.0	0.02	−9.8	0.04
	(0.9)		(1.3)	
5 year	3.3	0.03	−6.1	0.02
	(1.0)		(0.8)	
10 year	5.2	0.07	0.8	0.00
	(1.7)		(0.1)	
30 year	4.0	0.05	−0.3	0.00
	(1.5)		(0.1)	

Notes: Parentheses contain t-statistics. See also notes to Table 3.

Figure 2: Target rate changes and the 5-year rate

target change, percent
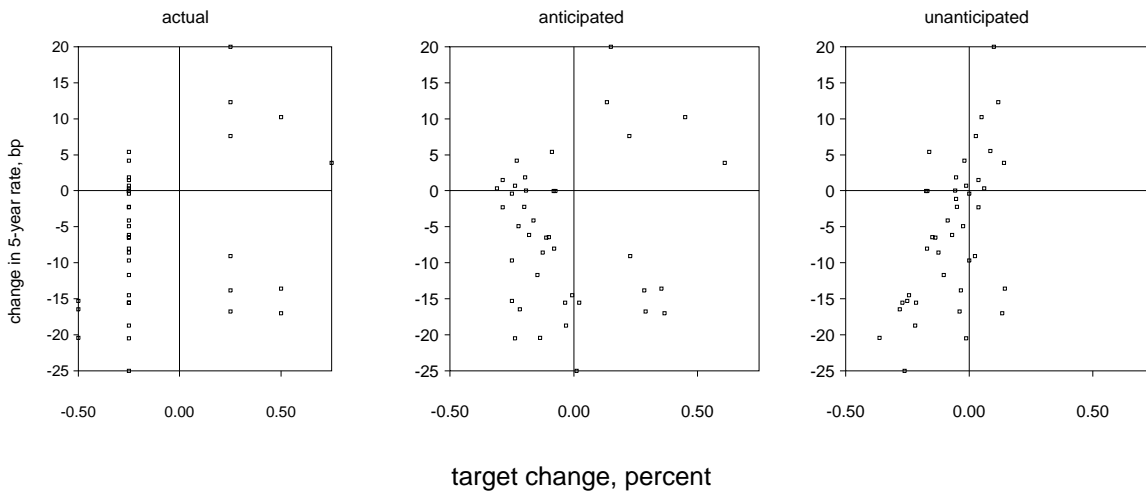
The second main result is that the response of market rates to surprise changes in the target is considerably larger than the response to "raw" changes — as expected, since the raw changes are contaminated by noise in the form of *expected* rate changes, whose true coefficient is near zero. For the three-month maturity, the response to the surprise element of the rate change is more than twice as large as it is to the raw change: 50 basis points (for a one percentage point change in the target), compared with 24. At the short end of the yield curve, the coefficients are similar to those reported by Cook and Hahn, and not far from the contemporaneous effects in the impulse response functions estimated by Edelberg and Marshall (1996).

Replacing the raw target rate changes with the surprise component makes even more of a difference for longer-term interest rates. For five-year notes, the response is a highly significant 48 basis points, compared with an insignificant 10 basis points. Even the 30-year bond now shows a statistically significant 19 basis point reaction. All are considerably larger than those reported by Cook and Hahn. The results are also much stronger than those of Roley and Sellon (1999), perhaps owing to the different procedure used for calculating the surprise component of the rate change.

The scatterplots in Figure 2 confirm these results: the raw target rate changes (left-hand panel) and the expected target rate changes (center panel) bear little, if any, relation to changes in the five-year rate. By contrast, changes in the five-year rate line up quite nicely with the surprise target rate changes — all except for two observations deep in the southeast quadrant, where unexpected rate increases were associated with bond market rallies.

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A closer examination of these two outliers is revealing. Both correspond to larger-than-expected 50 basis point increases in the target Fed funds rate in 1994: the first on May 17, and the second on August 16. Why did these rate increases incite bond market rallies? It turns out that both actions were accompanied by statements suggesting that further rate increases were not imminent.[9] Therefore, although the policy actions boosted short-term interest rates, the expected future rates fell, leading to the decline in long rates. It is interesting to note that the Fed's policy of announcing a rationale for monetary actions, adopted in February 1994, seems to have played a key role in the bond market's unusual reactions.[10]

Short-term interest rates tend to move roughly one-for-one with the Funds rate, however, so it remains something of a puzzle as to why a one percentage point surprise increase in the target generates only a 50–70 basis point increase in the bill rates. One possibility is that policy actions are viewed as relatively transitory. This is unlikely, however, in light of the observed persistence of target rate changes. Another is that the surprise is associated with increases in bill rates on subsequent days. This implausibly says that financial markets respond to "old news," however. Nor is this supported by regressions of the change in market interest rates on lagged changes in the Fed funds target, or its surprise element, shown in Table 4. Unlike the results reported in Cook and Hahn, only the three-month rate shows a systematic response to the lagged changes. (This may be because the Fed's recent actions have been more transparent than those of the 1970s.) A third possibility is that the Fed's actions — if not their exact timing — were anticipated, a possibility explored below.

4   Interest rates' response at the one-month horizon

The event-study approach employed by Cook and Hahn, and used in the preceding section, focused on very the high frequency response to irregularly-spaced events. For some purposes, it may be more useful to take a time-series approach, and look at surprises defined at regularly-spaced monthly intervals. By allowing for a possible target change in any month,

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[9]The May 17 announcement included the statement that "These actions ... substantially remove the degree of monetary accommodation which prevailed throughout 1993." The August 16 announcement stated that "these actions are expected to be sufficient, at least for a time, to meet the objective of sustained, noninflationary growth." Both were widely interpreted as reducing the likelihood of subsequent rate increases; see Wessel (1994), Thomas (1994) and Vogel (1994).

[10]Bomfim and Reinhart (1999) take a more systematic look at disclosure policy's impact on financial markets' reaction, but find little discernible effect. There might also have been some reaction to the FOMC's announced "bias," which was made public for a brief period from May through December 1999. But with only six FOMC meetings during this period, any effect would be hard to quantify.

this method recognizes that Fed *inaction* may itself represent a policy surprise. This has more of the flavor associated with the VAR literature mentioned earlier, and shifts the focus away from the precise timing of the policy actions.[11] In addition, the assumption that the dates of possible policy actions are known is no longer necessary.

To avoid distorting the timing and magnitude of interest rate changes with time-averaging, one would ideally want to define interest rate changes in terms of point-in-time data: e.g., the change in the target rate from the last day of month $s - 1$ to the last day of month s. The problem, as discussed above, is that the Fed funds futures contracts' settlement price is determined by the monthly average funds rate, rather than the rate prevailing on a certain day. This averaging means that the difference between the average funds rate in month s and the one-month futures rate on the last day of month $s - 1$ understates the "true" surprise, measured in terms of month-end rates.[12]

The shift to a monthly frequency makes it hard to use successive days' futures rates to measure the true surprise. And as discussed above, using the scaled-up difference between the funds rate and the previous month's futures rate will exaggerate any forward premium, introducing potentially serious noise into the measure.

Rather than trying to correct the measured Fed funds surprises, it is easier simply to introduce the same distortion into the changes in market interest rates. The unexpected change in the funds rate is defined as the average rate in month s, minus the one-month futures rate on the last day of month $s - 1$,

$$\bar{\Delta}\tilde{r}_s^u \equiv \frac{1}{m_s} \sum_{t \in s} \tilde{r}_t - f_{s-1,m_{s-1}}^1 \quad,$$

and the expected change in the funds rate target is defined analogously as

$$\bar{\Delta}\tilde{r}_s^e \equiv f_{s-1,m_{s-1}}^1 - \tilde{r}_{s-1,m_{s-1}} \quad,$$

i.e., spread between the future rate and the Fed funds target on the last day of month $s - 1$. The sum of the two is just the month-s average funds rate target minus the target on the last day of month $s - 1$, denoted $\bar{\Delta}\tilde{r}_s$. (The non-standard $\bar{\Delta}$ notation is used to refer to the change from the last day of month $s - 1$ to the average of month s.)

To mimic the time-averaging in the Fed funds futures rates, the $\bar{\Delta}$ filter is also applied to market interest rates:

$$\bar{\Delta}R_s^i \equiv \frac{1}{m_s} \sum_{t \in s} R_t - R_{s-1,m_{s-1}}^i \quad.$$

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[11]To the extent that policy responds to information received within the month, these month-ahead surprises do not match up exactly with the orthogonalized "policy shocks" from VARs, however.

[12]These time aggregation issues are discussed in greater detail in Evans and Kuttner (1998).

By defining the change in this way, the effect of time-averaging on the measured Fed funds surprise is duplicated in the changes in market interest rates.[13]

Table 5 displays the results of a regression of changes in market interest rates on monthly changes in the target Fed funds rate,

$$\bar{\Delta}R_s^i = \alpha^i + \beta^i \bar{\Delta}\tilde{r}_s + \varepsilon_s^i \, ,$$

analogous to those reported above for the one-day changes. Comparing Table 5 with Table 1, one finds that the response to the raw change in the Fed funds target is *much* larger at the monthly frequency than for one-day changes: 73 versus 24 basis points for three-month bills, and 33 versus less than one basis point for thirty-year bonds. There are at least two possible explanations for this difference. One is simply that if the Fed somehow telegraphs its intentions in the days prior to its actions, the one-month change in the Fed funds target contains a larger surprise element than the one-day change. The other is that target changes over the span of a month incorporate the Fed's systematic response to macroeconomic conditions, whereas the one-day changes presumably do not.

The estimated responses are even stronger when the expected and unexpected target rate changes are broken out separately. Table 6 reports the results of the regression,

$$\bar{\Delta}R_s^i = \alpha^i + \beta_1^i \bar{\Delta}\tilde{r}_s^e + \beta_2^i \bar{\Delta}\tilde{r}_s^u + \varepsilon_s^i \, , \tag{3}$$

where futures rates are used to compute the surprise target rate changes, as described above. The yield on three-month bills rises by 79 basis points in response to an unexpected one percent increase in the target, and the response of six- and twelve-month bills is nearly one-for-one. Not only are these estimates larger than those for the one-day surprises, but they also display a bit more of the "hump shape" often associated with the yield curve's reaction to news [see, e.g., Fleming and Remolona (1999)]. The estimated responses of note and bond rates are also more robust than those observed at a one-day horizon, with the 30-year bond yield rising by over 50 basis points after a one percentage point surprise tightening.

It also turns out that interest rates (at least those for three- and six-month bills) respond quite strongly to the *expected* change in the Fed funds target. At first glance, this would seem to contradict the efficient markets proposition that asset prices should respond only

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[13]To remain comparable to the futures rate calculation, the average is taken over every calendar day of the month. The measured funds rate surprise may be contaminated by a forward premium, but if the premium is constant, it will be absorbed into the constant terms in the regressions that follow.

Table 5: The one-month response of interest rates to changes in the Fed funds target

Maturity	Intercept	Response	R^2	SE	DW
3 month	−0.7	72.8	0.40	10.8	2.08
	(0.7)	(5.5)			
6 month	0.2	77.2	0.37	12.3	2.02
	(0.1)	(4.9)			
12 month	−0.4	77.0	0.29	14.7	1.68
	(0.2)	(4.7)			
2 year	0.0	70.7	0.20	17.4	1.64
	(0.0)	(4.0)			
5 year	0.5	57.0	0.14	17.4	1.56
	(0.3)	(3.5)			
10 year	0.7	43.1	0.10	15.7	1.63
	(0.4)	(3.3)			
30 year	0.4	33.1	0.08	13.8	1.63
	(0.3)	(3.3)			

Notes: The change in the target Fed funds rate is expressed in percent, and the interest rate changes are expressed in basis points. The sample runs from June 1989 through January 2000. Parentheses contain t-statistics.

Table 6: The one-month response of interest rates to Fed funds surprises

Maturity	Intercept	Response to target change:		R^2	SE	DW
		anticipated	unanticipated			
3 month	0.1	60.8	79.3	0.41	10.8	2.01
	(0.1)	(3.2)	(7.9)			
6 month	1.8	52.0	90.8	0.41	11.9	1.93
	(1.6)	(2.2)	(8.4)			
12 month	1.7	44.4	94.6	0.34	14.2	1.60
	(1.0)	(1.7)	(7.5)			
2 year	2.7	28.5	93.6	0.27	16.6	1.55
	(1.4)	(1.2)	(6.2)			
5 year	3.3	12.7	81.1	0.22	16.6	1.47
	(1.7)	(0.6)	(5.3)			
10 year	3.1	5.8	63.3	0.18	15.1	1.58
	(1.7)	(0.4)	(5.4)			
30 year	2.6	−1.6	51.9	0.17	13.2	1.61
	(1.7)	(0.1)	(6.6)			

Notes: Parentheses contain t-statistics. See also notes to table 5.

Table 7: The response of interest rates to Fed action and inaction

Maturity	Months w/ target change		Months w/o target change	
	Response	R^2	Response	R^2
3 month	91.3	0.52	−5.7	0.00
	(5.7)		(0.3)	
6 month	100.4	0.52	25.9	0.03
	(5.9)		(1.1)	
12 month	93.7	0.43	58.1	0.09
	(4.7)		(2.0)	
2 year	88.1	0.38	82.2	0.12
	(4.3)		(2.9)	
5 year	73.4	0.33	91.1	0.14
	(4.0)		(3.9)	
10 year	60.9	0.31	75.2	0.11
	(4.3)		(4.3)	
30 year	52.4	0.34	62.8	0.10
	(6.0)		(4.0)	

Notes: Parentheses contain t-statistics. The sample consists of 38 months containing at least one target rate change, and 90 months containing no target rate change. See also notes to table 5.

to new information. It is important to remember, however, that the change in the rate does not represent an excess return. In fact, under the pure expectations hypothesis, the expected one-month change in the k-month interest rate can be expressed as $1/k$ times the expected k-month change in the one-month rate. Hence, the relationship between interest rate changes and expected policy actions should be inversely related to the maturity.

Aside from the different time interval over which interest rate changes are defined, these results also differ from those in section 3 in that the sample includes months in which *no* target change took place. An interesting check, therefore, would be to see whether the bond market responded in the same way to Fed *inaction* as it did to its actions.

Table 7 displays the results when the sample is split according to whether the month contained a Fed action. For those 38 months containing a target rate change, bill rates' response is nearly one-for-one, as it was over the whole sample. During these months, monetary policy accounts for half the variance in the three- and six-month bill rates. For those months without policy changes, however, bill rates' responses are much weaker, and statistically insignificant.[14] Such a discrepancy is not apparent in responses of note and

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[14]The opposite result is obtained by Roley and Sellon (1999), looking at one-day changes on FOMC

bond rates, however. For longer-term interest rates, the response is similar, regardless of subsample. In both cases, the R^2 is much lower in the "no change" subsample.

5 Implications for the term structure of interest rates

The behavior of the short end of the yield curve has been something of a puzzle for researchers. Contrary to the implications of the expectations hypothesis, the slope of the yield curve over the three- to 12-month range seems to have very little predictive power for subsequent changes in short-term interest rates.[15]

Cook and Hahn (1989) argued that the persistence of funds rate changes is to blame for the failure. If changes in the target rate tend to persist for months at a time, then the slope of the yield curve will contain little information about the expected path of policy. And since Fed policy is presumably the major factor driving the short end of the yield curve, this means the term spread will be dominated by changes in the term premium. Evidence presented by Rudebusch (1995) corroborates the Cook and Hahn argument. Using a high-frequency duration model, Rudebusch found that a change in the funds rate had no implications for further changes beyond a horizon of about five weeks.

The effect of surprise target rate changes on expected future Fed policy can be examined directly using the Fed funds futures data. The results provide further evidence supporting the Cook-Hahn and Rudebusch findings: an unexpected change in the funds rate today has virtually the same effect on the expected level of the funds rate over the horizons spanned by the futures contracts.

Since changes in the futures rate can be interpreted as market expectations of future target rate changes, they can be used to gauge the effect of surprise policy actions on policy expectations. As in section 3, one-day changes in the one- through five-month futures rates are regressed on the expected and unexpected change in the target, for those days when the target rate was changed. The results appear in the top panel of table 8.

Two results stand out. The first is that the coefficients on the funds rate surprise are in the neighborhood of 0.6 — significantly less than one in both an economic and statistical sense. This, again, is consistent with the view that day-ahead surprises have more to do with the *timing* of FOMC actions, rather than with the actions themselves. The second

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meeting dates.

[15]It should be noted that this puzzle is less evident in the more recent sample than in earlier periods. The regression of the three-month change in the three-month bill rate on the forward-spot spread yields an estimated slope coefficient of 0.54, with a t-statistic of 3.4.

Table 8: The response of funds rate expectations to target rate surprises

Horizon	Intercept	Response to target change: anticipated	Response to target change: unanticipated	R^2	SE	DW
Daily data						
1 month	−0.00	0.03	0.64	0.74	0.053	1.50
	(0.4)	(0.8)	(9.3)			
2 months	−0.01	0.00	0.62	0.65	0.061	1.66
	(1.0)	(0.1)	(7.7)			
3 months	−0.02	0.03	0.55	0.57	0.066	1.52
	(1.7)	(0.6)	(6.4)			
4 months	−0.02	0.01	0.61	0.56	0.074	1.51
	(1.6)	(0.3)	(6.3)			
5 months	−0.02	0.02	0.57	0.47	0.087	1.44
	(1.3)	(0.3)	(4.7)			
Monthly data						
1 month	0.01	0.15	0.78	0.70	0.056	1.72
	(1.5)	(1.6)	(11.6)			
2 months	0.01	0.16	0.79	0.50	0.086	1.76
	(0.7)	(1.1)	(7.7)			
3 months	0.00	0.18	0.82	0.43	0.102	1.67
	(0.3)	(0.9)	(8.1)			
4 months	0.00	0.21	0.84	0.38	0.118	1.78
	(0.1)	(1.0)	(7.0)			

Notes: Anticipated and unanticipated changes in the Fed funds target are computed from Fed funds futures rates, as described in the text. Parentheses contain t-statistics. See also notes to Table 1.

observation is that the coefficients for the five horizons are similar in magnitude, and all within one standard error of each other. Apparently, a surprise increase in the current month implies a higher *level* of rates in coming months, but says little about any future *changes* in rates.

The bottom panel of table 8 confirms this conclusion, using surprise target changes measured at monthly intervals.[16] A one percentage point funds rate surprise increases expected future rates by roughly 80 basis points at a horizon of one through four months.

6 Conclusions

The aim of this paper has been to estimate the effect of changes in Federal Reserve policy on a spectrum of market interest rates, using Fed funds futures data to distinguish anticipated from unanticipated changes in the target. Its main finding has been to document a strong and robust relationship between surprise policy actions and market interest rates; the response to anticipated actions is generally small. A second finding is that except at the short end of the yield curve, interest rates' reaction to Fed inaction is similar to their response to overt actions. Third, surprise changes in the target rate have minimal effects on expectations of future Fed actions, helping to explain the failure of the expectations hypothesis on the short end of the yield curve.

More generally, this paper has discussed the use of Fed funds futures contracts in extracting measures of expected policy actions, highlighting possible pitfalls introduced by the contracts' unique time-averaged structure. An interesting line of future research would be to use the methods developed here to analyze the effects of monetary policy on other financial markets, such as those for equity and foreign exchange.

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[16]Because of the time averaging problem discussed earlier, the change in the one-month-ahead funds rate expectation is computed as the average one-month futures rate in month s minus the two-month futures rate on the last business day in month $s - 1$.

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