The Behavior of Federal Funds Futures Prices over the Monetary Policy Cycle

JEFF MOORE AND RICHARD AUSTIN

Moore is a senior economic analyst in the Atlanta Fed's research department, and Austin is a senior financial analyst in the credit and risk management department. *The authors thank Ellis Tallman, Mark Kamstra, and Will Roberds for helpful comments.*

The use of federal funds futures derivative contracts has grown remarkably over the past decade. Commercial banks, corporations, and other market participants use these contracts to hedge interest rate risk and to speculate on interest rate movements. In addition to acting as a useful hedging tool, the contract prices also provide an information externality, implicitly reflecting the markets' view of the federal funds rate's expected path. More than a decade of federal funds futures market data, spanning two recessions and numerous monetary policy cycles, is now available and provides sufficient information to draw conclusions relating the behavior of federal funds futures prices to monetary policy. Because a larger amount of data was available, this study draws more specific conclusions than did previous research. (See Boxes 1 and 2 for more information about derivatives and the federal funds future market).

Earlier research addresses two main issues. First, Carlson, McIntire, and Thomson (1995), Krueger and Kuttner (1996), and Söderström (2001), among others, have focused on the efficiency and predictive accuracy of implied rates of federal funds futures. Using data mostly from the early 1990s, they find futures prices to be relatively accurate, efficient predictors of the path of the funds rate, with Krueger and Kuttner estimating a modest positive bias at one- and two-month horizons.

The second issue relates to increasing Federal Open Market Committee (FOMC) information disclosures and their ability to synchronize the expectations of market participants and policymakers. These disclosures include the prompt announcement of target rate changes following FOMC meetings (since February 1994), making target rate changes more often at regularly scheduled FOMC meetings (a gradual shift starting in 1994), and announcing a bias toward output weakness or inflation risk (since 2000). A decline in futures market forecast errors over the latter half of the 1990s is viewed as support for the contention that greater disclosure has resulted in greater synchronicity between actual monetary policy and market expectations of monetary policy (Poole 1999). This synchronicity should result in improved asset pricing and more efficient resource allocation, among other benefits.

Previous federal funds futures market research has generally treated futures market data as a single sample, often out of necessity given the small sample sizes available to early studies. But even more recent work has generally not looked at the relationship between federal fund futures prices and the path of the funds rate over different time periods. The following analysis breaks apart a thirteen-year sample and examines futures prices over different stages in the monetary policy cycle and around turning points in the trajectory of policy. The analysis also investigates the relationship

BOX 1

Interest Rate Derivatives

The profits of many industries within the U.S. economy are sensitive to changes in the term structure of interest rates. For example, banks may borrow short-term funds and make long-term loans. When short-term interest rates rise, the spread between the cost of new funds and the interest earned on previously loaned funds declines, adversely affecting bank profits. Given this possibility, banks and other firms with similar interest rate exposures may desire to protect themselves against some or all of this risk. The demand to hedge against interest rate risk led to the creation and expansion of interest rate derivatives markets in recent decades. There now exist options, futures, swaps, and more complex derivative instruments whose prices or payments are based on movements in underlying interest rates.[1] These instruments can be used separately or in combination to bound a firm's exposure to interest rate risk.

For instance, a bank can protect itself against increases in short-term interest rates by selling federal funds futures contracts. If the underlying interest rate rises, those short positions in futures contracts will increase in value, effectively limiting the rise in the costs of short-term funds over the term of the contract. This increase offsets the contraction of the spread between the costs of funds and the return on loans. A similar hedge could be accomplished with an option contract.[2]

1. For an extended introduction to interest rate derivatives, see Pitts and Fabozzi (1990).
2. Option contracts are not generally available on the underlying interest rate itself; rather, they are typically written on futures contracts on this underlying interest rate. See Fabozzi (1996, chap. 22) for a good explanation as to why writing options on interest rate futures is essentially equivalent to writing options on the movements of the interest rate itself.

BOX 2

The Federal Funds Futures Market

Started in late 1988 at the Chicago Board of Trade (CBOT), the federal funds futures contract is the most widely used futures contract that is directly tied to the federal funds rate. The contract price is based on the monthly average of the daily effective federal funds rate as published by the Federal Reserve Bank of New York.[1] The second section of this box lays out the exact specifications of the CBOT federal funds futures contract.[2]

Although designed as a hedging vehicle, prices on federal funds futures contracts also contain important information that has proved extremely useful to Federal Reserve policymakers. Under certain assumptions, the actions of hedgers and speculators in the federal funds futures market result in contract prices that represent the market participants' mean expectation for the future path of the average effective federal funds rate.[3] As a result, by looking at the term structure of implied rates on federal funds futures, policymakers are able to assess market participants' expectations and understand what interest rate forecasts are implicit in other asset prices.

The popularity of the CBOT federal funds futures contracts has grown consistently since their introduction. As Charts A and B demonstrate, both volume and open interest have increased substantially, with market participation surging through 2001 as the FOMC aggressively reduced the federal funds rate.

Chart C shows the composition of participants in the federal funds futures market. The data show banks and other hedgers to be the dominant market participants as measured by number of positions taken. However, speculators comprise a small but crucial segment of the market, capitalizing on arbitrage opportunities and moving market prices to reflect the anticipated path of monetary policy.

Federal Funds Futures Contract Highlights and Terminology

Contract months. Counting from a specific day of the year, the CBOT is willing to make federal funds futures contracts for the current month and the following twenty-four calendar months available for trade. In addition to these twenty-five contracts, the CBOT may list two additional contracts for the first two months of March, June, September, and December that follow the first twenty-five months. For example, a June 2006 contract could be listed as early as December 2003.

However, contracts are rarely made so far from settlement. Typically, trading volume and open interest for federal funds futures are relatively low until the contracts are within six months of settlement.

Trading hours. Federal funds futures are traded on the floor of the CBOT from Monday through Friday between 7:20 A.M. and 2:00 P.M. CST. Federal funds futures are also traded electronically at the CBOT from Sunday through Friday between 8:00 A.M. and 4:00 P.M. CST.

According to 2001 statistics, 98.7 percent of CBOT federal funds futures were traded in traditional open outcry sessions—on the floor of the exchange between traders shouting and using hand signals. The remainder were traded on a/c/e (an abbreviation of Alliance/CBOT/Eurex), an electronic exchange run as a joint venture between the CBOT and Eurex exchanges.

Price basis. Federal funds futures prices are expressed as 100 minus the expected average effective federal funds rate for the delivery month. For example, if a January contract has a price of 92.75, it reflects an anticipated average rate of 100 – 92.75 = 7.25 percent for that month.

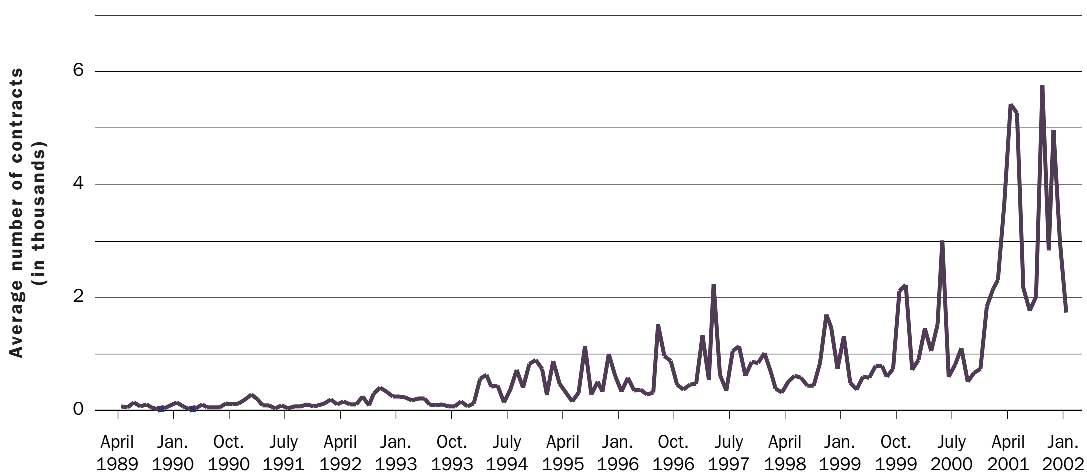
Tick size. Federal funds futures contract prices are not allowed to move in increments smaller than one-half of 1 basis point. A price movement of one-half basis point, or a tick, is associated with a value of $20.835. The value of $20.835, known as the tick size, represents thirty days' interest on $5 million dollars at a rate of one-half of 1 basis point, based on a 360-day year. The value is calculated as $0.5 \times 0.01 \times 0.01 \times \$5{,}000{,}000 \times (30/360) \approx \$20.835$. Thirty days' interest is used to calculate the tick size regardless of how many days are actually in the contract month. This calculation produces a constant tick size of $20.835 and gives the federal funds futures their official name of "thirty-day federal funds futures."

Marking to market. The price movements of federal funds futures result in unrealized gains and losses for market participants. Each day after the market closes, the CBOT squares the positions of contract buyers against sellers by assessing the effect of the day's price movement on each participant's holdings. Each participant's position is said to be marked to the market.

For each one-half basis point drop in price, a contract buyer's margin account will be reduced by $20.835 per contract, and the contract seller's account will be credited by the same amount. An increase in price will have opposite effects on the buyer and the seller. For example, assume an investor has bought five federal funds futures

CHART A

Volume of Current-Month Contract



1. The daily effective federal funds rate is a transaction-weighted average of rates on brokered federal funds trades. These data are available daily in Federal Reserve Statistical Release H.15.
2. For more information on CBOT federal funds futures contracts, see Chicago Board of Trade (1997a, 1997b, 1999, 2002).
3. These assumptions for futures markets in general include costless transactions, riskless borrowing, and costless and perfect storage. See Duffie (1989, chap. 5) for the arbitrage argument.

BOX 2 (continued)

contracts. If federal funds futures previously closed at 92.75 and then fell to 92.55 at the end of the trading day (a one-day decline of 20 basis points, or 40 ticks), marking to market will reduce the investor's margin account by 5 × 40 × $20.835 = $4,167.

Settlement. Federal funds futures contracts can trade until the last business day of the contract month. On the next business day, the positions of contract buyers and sellers are cash settled according to the final settlement price. As an example, the June 2006 contract will stop trading on Friday, June 30, 2006, and settle on Monday, July 3, 2006.

The settlement price is based on daily effective federal funds rates published by the Federal Reserve Bank of New York. The settlement price is calculated as 100 minus the average effective federal funds rate for the contract month, with the most recent daily rate applied to any weekends or holidays.

CHART B

Open Interest of Current-Month Contract

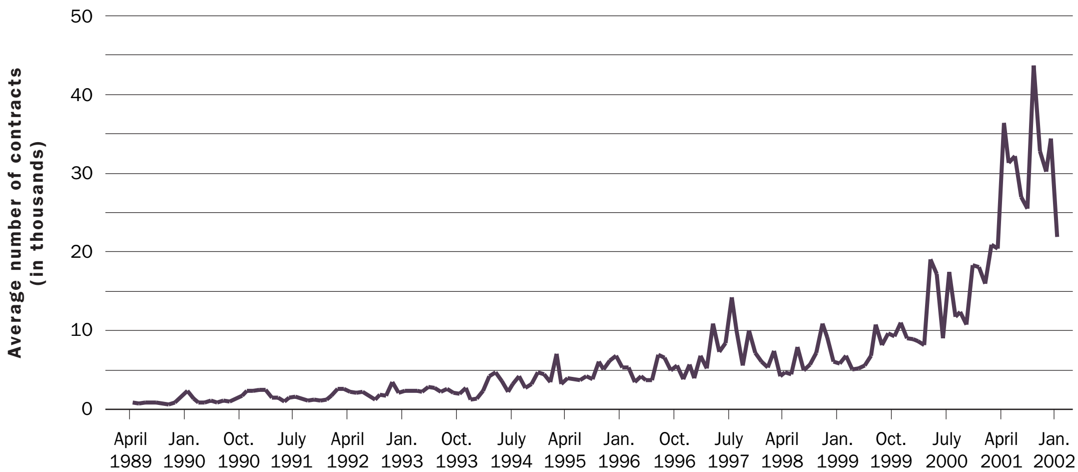
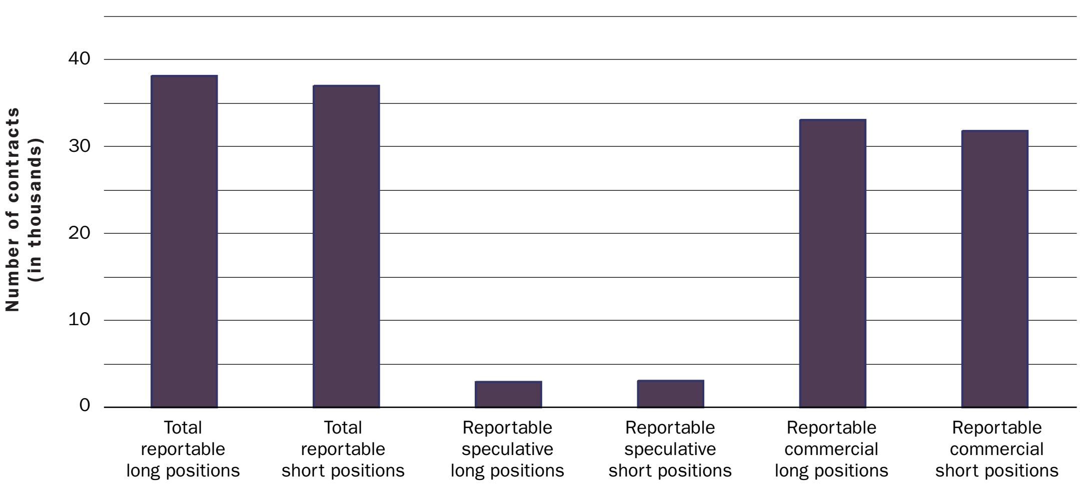


CHART C

Trading Positions, Year 2000

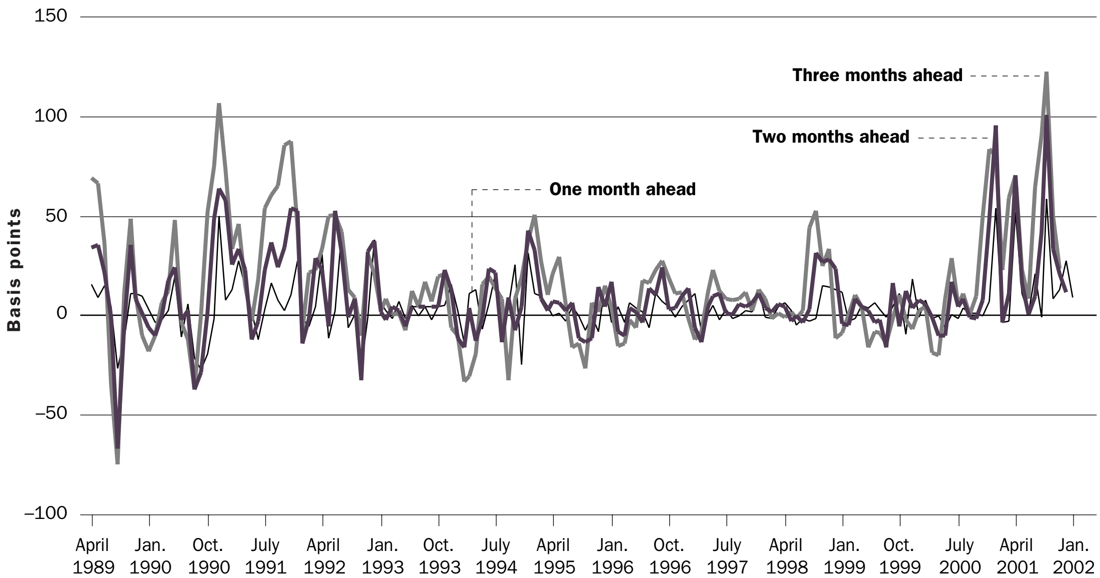


Note: Positions in federal funds futures in excess of 300 contracts must be reported to the Commodities Futures Trading Commission. Such reportable positions comprise more than 90 percent of open interest in federal funds futures.

Source: Commodities Futures Trading Commission

CHART 1

Realized Forecast Errors from the Federal Funds Futures Market



of futures prices to the variance of the underlying federal funds rate.

The general conclusion that emerges is that predictive accuracy and forecast error variances differ over stages of the monetary policy cycle and at transition points in the trajectory of monetary policy. Furthermore, the low variance of the target federal funds rate over the latter half of the 1990s is primarily responsible for the reduction in forecast error bias and variance over this time period. The increased disclosure of information by the FOMC appears to have played a secondary role.

Forecast Errors from the Federal Funds Futures Market

This discussion begins by looking at monthly realized forecast errors over the sample, from April 1989 through January 2002. Chart 1 displays the realized forecast errors at the one-, two-, and three-month horizons while Chart 2 shows the trailing two-year moving averages of these forecast errors. Forecast errors are constructed by taking the closing prices of futures contracts on the first business day of each month and comparing them to their eventual settlement price. For example, for the month of January 2001 the closing prices for the January, February, and March futures contracts are collected as of January 2, 2001. The difference between these closing prices on January 2 and their respective settlement prices on January 31, February 28, and March 30 represent the one-, two-, and three-month realized forecast errors. All forecast errors referenced in subsequent sections use this convention. Forecast errors are expressed in basis points, with a positive error indicating that the forecast rate was in excess of the realized average effective federal funds rate.

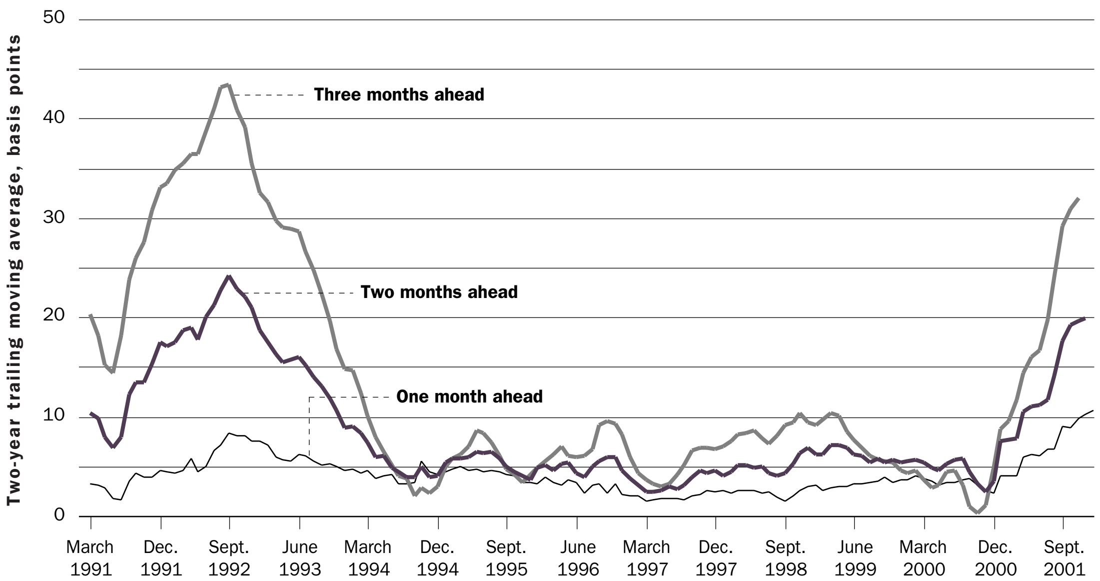
As is clear from Charts 1 and 2, the futures market's predictive accuracy has fluctuated considerably over the past twelve years. The bias and error variance declined through the mid-1990s before rising in recent years. This variation motivates the subsequent inspection of federal funds futures market forecast errors, which focuses closely on the behavior of futures prices at different time periods over the past thirteen years. The analysis also examines certain factors that may have contributed to the changes in bias and error variance.

Federal Funds Futures Market Predictive Accuracy and Bias

Previous authors have concentrated on measuring how well implied rates on federal funds futures actually forecast the effective federal funds rate. The nature of this prediction problem is more complex than it might first appear (see Robertson and Thornton 1997). Futures market participants face the joint problem of correctly anticipating both forthcoming economic data and the timing and magnitude of the FOMC's reaction to that data. To make matters worse, federal funds futures contracts are written on the average daily effective federal

CHART 2

Moving Average of Realized Forecast Errors from the Federal Funds Futures Market



funds rate over the contract month. The extent to which the Federal Reserve Bank of New York's open market desk fails to keep the average of daily funds rates close to the target specified by the FOMC proves to be an additional source of potential forecast error.[1] Hence, tests of the forecast accuracy of implied rates on federal funds futures contracts should be seen as joint tests of forecasts of macroeconomic data, the reaction of the FOMC to these data, and the precision with which the open market desk keeps the effective funds rate close to its specified target rate.

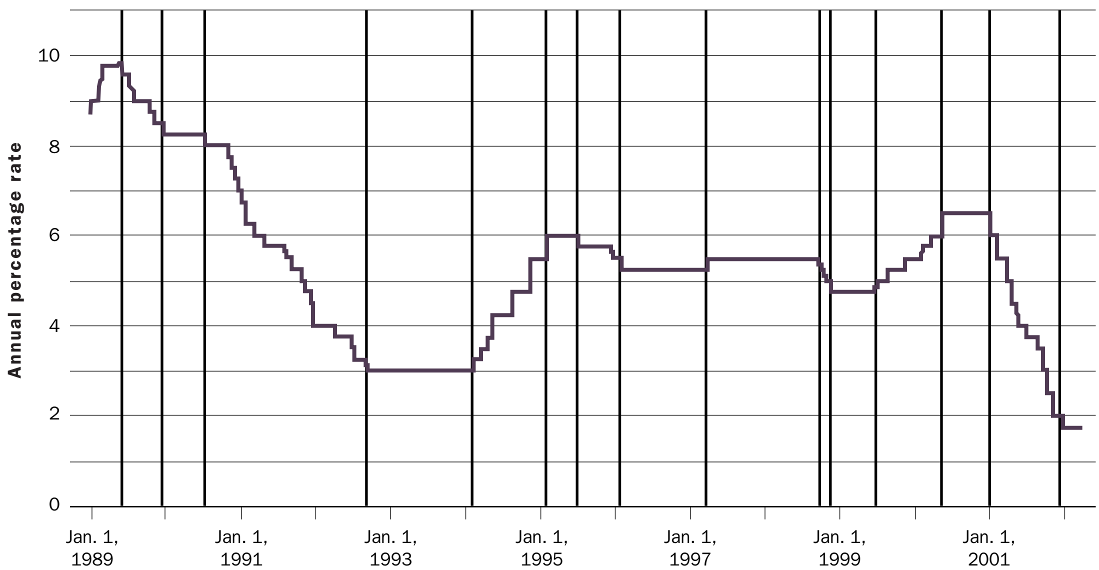
In an early descriptive paper, Carlson, McIntire, and Thomson (1995) examine the predictive ability of federal funds futures prices by comparing the out-of-sample forecasting performance of a simple autoregressive model of changes in the effective federal funds rate with forecasts implied by federal funds futures prices. Over their October 1988 through December 1994 sample, they find implied rates on federal funds futures predict better on a mean squared error basis than a simple random walk model or a univariate autoregression.

Krueger and Kuttner (1996) subsequently pursue the same question in a more sophisticated manner. They test whether futures market forecast errors contain a bias and whether this bias can be explained by other macroeconomic data such as employment or industrial production. The latter test addresses whether federal funds futures prices fully and efficiently incorporate information relevant to forecasting monetary policy. Using univariate and vector autoregressions with data from June 1989 through November 1994, Krueger and Kuttner find an average bias of roughly 6 basis points at the one-month horizon and 12 basis points at the two-month horizon, rejecting the hypothesis of unbiased futures rates. In contrast, the rationality hypothesis—that futures prices incorporate all other relevant information—appears to hold. Parameters on additional regressors such as the consumer price index (CPI) or M2 growth are generally statistically insignificant. As such, futures prices appear to correctly incorporate the information useful for forecasting the funds rate contained in these other macroeconomic variables.

While these papers look at the predictive ability of the federal funds futures market over subsequent months, Söderström (2001) focuses on the forecast accuracy of the futures market within the contract month. Using daily data from October 1988 through March 1998, Söderström tests the ability of implied rates of federal funds futures to forecast the average effective federal funds rate over the remainder of each month. The analysis of daily data is complicated by regularities in the federal funds market that can generate predictable fluctuations in the effective funds rate.[2] Taking these fluctuations into account through dummy variables, regression results show futures prices are only modestly accurate in predicting the average effective funds rate over the remainder of the month. Interestingly, if one looks at dates near scheduled FOMC meetings, implied

CHART 3

Target Federal Funds Rate and Selected Turning Points in Monetary Policy



futures rates do a rather good job of predicting the outcome of these meetings. Söderström goes one step further and compares the predictive accuracy of the futures market with that of the financial press, finding the futures market to be the superior forecaster.

While insightful, these papers implicitly assume that federal funds futures prices behave similarly regardless of the path of the federal funds rate underlying the futures contracts. This article suggests that this assumption masks some interesting variations in futures prices that are closely related to the trajectory of monetary policy. By examining futures prices between and around monetary policy cycle turning points, this analysis finds considerable differences in the forecast error and bias of implied federal funds futures rates over the policy cycle.

Predictability over Segments of the Monetary Policy Cycle

U.S. monetary policy in recent decades has been characterized by cyclical swings in the federal funds rate with periods of sustained rising, steady, and declining funds rates. The predictive accuracy of federal funds futures may be a function of policy trajectory. For example, forecast errors might be smaller during periods when the target federal funds rate remained unchanged for a considerable period of time relative to a period of increasing or declining target funds rates.

To examine this possibility, the sample here is divided into fifteen segments: three periods of rising federal funds rates, seven periods of steady federal funds rates, and five periods of declining federal funds rates. Beginning period dates that correspond to days when the FOMC began a series of similar interest rate moves demarcate the samples. For example, January 3, 2001, marked the beginning of a long decline in the target federal funds rate, which ended with a final 25 basis point reduction on December 11, 2001. The FOMC declined to change rates in subsequent meetings, so December 12 marks the beginning of a new period with a target federal funds rate steady at 1.75 percent. Chart 3 shows the cutoff dates for the samples. One- and two-month-ahead forecast errors and forecast error standard deviations for each period are computed and shown in Table 1.[3] Average forecasts errors are generally positive over each subsample and nearby contract but vary considerably by sample.

To obtain a clearer pattern from the data, the analysis averages subsamples characterized by similar

1. For a general discussion of open market desk operations, see Fisher and Hilton (1999) and Edwards (1997).
2. See, for example, Griffiths and Winters (1995) and the references therein.
3. At the end of each subsample, forecast error observations are curtailed appropriately to assure that futures prices are not expiring in months of the subsequent subsample.

TABLE 1

Realized Errors by Subsample

Start date	End date	Period average	Number of observations	Total number of observations	Median	Group average[a]	Standard deviation[b]
			One-month-ahead contract errors				
Declining federal funds rate periods							
06 Jun 89	19 Dec 89	–2.50	5	—	—	—	—
13 Jul 90	3 Sep 92	6.00	25	—	—	—	—
06 Jul 95	30 Jan 96	–0.91	6	—	—	—	—
29 Sep 98	16 Nov 98	15.00	1	—	—	—	—
03 Jan 01	11 Dec 01	15.55	10	47	3	6.44	18.68
Steady federal funds rate periods							
20 Dec 89	12 Jul 90	1.33	6	—	—	—	—
04 Sep 92	3 Feb 94	3.56	16	—	—	—	—
01 Feb 95	5 Jul 95	0.50	4	—	—	—	—
31 Jan 96	24 Mar 97	3.76	13	—	—	—	—
25 Mar 97	28 Sep 98	1.17	17	—	—	—	—
17 Nov 98	29 Jun 99	4.86	7	—	—	—	—
16 May 00	2 Jan 01	1.50	7	70	2.25	2.58	7.54
Rising federal funds rate periods							
23 Feb 89	5 Jun 89	12.25	2	—	—	—	—
04 Feb 94	31 Jan 95	7.32	11	—	—	—	—
30 Jun 99	15 May 00	3.00	10	23	5.5	5.87	12.33
			Two-month-ahead contract errors				
Declining federal funds rate periods							
06 Jun 89	19 Dec 89	–9.75	4	—	—	—	—
13 Jul 90	03 Sep 92	21.19	24	—	—	—	—
06 Jul 95	30 Jan 96	–3.60	5	—	—	—	—
29 Sep 98	16 Nov 98	0.00	0	—	—	—	—
03 Jan 01	11 Dec 01	30.83	9	42	19.25	17.36	31.57
Steady federal funds rate periods							
20 Dec 89	12 Jul 90	4.80	5	—	—	—	—
04 Sep 92	03 Feb 94	6.20	15	—	—	—	—
01 Feb 95	05 Jul 95	5.16	3	—	—	—	—
31 Jan 96	24 Mar 97	4.96	12	—	—	—	—
25 Mar 97	28 Sep 98	3.75	16	—	—	—	—
17 Nov 98	29 Jun 99	4.83	6	—	—	—	—
16 May 00	02 Jan 01	5.58	6	63	4	4.99	10.55
Rising federal funds rate periods							
23 Feb 89	05 Jun 89	34.00	1	—	—	—	—
04 Feb 94	31 Jan 95	6.90	10	—	—	—	—
30 Jun 99	15 May 00	2.11	9	20	4	6.10	15.50

[a] The unweighted average of observations from each subsample
[b] The unweighted standard deviation of observations from each subsample

behavior in the target federal funds rate (that is, a rising, declining, or steady target rate). The pattern that emerges for each nearby contract is one of higher errors and error variances during declining funds rate periods and slightly lower realized errors and error variance over periods with a rising funds rate. Sample periods characterized by a steady target federal funds rate, however, have a substantially lower average error and error variance. These data suggest that the futures market forecast bias is influenced to some degree by the stage of the monetary policy cycle.[4]

Turning Points in Monetary Policy Trajectory

The behavior of federal funds futures prices at turning points in monetary policy trajectory is also interesting. There are four such possible turning points: the beginning and end of an easing cycle and the beginning and end of a tightening cycle.

Turning points occur at the intersection of the subsample periods defined above. Futures market closing prices are taken from the last day of the previous subsample, providing a view of the futures market term structure just prior to a change in the trajectory of monetary policy and on the day of the target change. For example, closing prices on the afternoon of January 2 and 3, 2001, yield the futures market's view of expected monetary policy as the target federal funds rate heads into a period of decline.[5] Table 2 provides the realized forecast errors around each of these turning points.

Chart 4 shows the daily behavior of implied rates since the mid-1990s on the first through sixth nearby federal funds futures contracts. The chart makes clear that futures market participants often fail to anticipate shifts in the trajectory of the target federal funds rate, typically overshooting at the end of tightening or easing cycles and undershooting at the beginning of tightening or easing cycles. Such behavior is not particularly surprising. The market is trying to predict the timing and magnitude of policy shifts that are functions of macroeconomic data that are as yet unknown and notoriously difficult to forecast. However, this overshooting or undershooting is important in asset pricing since expectations for the path of the funds rate are incorporated into the term structure of short-term debt instruments and to a lesser magnitude into exchange rates, equities, and longer-term borrowing rates.[6]

Beginning of tightening cycles. At the two beginnings of tightening cycles in the sample, mixed evidence of undershooting is seen. Prior to the turning point in February 1994, futures market participants had begun to price in a rise in the target funds rate. Despite this adjustment, the market did not correctly anticipate the speed or magnitude of the subsequent rise in the funds rate, resulting in negative realized forecast errors. This episode contrasts with the situation in June 1999 (see Chart 5A), when futures prices proved amazingly accurate, predicting the correct effective funds rate within 6 basis points at the six-month horizon.

Predictive accuracy and forecast error variances differ over stages of the monetary policy cycle and at transition points in the trajectory of monetary policy.

End of tightening cycles. The behavior of futures prices around the end of the two tightening cycles displays substantial overshooting. As Charts 4 and 5B show, at those turning points, futures market participants anticipated a continued climb in the federal funds rate. At the six-month horizon the realized forecast error proved to be almost 100 basis points in February 1995 and roughly 50 basis points in May 2000.

Beginning of easing cycles. Data around the beginning of the four easing cycles are a bit more heterogeneous. The turning point in July 1990 corresponds to the easing cycle during the 1990–91 recession and shows that market participants generally anticipated a sharper decline in the target funds rate than what actually occurred. The realized

4. More formal testing of the hypothesis requires an ex ante definition of the regimes. Although a Markov-switching (see Hamilton 1994, chap. 22) or other regime-switching model may be able to provide such dates, this approach has not been attempted. Consequently, the data above, based on the ex post definition of regimes, are merely descriptive.

5. The Chicago Board of Trade federal funds futures market ends its open outcry session at 3:00 P.M. EST while the timing of most FOMC announcements is around 2:15 P.M. EST. As a robustness check, realized errors were also computed for the day subsequent to target changes to verify that the market had time to fully incorporate the FOMC announcement. These results were not appreciably different from the figures reported in Table 2.

6. See the empirical findings of Kuttner (2001), Rigobon and Sack (2002), and Bomfim and Reinhart (2000).

TABLE 2

Realized Forecast Errors Around Selected Turning Points

	Current month	Current month + 1	Current month + 2	Current month + 3	Current month + 4	Current month + 5
			Day prior to the turning point			
Beginning of tightening cycle						
03 Feb 94	–7.5	–7.5	–21.5	–58.0	–69.5	–66.5
29 Jun 99	1.5	6.5	3.0	–2.5	8.0	–6.0
End of tightening cycle						
31 Jan 95	–0.5	4.5	6.5	20.5	40.0	63.0
15 May 00	–4.0	–4.5	18.5	30.0	41.0	50.5
Beginning of easing cycle						
12 Jul 90	7.5	–2.5	–16.5	–11.5	17.5	67.5
05 Jul 95	1.0	4.5	–18.5	–20.5	–30.5	3.0
28 Sep 98	–1.5	11.0	27.5	33.5	30.5	–3.5
02 Jan 01	39.0	53.0	60.5	84.5	134.5	143.5
End of easing cycle						
19 Dec 89	17.5	10.0	–9.5	–24.5	–30.5	N/A
03 Feb 94	–7.5	–7.5	–21.5	–58.0	–69.5	–66.5
30 Jan 96	1.0	11.5	–1.5	–8.5	–16.5	–33.5
16 Nov 98	10.5	17.5	21.5	–10.5	–17.0	–13.5
Special case						
24 Mar 97	–5.5	–4.5	1.5	4.5	18.0	21.0
			Day of the turning point			
Beginning of tightening cycle						
04 Feb 94	2.5	1.5	–13.5	–51.0	–60.5	–58.5
30 Jun 99	0.5	2.5	–2.0	–9.5	0.0	–14.0
End of tightening cycle						
01 Feb 95	9.5	8.5	26.5	44.0	66.0	99.0
16 May 00	–1.5	–0.5	23.0	33.5	45.0	54.0
Beginning of easing cycle						
13 Jul 90	–0.5	–11.5	–25.5	–19.5	7.5	62.5
06 Jul 95	0.0	–2.5	–28.5	–32.5	–43.5	–12.0
29 Sep 98	–1.5	17.0	33.5	38.5	34.5	1.5
03 Jan 01	4.5	24.0	34.5	63.0	114.5	129.5
End of easing cycle						
20 Dec 89	11.5	0.0	–14.5	–31.5	–35.5	N/A
04 Feb 94	2.5	1.5	–13.5	–51.0	–60.5	–58.5
31 Jan 96	0.5	4.5	–7.5	–15.5	–23.5	–41.5
17 Nov 98	8.0	11.5	16.5	–15.5	–21.0	–16.5
Special case						
25 Mar 97	–5.0	–0.5	3.5	8.5	23.0	26.0

CHART 4

Recent Behavior of Implied Rates of Federal Funds Futures

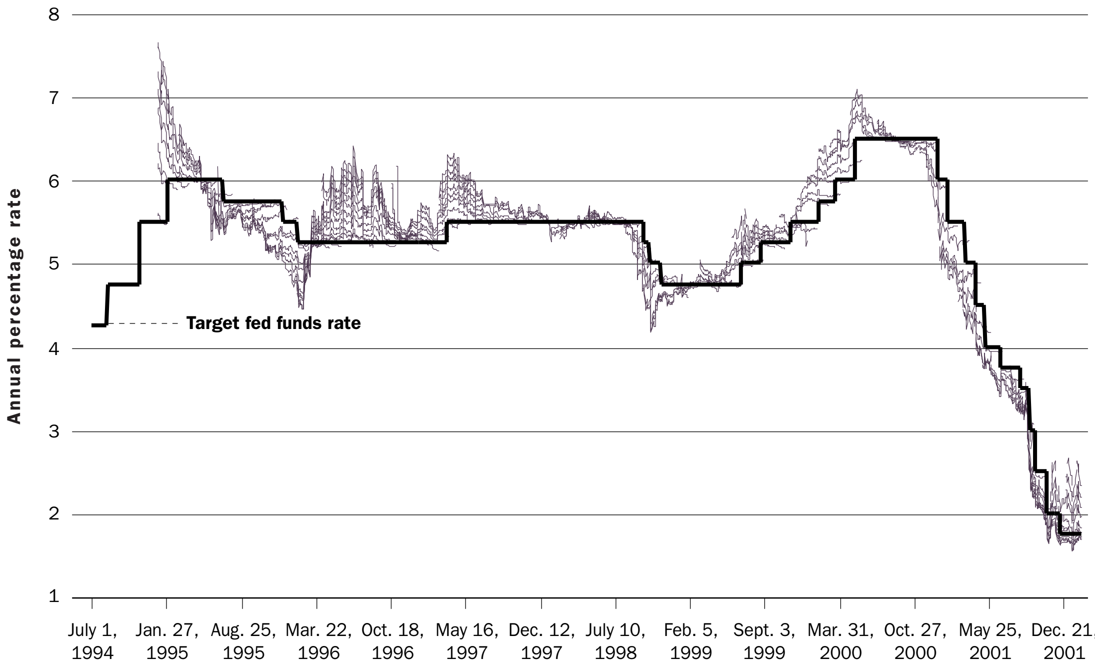
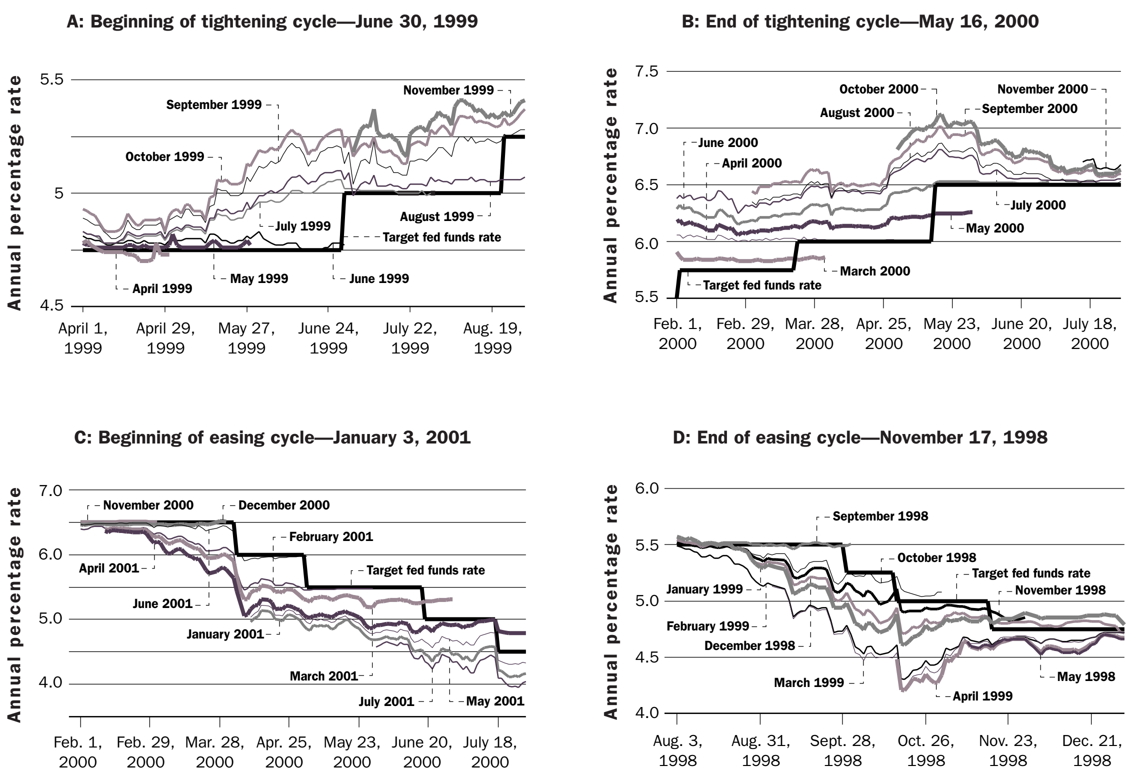


CHART 5

Implied Rates of Federal Funds Futures Contracts



errors for the two- and three-month-ahead contracts are subject to two interpretations. First, they may simply reflect the expectation that the funds rate would not fall as sharply as it eventually did. Alternatively, these figures may be viewed with skepticism given the extremely low trading volume of the two- and three-month-ahead contracts only a few months after these instruments began trading at the Chicago Board of Trade (CBOT). In fact, the average daily trading volumes for these contracts in July 1990 were only 60 and 14, respectively, making the latter interpretation, arguably, the more reasonable one.

The futures market forecast performance appears to be influenced substantially by the smoothness of the federal funds rate and perhaps to a much lesser extent by changes in FOMC operating procedures.

The realized errors around the beginning of the easing cycle in July 1995 are also unusual. Futures market participants were anticipating a series of steady declines in the target funds rate, but the FOMC chose to reduce the funds rate by only 25 basis points and to wait a number of months before making additional reductions. This somewhat atypical behavior largely explains the undershooting exhibited by futures prices around this turning point.

The remaining two observations at the beginning of easing cycles in September 1998 and January 2001 display a substantial degree of overshooting. At the three-month horizon, futures market forecasts missed by roughly 27 and 60 basis points, respectively. More dramatic is the degree to which futures prices failed to forecast the quick and sharp reduction in the funds rate over 2001 (see Chart 5C), when the six-month-ahead error proved a staggering 143 basis points.

End of easing cycles. For the end of easing cycles, futures prices generally show undershooting, with the market anticipating additional reductions to the federal funds rate that do not materialize. At the close of the easing cycles in December 1989, February 1994, and January 1996, futures market projections undershot by 31, 51, and 15 basis points, respectively, at the four-month horizon. November 1998 was an exception, when futures prices reflected further easing in October. At that time, market participants expected the FOMC to continue to reduce the target rate in its ongoing response to the Asian crisis. Expectations for further cuts moderated as November progressed, though, and by the time of the final 25 basis point cut for this easing cycle in late November, futures prices were reflecting a reasonably accurate forecast of the subsequent steady funds rate period (see Chart 5D).[7]

A special case. One special case that does not fit into the other categories is also worth noting: the slight upward adjustment in the funds rate in March 1997. Given the typical FOMC behavior of following one rate move with subsequent moves in the same direction, the single 25 basis point uptick in the funds rate shifted the slope of the futures term structure up substantially as market participants began to anticipate further tightening of monetary policy (see Chart 4). Subsequent FOMC decisions to hold the target funds rate steady at 5.5 percent resulted in positive forecast errors.

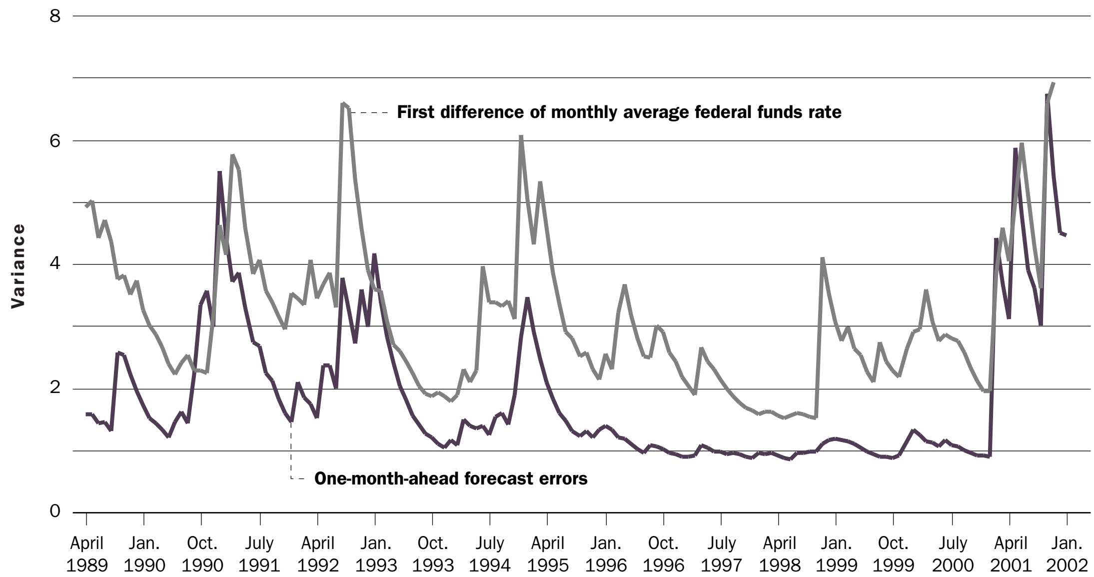
Most recently, the futures market accurately predicted the end of the sharp easing cycle that began on January 3, 2001. On the first business day of December 2001, the implied rate on the January federal funds futures contract was 1.77 percent. This rate proved just 4 basis points higher than the settlement price of the January 2002 futures contract.

FOMC Disclosure Policy

Recently, Thornton (1996), Poole and Raasche (2000), Lange, Sack, and Whitesell (2001), and Poole, Raasche, and Thornton (2001) have used federal funds futures data to argue that recent changes in FOMC operating procedures have helped synchronize market expectations of monetary policy with realized changes in the federal funds rate. Among the changes in procedure over the last decade are the shifts toward changing the federal funds rate at regularly scheduled FOMC meetings, making these changes in multiples of 25 basis points, publicly announcing the change in the funds rate, and issuing a statement of bias toward inflation or output weakness. A decline in average forecast errors following these institutional changes, controlling for other factors, would be evidence to support the contention that greater transparency in policy making has allowed the financial markets to more correctly forecast policy changes. Such greater synchronicity should minimize the mispricing of financial assets and result in a more efficient capital allocation.

CHART 6

Estimated Conditional Variances



Target Funds Rate Variance

As evidenced by the declining forecast errors in Chart 2, futures market participants' ability to forecast the path of the federal funds rate improved considerably in the latter half of the 1990s. Common explanations include the increased volume and open interest of the thirty-day federal funds futures contract over this time as well as the changes in the disclosure policy of the FOMC beginning around 1994.

One factor that is often overlooked, however, is that the variance of the federal funds rate has changed significantly in recent years.[8] Taking a quick look at the path of the federal funds rate over the past thirteen years (see Chart 3), one observes much larger swings in the federal funds rate in the period from 1988 through 1994 than over the later half of the 1990s. The question then arises whether the futures market's improved predictive accuracy in some recent years is in part a function of the smoothness of the underlying target federal funds rate rather than institutional changes or increased market depth. Chart 6 plots estimated conditional variances arising from GARCH (1,1) models of both the monthly changes in the federal funds rate and the one-month-ahead futures market forecast errors.[9] The positive correlation between these series suggests that the variability of the funds rate is a key factor explaining the variance and possibly the mean of futures market forecast errors.

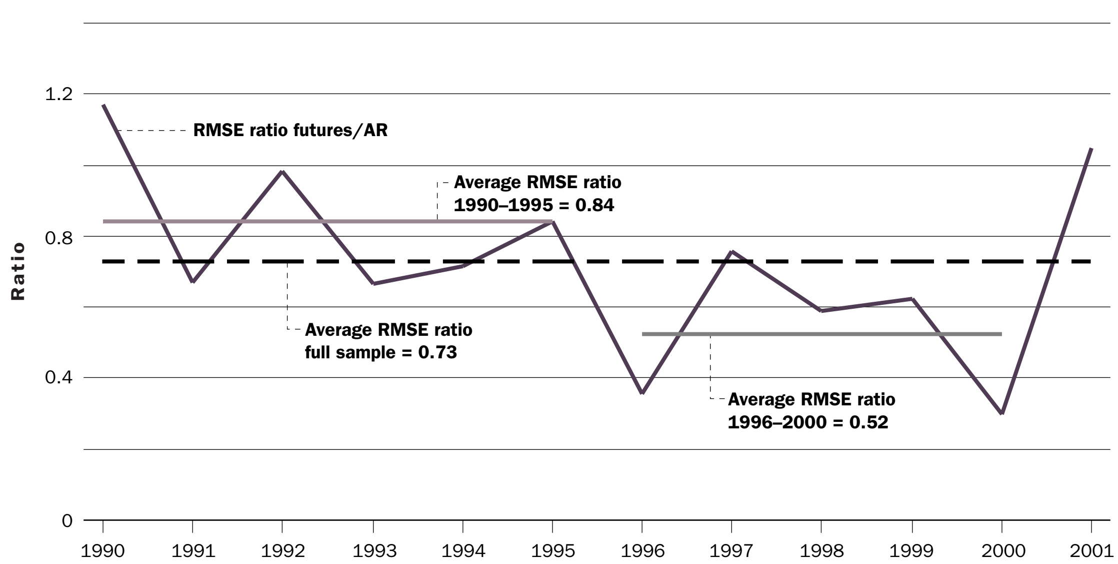
One approach to addressing this question is to examine futures forecast accuracy relative to a baseline autoregressive model whose forecast accuracy improves as the funds rate path becomes smoother.[10] A relative comparison of the forecast errors of each should measure the forecasting improvement of futures market prices due to disclosure and/or liquidity changes rather than the reduced variance in the federal funds rate.

Chart 7 shows the ratio of the root mean squared errors (RMSE) for one-month-ahead forecasts from the federal funds futures market and a simple second-order autoregressive model, AR(2), using first differences of the funds rate: $\Delta ff_t = \beta_0 + \beta_1 \Delta ff_{t-1} + \beta_2 \Delta ff_{t-2} + \varepsilon_t$. Although the futures market forecasts performed little better than that of the autoregressive model in

7. One conclusion is that the seemingly systematic large positive forecast errors found in July, September, and December over the sample studied by Söderström (2001) may merely reflect the forecast errors around turning points and segments of the policy cycle that have happened to occur more often in these months. Consequently, this previous finding should disappear as the sample grows larger.
8. Thornton (1996) also makes this observation and performs a more limited analysis than that conducted here.
9. See Hamilton (1994, chap. 21) for an introduction to ARCH models.
10. This approach is along the lines of that seen in Thornton (1996).

CHART 7

Root Mean Squared Errors (RMSE) Ratio—Futures Market RMSE/Fed Funds AR(2) RMSE



the early 1990s, with the ratio of RMSEs ranging from roughly 0.7 to 1.1, the futures market's relative forecasting performance improved considerably in subsequent years.[11] From 1996 through 2000 the average RMSE ratio fell to 0.52 from the 0.84 level seen over the previous six years. Indeed, the relative RMSE appears to be trending lower over the course of the 1990s, a movement indicative of continued improvement in forecast accuracy by futures market participants even after taking into account the smoother path of the target funds rate in the latter half of the decade. This observation is consistent with the hypotheses of Poole and Raasche (2000), who suggest that recent changes in the FOMC's operating procedure lead to greater synchronicity between the Federal Reserve and the capital markets.

This picture changed significantly in 2001, however. In early January the FOMC began a series of rapid and sharp reductions in the target federal funds rate. Although the futures market anticipated the January cut to some degree (see realized turning point errors in Table 2 and Chart 5C), the magnitude and speed of the subsequent target rate declines were generally missed by a considerable margin (see the final subsample average error in Table 1). As Chart 7 depicts, the relative forecasting performance of federal funds futures prices deteriorated significantly, proving no better than the prediction of the simple AR(2) model presented here.

The events of September 11 clearly added considerable uncertainty to the federal funds futures market, increasing realized forecast errors in the latter half of 2001. To assess whether the deterioration in the relative forecasting accuracy of futures market prices was primarily due to these events, the 2001 sample is curtailed in August and the relative RMSE is recomputed using only the first eight months of the year. From January 2001 to August 2001 the relative RMSE rose to 1.05, almost identical to the full-year estimate.

It appears then that as the path of the target federal funds rate becomes smoother the futures market's ability to forecast target rate movements improves relative to forecasts from a simple AR(2) model of the funds rate. However, significant departures from a relatively smooth funds rate path result in a proportionately larger deterioration in futures market forecasts accuracy relative to the AR(2) model's projections.

While the relative RMSE results are suggestive, a more formal investigation of the influences on futures market forecast errors is necessary to quantify the impact of changes in FOMC operating procedure and contract trading volume on forecast errors. To do so, the realized one-, two-, and three-month-ahead forecast errors are modeled as functions of previous errors, monthly average trading volume, concurrent and subsequent changes in the federal funds rate, and an institutional dummy variable (equal to one for 1995 to present), which serves as a proxy for FOMC disclosure changes. The parsimonious models that best fit the data take the form

$$ffferror_t^{+1} = \beta_0 + \beta_1 ffferror_{t-1}^{+1} + \beta_2 vol_{t-1}^{+1} + \beta_3 dum + \beta_4 \Delta ff_t + \beta_5 \Delta ff_{t-1} + \varepsilon_t,$$

$$ffferror_t^{+2} = \beta_0 + \beta_1 ffferror_{t-1}^{+2} + \beta_2 vol_{t-1}^{+2} + \beta_3 dum + \beta_4 \Delta ff_t + \beta_5 \Delta ff_{t+1} + \varepsilon_t,$$

$$ffferror_t^{+3} = \beta_0 + \beta_1 ffferror_{t-1}^{+3} + \beta_2 ffferror_{t-2}^{+3} + \beta_3 vol_{t-1}^{+3} + \beta_4 dum + \beta_5 \Delta ff_t + \beta_6 \Delta ff_{t+1} + \beta_7 ff_{t+2} + \varepsilon_t,$$

where $ffferror_t^{+i}$ is the realized federal funds futures forecast error looking i months into the future at month t, Δff_t is the change in the effective federal funds rate at month t, vol_{t-1}^{+i} is the average monthly futures market volume for the ith nearby contract, and *dum* is the dummy variable. Volume is lagged one month since the futures data are taken from the first day of each month.

If the arguments of Poole and Raasche (2000) are correct, the recent changes in FOMC operating procedures should be a statistically significant factor in the decline in forecast errors over the latter half of the 1990s. The regression results in Table 3, however, do not support this contention. The coefficients on both the institutional dummy variable and CBOT trading volume figures generally prove insignificantly different from zero, suggesting that, when one controls for other factors influencing futures market forecast errors, these variables have little explanatory power.[12] The factor found to be most influential was, unsurprisingly, changes in the federal funds rate on the month the contract expires.

Combined, the relative RMSE approach and the regression results above suggest that the major factor driving the forecast errors in the federal funds futures market is the variation in the funds rate rather than the institutional changes or increased trading volume that some argued have facilitated futures market forecast accuracy in recent years.[13] These results, however, are merely suggestive. Institutional changes are extremely difficult to proxy for in a statistical model. The choice here of a zero-one-dummy variable is by all measures a very blunt instrument. Consequently, the question of the impact of changes in FOMC operating procedures is still an important and open one.

Summary

The federal funds futures market, while allowing market participants to hedge interest rate risk, also serves the important role of revealing market participants' expectations of changes in FOMC policy. Armed with this information, monetary policymakers are able to assess the degree to which asset prices already reflect potential policy moves and, consequently, the likely reaction of asset prices to monetary policy changes that deviate from market expectations.

Previous papers have shown the federal funds futures market to be a relatively good forecaster of changes in the path of the federal funds rate on average. These studies, however, have been based on entire samples of futures market data (typically through only the mid-1990s) and fail to take into account the significant changes in forecast errors behavior over different periods of the last thirteen years. A detailed look at the futures market forecast performance shows substantial variation in forecast bias and error variance over different stages of the monetary policy cycle. In addition, the data reveal both substantial overshooting and undershooting by futures prices around turning points in the path of the funds rate. Finally, the futures market forecast performance appears to be influenced substantially by the smoothness of the federal funds rate and perhaps to a much lesser extent by changes in FOMC operating procedures and increased liquidity in the federal funds futures market.

11. Forecasts are computed from a rolling sample starting in January 1983. An additional year of data is added to each sample. For each set of parameter estimates, static one-month-ahead forecasts are computed for the subsequent twelve months. Mean squared errors are then calculated from these projections.
12. These conclusions are robust to different specifications of the dummy variable and transformations of the volume series. While trading volume is highly significant in the one-month-ahead equation, an inspection of its recursive +/– two standard error bands shows these bounding zero through all but the last few observations.
13. This conclusion is consistent with the findings of Bomfim and Reinhart (2000) that it is the actual changes in monetary policy that elicit a market response. The public announcements that accompany these changes are of second-order importance.

TABLE 3

Regression Results

Variable	Coefficient	*t*-statistic	Probability
	One-month-ahead forecast error		
C	2.689563	1.479424	0.1412
*ffferror*1 (–1)	0.034049	0.297446	0.7665
vol (–1)	0.001390	2.433264	0.0162
dum	–1.409398	–0.699632	0.4853
Δ*ff*	–0.443369	–8.049077	0.0000
Δ*ff* (–1)	0.252181	2.964181	0.0035

R^2	0.360236	Mean dependent variable	4.674342
Adjusted R^2	0.338326	Standard deviation dependent variable	13.505980
Standard error of regression	10.98621	Akaike information criterion	7.669833
Sum squared residual	17621.74	Schwarz criterion	7.789196
Log likelihood	–576.9073	*F*-statistic	16.441830
Durbin-Watson statistic	2.001058	Probability (*F*-statistic)	0.000000

Variable	Coefficient	*t*-statistic	Probability
	Two-month-ahead forecast error		
C	3.723522	1.359174	0.1762
*ffferror*2 (–1)	0.302252	3.125770	0.0021
vol (–1)	–0.000654	–0.515126	0.6072
dum	0.681652	0.215542	0.8296
Δ*ff*	0.090424	0.769210	0.4430
Δ*ff* (+1)	–0.663521	–7.232132	0.0000

R^2	0.473981	Mean dependent variable	9.621711
Adjusted R^2	0.455966	Standard deviation dependent variable	21.613020
Standard error of regression	15.94147	Akaike information criterion	8.414398
Sum squared residual	37103.04	Schwarz criterion	8.533762
Log likelihood	–633.4943	*F*-statistic	26.311270
Durbin-Watson statistic	1.793892	Probability (*F*-statistic)	0.000000

Variable	Coefficient	*t*-statistic	Probability
	Three-month-ahead forecast error		
C	6.837350	2.790652	0.0060
*ffferror*3 (–1)	0.653612	6.767882	0.0000
*ffferror*3 (–2)	–0.256000	–3.829814	0.0002
vol (–1)	0.003808	1.465005	0.1451
dum	–4.304001	–1.422083	0.1572
Δ*ff*	0.196797	2.009983	0.0463
Δ*ff* (+1)	–0.148278	–0.997209	0.3204
Δ*ff* (+2)	–0.675044	–8.983938	0.0000

R^2	0.696037	Mean dependent variable	15.183330
Adjusted R^2	0.681053	Standard deviation dependent variable	29.617780
Standard error of regression	16.72676	Akaike information criterion	8.523756
Sum squared residual	39729.41	Schwarz criterion	8.684323
Log likelihood	–631.2817	*F*-statistic	46.451700
Durbin-Watson statistic	2.168766	Probability (*F*-statistic)	0.000000

Note: For the one-month-ahead forecast error, the dependent variable is *ffferror*1, the sample (adjusted) is 1989:06–2002:01, and the number of included observations is 152 after adjusting endpoints. For the two-month-ahead forecast error, the dependent variable is *ffferror*2, the sample (adjusted) is 1989:06–2001:12, and the number of included observations is 152 after adjusting endpoints. For the three-month-ahead forecast error, the dependent variable is *ffferror*3, the sample (adjusted) is 1989:06–2001:11, and the number of included observations is 150 after adjusting endpoints. All results use Newey-West HAC standard errors.

REFERENCES

Bomfim, Antulio, and Vincent Reinhart. 2000. Making news: Financial market effects of Federal Reserve disclosure practices. Federal Reserve Board Finance and Economics Discussion Series Paper 2000-14, March.

Carlson, John, Jean McIntire, and James Thomson. 1995. Federal funds futures as an indicator of future monetary policy: A primer. Federal Reserve Bank of Cleveland *Economic Review* 31 (First Quarter): 20–30.

Chicago Board of Trade. 1997a. *Insights into pricing the CBOT fed funds futures contract.*

———. 1997b. *Practical applications of CBOT fed funds futures.*

———. 1999. *CBOT financial instruments guide.*

———. 2002. Contract specs: Financial contracts—30 day federal funds futures. <www.cbot.com/cbot/www/prod_detail/0,1499,14+58+140+30,00.html> (May 6, 2002).

Duffie, Darrell. 1989. *Futures Markets*. Englewood Cliffs, N.J.: Prentice Hall.

Edwards, Cheryl L. 1997. Open market operations in the 1990s. *Federal Reserve Bulletin* 83 (November): 859–74.

Fabozzi, Frank. 1996. *Bond markets: Analysis and strategy*. 3d ed. Englewood Cliffs, N.J.: Prentice Hall.

Fisher, Peter R., and Spence Hilton. 1999. Highlights of domestic open market operations during 1998. *Federal Reserve Bulletin* 85 (April): 217–35.

Griffiths, Mark, and Drew Winters. 1995. Day-of-the-week effects in federal funds rates: Further empirical findings. *Journal of Banking and Finance* 19 (October): 1265–84.

Hamilton, James. 1994. *Time series analysis*. Princeton, N.J.: Princeton University Press.

Krueger, Joel, and Kenneth Kuttner. 1996. The fed funds futures rate as a predictor of Federal Reserve policy. *The Journal of Futures Market* 16 (December): 865–79.

Kuttner, Kenneth. 2001. Monetary policy surprises and interest rates: Evidence from the fed funds futures market. *Journal of Monetary Economics* 47 (June): 523–44.

Lange, Joe, Brian Sack, and William Whitesell. 2001. Anticipations of monetary policy in financial markets. Federal Reserve Board Finance and Economics Discussion Series Paper 2001-24, April.

Pitts, Mark, and Frank Fabozzi. 1990. *Interest Rate Futures and Options*. Chicago: Probus Publishing Company.

Poole, William. 1999. Synching, not sinking, the markets. Speech presented at the Philadelphia Council for Business Economics, Federal Reserve Bank of Philadelphia, August 6.

Poole, William, and Robert Raasche. 2000. Perfecting the market's knowledge of monetary policy. *Journal of Financial Services Research* 18 (December): 255–98.

Poole, William, Robert Raasche, and Daniel Thornton. 2001. Market anticipations of monetary policy actions. Presented at the twenty-sixth annual economic policy conference, Federal Reserve Bank of St. Louis, October 11–12.

Rigobon, Roberto, and Brian Sack. 2002. The impact of monetary policy on asset prices. Federal Reserve Board Finance and Economics Discussion Series Paper 2002-4, January.

Robertson, John C., and Daniel Thornton. 1997. Using federal funds futures rates to predict Federal Reserve actions. Federal Reserve Bank of St. Louis *Review* 79 (November/December): 45–53.

Söderström, Ulf. 2001. Predicting monetary policy with federal funds futures prices. *Journal of Futures Markets* 21 (April): 377–91.

Thornton, Daniel. 1996. Does the Fed's new policy of immediate disclosure affect the market? Federal Reserve Bank of St. Louis *Review* 78 (November/ December): 77–88.