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Have Increases in Federal Reserve Transparency Improved Private Sector Interest Rate Forecasts?

Yes. This paper shows that, since the late 1980s, U.S. financial markets and private sector forecasters have become (1) better able to forecast the federal funds rate at horizons out to several months, (2) less surprised by Federal Reserve announcements, (3) more certain of their interest rate forecasts *ex ante*, as measured by interest rate options, and (4) less diverse in the cross-sectional variety of their interest rate forecasts. We also present evidence that strongly suggests increases in Federal Reserve transparency played a role: for example, private sector forecasts of GDP and inflation have not experienced similar improvements over the same period, indicating that the improvement in interest rate forecasts has been special.

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THE 1990s AND early 2000s witnessed an unprecedented increase in central bank transparency, with New Zealand, Canada, the UK, Sweden, Finland, Israel, Australia, Spain, the European Central Bank, Norway, and several developing countries all adopting an inflation targeting framework for monetary policy,¹ and many other central banks dramatically increasing the amount of information regularly released to the public. In the U.S., the Federal Reserve began explicitly announcing changes in its federal funds rate target in 1994, began indicating the

1. Inflation targeting is not synonymous with central bank transparency, but in practice countries that adopted inflation targeting in the 1990s at the same time significantly increased the amount of information about monetary policy regularly released to the public.

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TABLE 1
HIGHLIGHTED CHANGES IN FOMC TRANSPARENCY, 1990-2003

Date	FOMC Transparency Change
1992–2000	Gradually shifts policy actions to regularly scheduled meeting dates
March 1993	Begins releasing minutes of FOMC meetings (with 6–8 week lag)
November 1993	Begins releasing transcripts of FOMC meetings (with 5 year lag)
February 1994	Begins explicitly announcing changes in federal funds rate target and rationale for policy action
August 1994	Begins describing state of economy and more detailed rationale for policy action after FOMC decisions
1994–2003	Gradually shifts to longer, more descriptive press releases after FOMC decisions
May 1999	Begins releasing statement about economic outlook even after no change in federal funds rate target
May 1999	Begins announcing policy “tilt” indicating most likely future interest rate action
January 2000	Replaces “tilt” with statement describing “balance of risks” to economic outlook
October 2001	Chairman Greenspan delivers a speech highlighting FOMC’s moves toward greater transparency
March 2002	Begins releasing votes of individual Committee members and preferred policy choices of any dissenters

likely future course of interest rates or “balance of risks” to its economic outlook in 1999, and began releasing individual votes of Committee members in 2002, to name just a few examples (Table 1 provides additional highlights). Yet despite the apparent international consensus that increased central bank transparency conveys economic benefits, there is very little empirical work convincingly demonstrating the existence of any such benefits.

One reason for the shortage of conclusive results may be the ambitiousness of previous empirical studies. Demertzis and Hughes Hallett (2002) look for a relationship between central bank transparency and the level or the variability of inflation and output across countries. But cross-country differences in fiscal policies, institutions, and macroeconomic shocks are often large, and the length of time series since the last central bank regime change in most countries is small, particularly for the many countries that adopted inflation targeting in the 1990s. Thus, Bernanke et al. (1999) note that drawing any conclusions from this type of exercise “is difficult and somewhat speculative” (p. 252); Bernanke et al. nevertheless present evidence that inflation expectations and inflation have come down in inflation targeting countries, and by more than one would have expected *ex ante*, but in many cases their “control” countries, such as the U.S. and Australia (prior to the adoption of inflation targeting), also had similar experiences. The above authors’ evidence is thus suggestive, but is unlikely to convince many of those who may be skeptical. Indeed, Ball and Sheridan (2005) emphasize macroeconomic performance in control countries as well, and come to exactly the opposite conclusion—that once one allows for mean-reversion in inflation and other macroeconomic time series, there is no evidence that adopting inflation targeting has had any benefits, because countries that adopted inflation targeting were exactly those with above-average inflation prior to adoption.

The present paper asks a less ambitious question and, as a result, obtains much sharper results. The primary effect of an increase in central bank transparency—defined in this paper as the amount of information about the goals and conduct of monetary policy regularly released to the public—should be an improvement in financial market and private sector understanding of how the central bank will set policy as a function of the state of the economy. This should lead, *ceteris paribus*, to an increase in the private sector’s ability to forecast the central bank’s policy instrument: for example, if the central bank were following a Taylor-type rule, $r_t = r^* + \pi_t + ay_t + b(\pi_t - \pi^*)$, then an improvement in the private sector’s understanding of what values the central bank uses for r^* , a , b , and π^* and exactly how the central bank measures the output gap y_t would lead to improved private sector forecasts for r_t .²

The present paper investigates to what extent we see such an improvement in financial market and private sector forecasts of short-term interest rates in the U.S. over the past 15 years, given the increases in Federal Reserve transparency that took place over that period (Table 1). In particular, we document (1) an improvement in financial markets’ ability to forecast the federal funds rate, (2) a reduction in financial market surprises around Federal Open Market Committee (FOMC) announcements, (3) a reduction in financial market *ex ante* uncertainty about the future course of short-term interest rates, as measured by interest rate options, and (4) a fall in the cross-sectional dispersion of private sector forecasts of short-term interest rates. Moreover, we show that there have *not* been similar improvements in private sector forecasts of real GDP and inflation, indicating that private sector forecasts of Federal Reserve policy have improved relative to private sector forecasts of the rest of the economy. Taken together with additional evidence from the behavior of interest rate options pre- and post-1994, we will argue that this strongly suggests that increases in Federal Reserve transparency have played a significant role in the private sector’s forecast improvement.

A few earlier authors have studied financial market forecasts of short-term interest rates in the 1990s. Poole and Rasche (2000) and Poole, Rasche, and Thornton (2002) note that the frequency of days on which federal funds futures rates changed by a large amount (6 basis points or more) decreased from the pre-1994 to the post-1994 period, and that some case studies of federal funds futures behavior around FOMC meetings also suggest that markets have become better able to anticipate FOMC decisions since February 1994. Lange, Sack, and Whitesell (2003) econometrically document a steady improvement in financial markets’ ability to forecast the federal funds rate across three recent subsamples: pre-1989, 1989-93, and 1994-2000. The present paper updates the sample period of these earlier studies to include data since mid-2000 and finds some of their results to be fragile, due to a dramatic deterioration in financial market forecast accuracy since January 2001. This raises two

2. Of course, no central bank follows a policy rule as simple as a Taylor-type rule, but the same reasoning holds for more general mappings from the state of the economy to the policy instrument r_t , discussed below. Further discussion of a wide variety of Taylor-type rules can be found in Taylor (1999).

important questions. First, what are the underlying reasons for the recent forecast deterioration? Second, is the forecast improvement prior to 2001 a robust feature of the data, or does it disappear once we control for factors that explain the deterioration since 2001? In other words, if we blame the recent losses in forecast accuracy on increased volatility in the federal funds rate, then do we also have to attribute the earlier gains in forecast accuracy to reductions in federal funds rate volatility, rather than to increases in Federal Reserve transparency? We bring to bear additional financial market data, such as implied volatility from interest rate options and panel data from private sector forecasts of output, inflation, and interest rates, to help answer these questions.

The remainder of the paper proceeds as follows. Section 1 presents a simple theoretical framework for monetary policy and private sector forecasts. Section 2 shows that private sector forecasts of short-term interest rates have improved throughout the 1990s by all four measures cited earlier. Section 3 analyzes and expands on the basic results, showing that the forecast deterioration in 2001-2 is well-explained by recent increases in federal funds rate volatility and uncertainty about the U.S. economy, that despite this deterioration there is still an improvement in the private sector's interest rate forecasts over our sample, and that this improvement seems to have come at least in part from better understanding of the FOMC's policy reaction function that resulted from increases in Federal Reserve transparency. Section 4 concludes. An Appendix provides details of the precise timing of monetary policy announcements over our sample and how the various private sector and financial market forecast error and forecast uncertainty measures are constructed.

1. A SIMPLE THEORETICAL FRAMEWORK

To organize our results and discussion in the following sections, we set up the following simple theoretical framework for monetary policy. Let X_t denote an n -dimensional vector of variables describing the state of the economy at time t . We will think of X_t as being possibly very large and including as many lags of variables as is necessary to describe the economy. Let $f: \mathbb{R}^n \rightarrow \mathbb{R}$ denote the mapping from the state of the economy X_t to the FOMC's setting of the federal funds rate i_t at time t .³

$$i_t = f(X_t) \tag{1}$$

In particular, we assume that the function f and the state of the economy X_t are sufficiently richly specified that we do not need to append a stochastic "shock" to the end of Equation (1). This is in contrast to simple interest rate rules such as the Taylor Rule or a VAR interest rate setting equation, which typically include a shock ε_t to capture the effects of omitted variables and special factors such as financial market instability or a terrorist attack, for example.

3. Given a loss function for policymakers and a model of the economy, one can derive the reaction function f from policymakers' optimization problem, although we will not pursue that route here.

In our empirical analysis below, we will show that the private sector's k -month-ahead forecasts for the federal funds rate, $E_t f(X_{t+k})$, have improved over time for a variety of horizons k , in the sense that the forecast errors

$$f(X_{t+k}) - E_t f(X_{t+k}) \quad (2)$$

and *ex ante* uncertainty about the funds rate, $\text{Var}_t f(X_{t+k}) \equiv E_t [f(X_{t+k}) - E_t f(X_{t+k})]^2$, have diminished over time.

There are two ways that this could have occurred:

- (1) The private sector's k -month-ahead forecasts of the state of the economy, X_{t+k} , could have improved over time. This could be due to any of several factors: for example, private sector forecasts could have benefited from improvements in forecasting methodology, improvements in computing power, or simply good luck. However, we will present evidence below that strongly favors the alternative explanation.
- (2) The private sector's understanding about the policy function f could have improved over time. Again, this could be due to several factors: gradual private sector learning about the policy reaction function f , or an increase in the amount of information released to the private sector by the Federal Reserve about the goals and conduct of policy (i.e., greater transparency).⁴ We will present some evidence below that suggests increases in transparency by the FOMC have been responsible, rather than gradual private sector learning.

Before proceeding to the empirical results, it is worth discussing some alternative explanations that are also sometimes offered as to why the private sector's interest rate forecasts might have improved over time:

- (A) Monetary policy shocks. It is sometimes suggested that monetary policy "shocks" ε_t have diminished over time, because the FOMC's policy has become more systematic. In our framework above, however, the policy reaction function f in Equation (1) is richly specified enough that there is no room left over for a random "shock" component of policy, in contrast to a Taylor rule or other stripped-down policy rule. Thus, a reduction in "shocks" has no place in this framework, and instead simply corresponds to an improvement in the private sector's understanding of what variables policy is responding to and the policy reaction function f (which is our explanation number 2, above).
- (B) Leaks to the press. It is sometimes suggested that the FOMC has reduced financial market volatility around its announcements by "leaking" the outcome of the meeting to the financial press a few days ahead of time. This

4. It is important to note the distinction here (and throughout this paper) between "transparency" and "forecastability." Transparency, as defined in this paper, can be thought of as the information given by the central bank to the private sector about the parameters α in a rule such as $i_t = \alpha X_t$. By contrast, forecastability depends as well on uncertainty about the *state variables* X_t . Thus, an interest rate rule might be difficult to forecast even if it is perfectly transparent (α is perfectly known by the private sector), just because X is difficult to forecast.

alternative hypothesis has the testable implication that interest rate forecast errors $f(X_{t+k}) - E_t f(X_{t+k})$ should have diminished over time for $k = 1$, but *not* for any $k > 1$. We show below that this hypothesis is refuted: that financial market forecasts have improved for horizons $k \gg 1$ as well as $k = 1$. Thus, either explanation (1) or (2) above must still have been operative.

- (C) Changes in f over time. The simple theoretical framework above makes the assumption that the policy reaction function f is constant over time. Over the sample period of our data, 1985-2003, this is probably a reasonable assumption. Nonetheless, modifying the above framework to incorporate a time-varying policy function, $i_t = f_t(X_t)$, has no impact on the main points of the discussion above. In particular, the private sector's k -month-ahead forecasts, $E_t f_{t+k}(X_{t+k})$, could have improved either because of improved forecasts of X_{t+k} or because of improved forecasts of f_{t+k} , and our empirical evidence below will suggest that the latter effect has dominated.

2. PRIVATE SECTOR INTEREST RATE FORECAST PERFORMANCE

This section lays out our basic empirical evidence. We defer analysis of the broader implications of this evidence to Section 3.

2.1 Federal Funds Futures Forecasts

The basic patterns in financial markets' ability to forecast short-term interest rates from the late 1980s through the present can be seen in Figure 1, which graphs the federal funds futures market's forecast errors from October 1988 through December 2003.

Federal funds futures contracts have traded on the Chicago Board of Trade exchange since October 1988 and settle based on the average federal funds rate that prevails over a given calendar month.⁵ The market is liquid, volumes for the current-month and near-future (next 1–6 months) fed funds futures contracts are high, and spreads are narrow. Most importantly, Krueger and Kuttner (1996), Rudebusch (1998), and Gürkaynak, Sack, and Swanson (2006) have shown that federal funds futures-based forecasts pass standard tests of efficiency.

The top panel of Figure 1 plots the absolute value of the 1-month-ahead federal funds futures forecast error, defined to be the realized average federal funds rate for a given month minus the fed funds futures forecast made on the last day of the previous month (e.g., the realized average federal funds rate for June minus the futures market forecast for June as of May 31); the bottom panel plots the absolute value of the 3-month-ahead market forecast error (e.g., the realized funds rate for June minus the futures market forecast dated March 31). These series correspond to $i_{t+k} - E_t i_{t+k}$ for $k = 1, 3$ in the framework of Section 1.

5. The average federal funds rate is calculated as the simple mean of the daily averages published by the Federal Reserve Bank of New York, and the federal funds rate on a non-business day is defined to be the rate that prevailed on the preceding business day. See the Appendix for details.

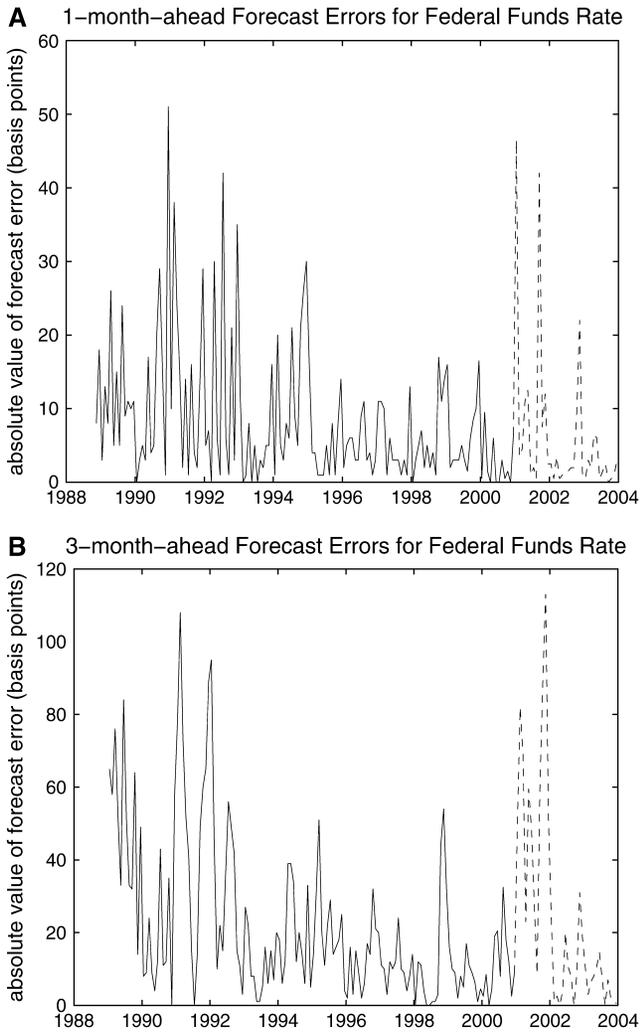


FIG. 1. Federal Funds Futures Market Forecast Errors. Solid line: 1988:11–2000:12 (top panel), 1989:1–2000:12 (bottom panel); dashed line: 2001:1–2003:12 (both panels). Data are monthly. Forecast error is realized average federal funds rate for given month minus federal funds futures forecast made 1 or 3 months previously. See text for details.

Basic regression analysis of these forecast errors (and also the 5-month-ahead forecast errors) on a time trend or a post-1994 dummy variable is performed in Table 2. Standard errors are computed using the heteroskedasticity- and autocorrelation-consistent procedure (1A) described in Hodrick (1992), which generalizes the Hansen and Hodrick (1980) standard errors to the case of heteroskedastic disturbances.

TABLE 2
FED FUNDS FUTURES MARKET FORECAST ERRORS

Sample Period	Constant	Time Trend	Post-1994 Dummy
(a) 1-month-ahead fed funds futures forecast errors:			
1988:11–2000:12:	13.7 [8.00] 11.2 [7.82]	–0.86 [–4.52]	–4.92 [–3.12]
1988:11–2003:12:	12.7 [8.20] 11.2 [7.82]	–0.62 [–3.89]	–4.96 [–3.12]
(b) 3-month-ahead fed funds futures forecast errors:			
1989:1–2000:12:	42.3 [6.01] 33.3 [5.47]	–3.21 [–3.96]	–19.4 [–3.04]
1989:1–2003:12:	35.6 [5.36] 33.3 [5.48]	–1.67 [–2.22]	–16.2 [–2.39]
(c) 5-month-ahead fed funds futures forecast errors (not shown in Figure 1):			
1989:3–2000:12:	74.3 [5.42] 61.5 [5.32]	–5.27 [–3.45]	–35.6 [–2.97]
1989:3–2003:12:	60.4 [4.38] 61.5 [5.33]	–2.21 [–1.30]	–27.5 [–2.02]

NOTES: Data are monthly; Hodrick (1992) HAC *t*-statistics reported in square brackets; forecast errors are in basis points; time trend is in years. See text for details.

Figure 1 and Table 2 both display a dramatic improvement in the futures market's ability to forecast the federal funds rate from 1988 through the end of 2000, but this earlier downward trend shows a marked deterioration or even a reversal beginning in 2001. This deterioration is obvious just from looking at the figure, but is also confirmed statistically by the decrease in magnitude and significance of the downward trends (or post-1994 dummies) for the longer-horizon regressions when they are estimated over the full sample. In light of this significant deterioration of the earlier trend, the brief rise in market forecast errors that occurred in 1994 and early 1995 begins to take on added significance as well, and raises the possibility that perhaps it was a decline in federal funds rate volatility—or output or inflation variability—over the 1990s that was responsible for the improved financial market forecasts over this period, rather than increases in Federal Reserve transparency. We will address this question directly in Section 2, below, and show that the improvements in interest rate forecast accuracy from the late 1980s to the present remain even after controlling for these kinds of effects.

Finally, note that as long as the improvement in interest rate forecasts is robust, Figure 1 and Table 2 directly contradict the hypothesis that the FOMC has improved financial market forecasts only by leaking its decisions a few days in advance to the press. The figure and table show substantial improvements in interest rate forecasts 3 and 5 months ahead, and not just a few days in advance.

2.2 Surprise Component of FOMC Announcements

The general patterns in Figure 1 are representative of those in a wide variety of financial market and private sector forecast accuracy measures. Figure 2 plots the

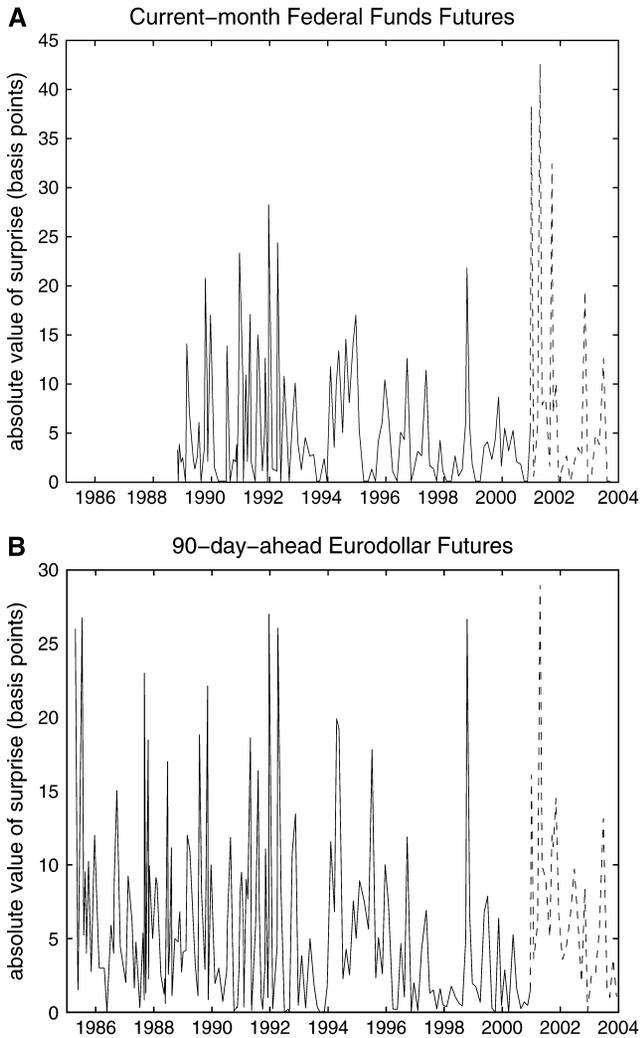


FIG. 2. Surprise Component of FOMC Announcements. Solid line: 1988:10–2000:12 (top panel), 1985:4–2000:12 (bottom panel); dashed line: 2001:1–2003:12 (both panels). Surprise component is change in current-month or next-month fed funds futures contract scaled to account for number of days remaining in month (top panel) or change in 90-day eurodollar futures rate (bottom panel). See text for details.

absolute value of the surprise component of FOMC policy announcements, as measured by changes in federal funds futures (top panel) and eurodollar futures (bottom panel) around each announcement. Since February 1994, the FOMC's monetary policy announcements have been explicit, typically made at about 2:15 pm after regularly scheduled FOMC meetings. Prior to 1994, FOMC monetary policy announcements were typically made through the size and type of open market

operation conducted by the New York Fed's Open Market Desk the morning following the FOMC decision.⁶

The top panel of Figure 2 graphs the absolute value of the surprise component of FOMC policy announcements from October 1988 through December 2003, as measured by changes in the current-month federal funds futures contract rate around the announcement. These are computed in essentially the same way as in Kuttner (2001); see the Appendix for details. These surprise components correspond to $E_{t,d} \dot{i}_{t,(d,D)} - E_{t,d-1} \dot{i}_{t,(d,D)}$ in the framework of Section 1, where the monetary policy announcement occurs on day d of month t , $\dot{i}_{t,(d,D)}$ denotes the average federal funds rate over the remainder of month t (from day d to the final day D of month t),⁷ and $E_{t,d}$ and $E_{t,d-1}$ denote the futures market's expectation as of the end of day d or day $d - 1$ of month t . Note that we consider surprises generated by FOMC inaction on FOMC dates as well as surprises generated by FOMC actions.

The bottom panel of Figure 2 graphs changes in the 90-day-ahead *eurodollar* futures rate around each monetary policy announcement from April 1985 to December 2003.⁸ Eurodollar futures contracts settle based on the spot 90-day eurodollar rate prevailing on the date of expiration; these contracts are thus very closely tied to financial markets' expectations about the federal funds rate over the 90-day period beginning 90 days from now. Changes in the eurodollar futures rate around an FOMC announcement correspond closely to $E_{t,d} \bar{r}_{t+4,t+6} - E_{t,d-1} \bar{r}_{t+4,t+6}$, where $\bar{r}_{t+4,t+6}$ denotes the average federal funds rate from month $t + 4$ through month $t + 6$ and $E_{t,d}$ denotes the futures market's expectation on day d of month t . The advantage of measuring changes in policy expectations farther out the term structure, as in these eurodollar data, is that market reactions to FOMC announcements will be much less sensitive to the exact *timing* of monetary policy actions. For example, markets may correctly forecast the size and sign of the next policy move, but be unsure as to whether it will occur at the next FOMC meeting or the meeting after. The federal funds futures surprises in the top panel of Figure 2 can be very sensitive to these timing surprises, while the longer-horizon eurodollar futures surprises in the bottom panel will not be. In support of this last observation, note that the surprises in the bottom panel are often smaller than those in the top panel,

6. There are some exceptions to these basic timing rules; see the Appendix for details. Moreover, prior to 1994, there were several dates on which the FOMC eased policy in response to a weak Employment Report released earlier in the day. To distinguish the surprise component of the monetary policy announcement itself from the surprise associated with the macroeconomic data release earlier in the day, we use intraday data on fed funds and eurodollar futures to measure the monetary policy surprise on those days (on non-employment report days, the intraday and daily measures of monetary policy surprises are essentially identical). See Gürkaynak, Sack, and Swanson (2006) for details.

7. This is typically just the FOMC's target for the federal funds rate announced on day d of month t , although the futures market sometimes expects the funds rate to deviate from target, such as around year-end, quarter-ends, and settlement Wednesdays, particularly in the early years of our sample.

8. The spot 90-day eurodollar rate is the interest rate paid on 90-day time deposits of U.S. dollars in London. Daily quotes are produced by the British Bankers' Association. The spot eurodollar market is very active, so the spot 90-day eurodollar rate tracks very closely 90-day term rates in the U.S. Only the eurodollar futures contracts with expiration in March, June, September, and December are actively traded, so to keep the forecast horizon roughly constant at a 3-month window beginning 3 months ahead, we interpolate between the current- and next-quarter contracts. See the Appendix for details.

TABLE 3
SURPRISE COMPONENT OF FOMC ANNOUNCEMENTS

Sample Period	Constant	Time Trend	Post-1994 Dummy
(a) Current-month federal funds futures:			
1988:11–2000:12:	6.5 [6.82] 5.6 [7.59]	–0.25 [–1.71]	–1.0 [–0.97]
1988:11–2003:12:	5.7 [5.32] 5.6 [6.14]	–0.02 [–0.18]	–0.1 [–0.06]
(b) 90-day-ahead eurodollar futures:			
1985:4–2000:12:	7.6 [8.92] 6.2 [10.89]	–0.28 [–2.69]	–1.7 [–1.70]
1985:4–2003:12:	6.8 [8.55] 6.2 [10.82]	–0.11 [–1.39]	–0.8 [–0.94]

NOTES: Data are sampled on dates of FOMC announcements; *t*-statistics reported in square brackets; surprises are in basis points; time trend is in years. See text for details.

despite the longer forecast horizon. Nonetheless, both sets of surprises in the top and bottom panels of Figure 2 show significant declines through the end of 2000; declines through the end of 2003 are generally not statistically significant here.

It is clear from Figure 2 that financial markets were less surprised by FOMC announcements in the late 1990s than previously, an observation that is confirmed by the significantly negative time trends and post-1994 dummies estimated through the end of 2000 in Table 3.⁹ As in Figure 1, however, and as is true in general, this pattern breaks down substantially when we include data after the end of 2000: the estimated time trends and dummy variables decrease in magnitude and lose their statistical significance when estimated over the full sample.

2.3 Financial Market Uncertainty from Eurodollar Options

While financial market forecasts of short-term interest rates in the 1990s were becoming more accurate *ex post*, market participants were becoming more certain of their forecasts *ex ante* as well. Figure 3 plots the level of market uncertainty about interest rates from January 1989 through December 2003 derived from 6-month-ahead options on 90-day eurodollar rates.¹⁰

The top panel plots the implied volatility in basis point terms derived from eurodollar options with 6 months to expiration, sampled on days before regularly scheduled FOMC meetings. This measure (squared) corresponds to $\text{Var}_t \bar{\tau}_{t+7,t+9} \equiv E_t[\bar{\tau}_{t+7,t+9} - E_t \bar{\tau}_{t+7,t+9}]^2$ in the framework of Section 1, where $\bar{\tau}_{t+7,t+9}$ denotes the

9. The October 15, 1998, intermeeting ease is the obvious exception to this rule and reduces the significance of the downward trend for fed funds futures (as does the lack of fed funds futures data prior to October 1988). The downward trend is still significant at the 5% level for a one-sided test (which is the appropriate test assuming that increases in FOMC transparency do not increase financial market surprises).

10. Eurodollar options settle based on the value of the current-quarter 90-day eurodollar futures contract at expiration (which essentially equals the spot 90-day eurodollar rate at expiration). Only the March, June, September, and December options contracts are actively traded, so we interpolate between contracts to maintain a roughly constant 6-month-ahead forecast horizon. See the Appendix for details.

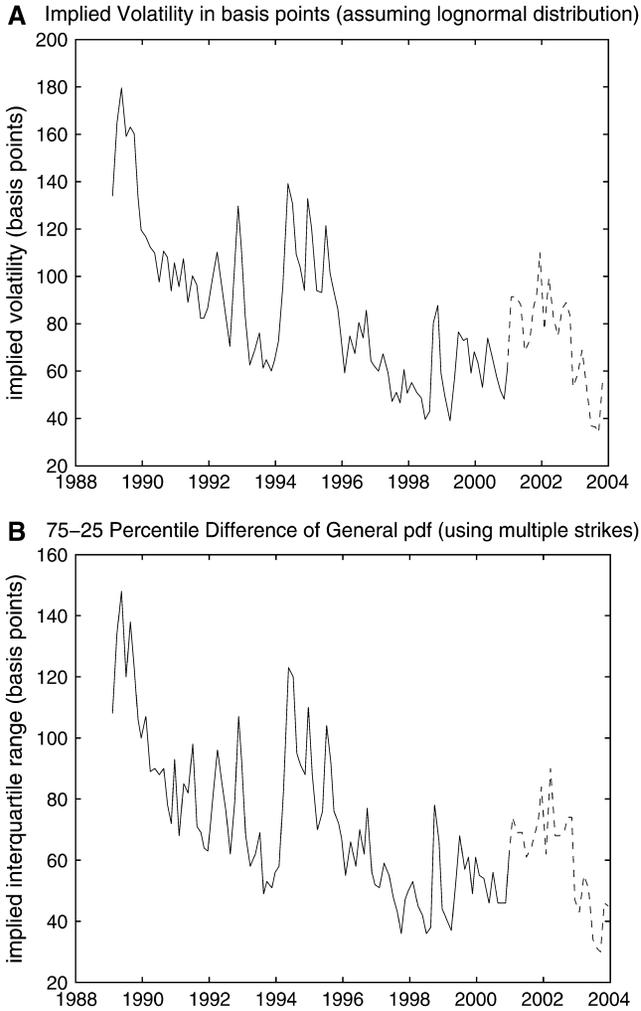


FIG. 3. Market Uncertainty from Eurodollar Options. Solid lines: 1989:1–2000:12; dashed lines: 2001:1–2003:12. Data are sampled on days before scheduled FOMC meetings. Options are on 90-day eurodollar deposits with expiration 6 months ahead. “Implied volatility” (top panel) is derived from at-the-money option assuming a lognormal distribution, and is expressed in basis points rather than logs. The bottom panel uses all available options with the same expiration to estimate a more general probability distribution, and plots the difference between the 75th and 25th percentiles. See text for details.

average federal funds rate from month $t + 7$ through month $t + 9$. Note that we multiply the implied volatility on the option (where “implied volatility” is the usual measure that assumes a lognormal distribution for the underlying rate) by the expected 90-day eurodollar rate in order to express the implied volatility in

basis point terms rather than in logs.¹¹ The problem with implied volatility measured in logs is that it effectively divides uncertainty about the interest rate by the expected level of the interest rate, and the level of the expected 90-day eurodollar rate has been at all-time lows recently; thus, the surge in implied volatility (measured in logs) in 2001 and 2002 might simply reflect the recent fall in the *level* of interest rates rather than any increase in market uncertainty (measured in basis points) about the eurodollar rate itself. The recent upswing in uncertainty that is evident in Figure 3 is immune to this criticism, and clearly depicts an increase in market uncertainty about the eurodollar rate itself, measured in basis points.

To ensure that the trends in the top panel are not an artifact of the lognormal distributional assumption, the bottom panel of Figure 3 plots a simple measure of market uncertainty for a more flexible functional form for the probability distribution on the underlying eurodollar rate. This requires using multiple eurodollar options, each with the same expiration date but a different strike rate.¹² The difference between the 75th and 25th percentiles of the implied distribution for the underlying eurodollar rate is then plotted. As can be seen in the figure, the overall patterns in financial market uncertainty are not sensitive to the lognormal distributional assumption.

As is clear from Figure 3, financial markets' *ex ante* uncertainty about the eurodollar rate has trended downward very strongly since 1989, an observation that is confirmed by the highly significant time trends and post-1994 dummy variables in Table 4. As in earlier figures, there are significant deviations from this downward trend in 2001 and 2002, and also in 1994 and 1995.

2.4 Cross-Sectional Dispersion of Private Sector Forecasts

Finally, just as financial markets were becoming more certain of their short-term interest rate forecasts *ex ante*, their forecasts were converging toward greater unanimity as well. Figure 4 graphs the cross-sectional dispersion of individual private sector forecasters' predictions for the 3-month Treasury bill rate, as published in the monthly Blue Chip Consensus survey of forecasters from June 1991 through December 2003.

The top panel plots the difference between the 90th and 10th percentile forecasts of the level of the Treasury bill rate one quarter ahead, and the bottom panel plots the same difference for forecasts of the Treasury bill rate one year ahead. The same trends that were evident in earlier figures are evident in Figure 4 and Table 5: namely, a generally declining level of cross-sectional dispersion over the 1990s, with an upswing in 1994 and a more significant rise since January 2001.

11. The expected value of the 90-day eurodollar rate at expiration is estimated using the corresponding eurodollar futures contract. The implied volatility of the option is calculated by assuming a lognormal distribution for the underlying eurodollar rate at expiration and backing out the variance of the log eurodollar rate from the price of the option. We use the closest to at-the-money option (which is typically the most liquid) in the top panel of Figure 3. See the Appendix for details.

12. For simplicity, we assume a step density function with steps centered on the available strike rates.

TABLE 4
MARKET UNCERTAINTY FROM EURODOLLAR OPTIONS

Sample Period	Constant	Time Trend	Post-1994 Dummy
(a) Implied volatility in basis points (lognormal distribution):			
1989:1–2000:12:	125.9 [10.85] 103.8 [8.43]	–6.6 [–4.62]	–30.4 [–1.94]
1989:1–2003:12:	116.4 [9.98] 103.8 [8.45]	–4.4 [–3.35]	–30.6 [–2.12]
(b) 75–25 percentile difference of general pdf:			
1989:1–2000:12:	103.2 [11.40] 85.7 [9.02]	–5.1 [–4.68]	–22.5 [–1.81]
1989:1–2003:12:	96.4 [10.71] 85.7 [9.04]	–3.5 [–3.47]	–23.3 [–2.06]

NOTES: Data are sampled on days before scheduled FOMC meetings; HAC t -statistics reported in square brackets; left-hand side variables are measured in basis points; time trend is in years. See text for details.

3. ANALYSIS AND DISCUSSION

3.1 *Why Did Interest Rate Forecasts Deteriorate in 2001-2?*

It is clear from Figures 1 through 4 that financial market and private sector forecasts of short-term interest rates improved substantially throughout the 1990s, but equally clear that they lost a significant part of this gain in 2001 and 2002. This raises two important questions. First, what are the underlying reasons for the forecast deterioration? Second, is the forecast improvement prior to 2001 a robust feature of the data, or does it disappear once we control for factors that potentially explain the forecast deterioration in 2001-2? In other words, if we blame the recent losses in forecast accuracy on increased volatility in the federal funds rate, then do we also have to attribute the earlier gains in forecast performance to reductions in federal funds rate volatility, rather than to increases in Federal Reserve transparency?

To answer the first question, we will be interested in what economic events in 2001-2 could plausibly have led to a deterioration in the private sector's interest rate forecasts. Of course, one explanation is that there simply could have been a lack of Federal Reserve transparency over this period, perhaps something of a temporary relapse from earlier gains, which deprived the private sector of information about the future conduct of policy it had previously been receiving. But even in this case, if the Fed reduced transparency as an *endogenous* response to other economic events that were taking place at the time, what those driving events were would still be of interest. To answer the second question above, we will be interested in the robustness of the estimated downward time trends (or post-1994 dummy variables) in the previous section to the inclusion of any such economic factors as explanatory variables over the whole sample.

January 2001 marked a turning point for the U.S. economy in two key respects. First, on January 3, 2001, the Federal Reserve made the first of what was to become a long series of significant cuts in the federal funds rate, and a moving federal funds rate target is presumably much more difficult to forecast than is a stable one. Second,

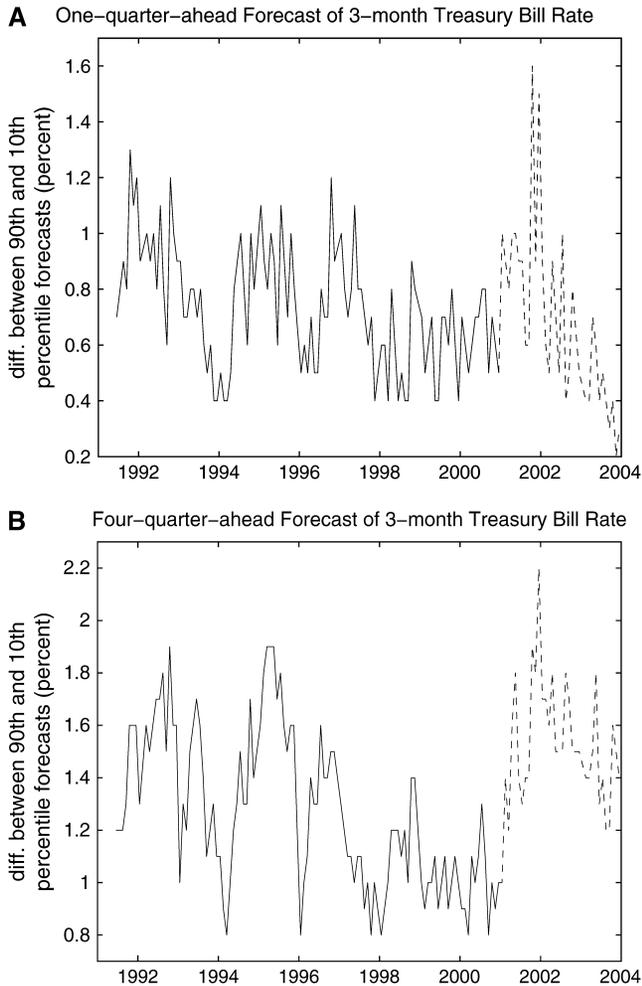


FIG. 4. Cross-sectional Dispersion of Private Sector Forecasts. Solid lines: 1991:6–2000:12; dashed lines: 2001:1–2003:12. Data are monthly. Cross-sectional dispersion is difference between 90th and 10th percentile Blue Chip forecast of Treasury bill rate. See text for details.

January 2001 roughly coincides with a significant increase in uncertainty about the state of the U.S. economy, particularly the future prospects for U.S. output and employment; thus, the deterioration in private sector forecasts of interest rates in 2001-2 might simply reflect a deterioration in the ability of the private sector to forecast the U.S. economy as a whole.

Casual observation of the preceding figures lends some support to each of these hypotheses. For example, earlier periods of rapidly changing monetary policy, such as the tightening cycle by the Fed in 1994-95 and the easing cycle in 1991-92, also correspond to periods of unusually poor private sector forecast performance.

TABLE 5
CROSS-SECTIONAL DISPERSION OF PRIVATE SECTOR FORECASTS

Sample Period	Constant	Time Trend	Post-1994 Dummy
(a) 90–10 percentile range in 1-quarter-ahead forecast of 3-months. T-bill rate:			
1991:6–2000:12:	0.890 [12.93]	–0.032 [–3.27]	
	0.834 [11.23]		–0.137 [–1.69]
1991:6–2003:12:	0.860 [12.74]	–0.022 [–2.19]	
	0.834 [11.24]		–0.141 [–1.71]
(b) 90–10 percentile range in 4-quarter-ahead forecast of 3-months. T-bill rate:			
1991:6–2000:12:	1.566 [20.46]	–0.062 [–6.59]	
	1.450 [25.40]		–0.250 [–2.14]
1991:6–2003:12:	1.362 [12.27]	–0.005 [–0.27]	
	1.450 [25.38]		–0.153 [–1.39]

NOTES: Data are monthly; HAC t -statistics reported in square brackets; left-hand side variables are in percent; time trend is in years. See text for details.

Similarly, the 1990-91 recession and slow recovery afterward correspond to a period of relatively high levels of uncertainty about the future course of the U.S. economy as a whole.

To investigate whether rapid changes in the federal funds rate can help explain the pattern of financial market forecast errors and uncertainty seen in the data, we need a measure of recent federal funds rate volatility or “momentum.” Figure 5 graphs the FOMC’s target for the federal funds rate from January 1985 through December 2003 (top panel) and a measure of federal funds rate momentum (bottom panel) defined as the absolute value of the difference between the federal funds rate target the day before an FOMC meeting and the value of the target 90 days prior to that meeting. The momentum variable can thus be used to investigate whether a federal funds rate target that has moved substantially in the recent past is also more difficult to forecast going forward.¹³ In the bottom panel of Figure 5, we can see that federal funds rate momentum shows noticeable increases in 2001-2, 1994-95, and 1991-92, as well as being higher on average prior to 1990.

To investigate whether macroeconomic uncertainty affects interest rate forecast performance, we use the cross-sectional dispersion of private sector forecasters’ projections for real GDP growth and inflation, depicted in Figure 6. For each month from June 1991 through December 2003, the figure plots the difference between the 90th and 10th percentile one-quarter-ahead forecasts for real GDP growth (top panel) and GDP deflator inflation (bottom panel) in the Blue Chip Consensus survey

13. For a perfectly transparent central bank, there is no reason in principle why recent changes in the federal funds rate should make the funds rate more difficult to forecast going forward. However, for a central bank that is not perfectly transparent, lagged policy rate changes will tend to make the future policy rate more difficult to forecast, if the central bank follows some degree of interest rate inertia (Rudebusch, 1995) and the private sector is uncertain about the extent of that inertia. For example, if the central bank follows a rule such as $\Delta i_t = \rho \Delta i_{t-1} + f(y_{t-1}, \pi_{t-1})$ and the private sector is uncertain about the parameter ρ , then $\text{Var}_t \Delta i_{t+1}$ equals $(\Delta i_t)^2 \text{Var}_t \rho$ plus additional terms, so that interest rate “momentum,” $|\Delta i_t|$, will tend to make forecasting Δi_{t+1} (or i_{t+1}) more difficult, all else equal.

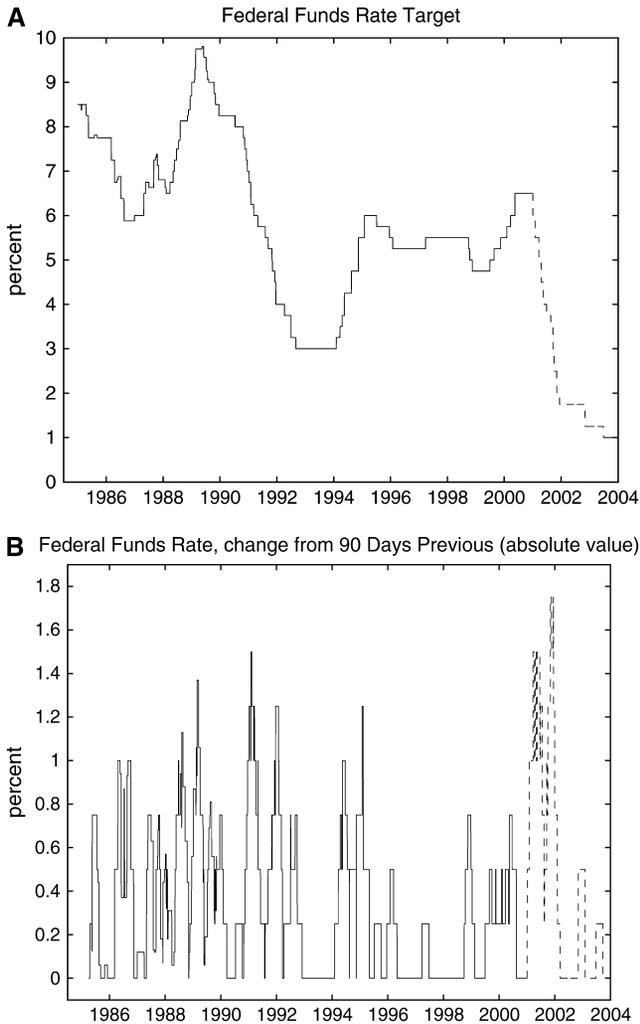


FIG. 5. Federal Funds Rate Target and 90-day "Momentum". Solid lines: 1985:1–2000:12; dashed lines: 2001:1–2003:12. Data are daily. "Momentum" is absolute value of difference between current federal funds rate target and funds rate target from 90 days previous. See text for details.

of forecasters.¹⁴ Some prominent features of these data are a noticeably higher level of macroeconomic uncertainty during the recessions and early recoveries in 1991-92 and 2001-2, a rise in uncertainty about inflation in 1995, and a pronounced spike

14. We have also experimented with using the 90–10 percentile difference in forecasts one year ahead, and with realized private sector forecast errors for output growth and inflation from the Blue Chip survey (the latter are depicted in Figure 7 and analyzed below). The one-quarter-ahead dispersion of forecasts performed better as explanatory variables than did either of these other measures, so results are only reported for the one-quarter-ahead dispersion measures for simplicity.

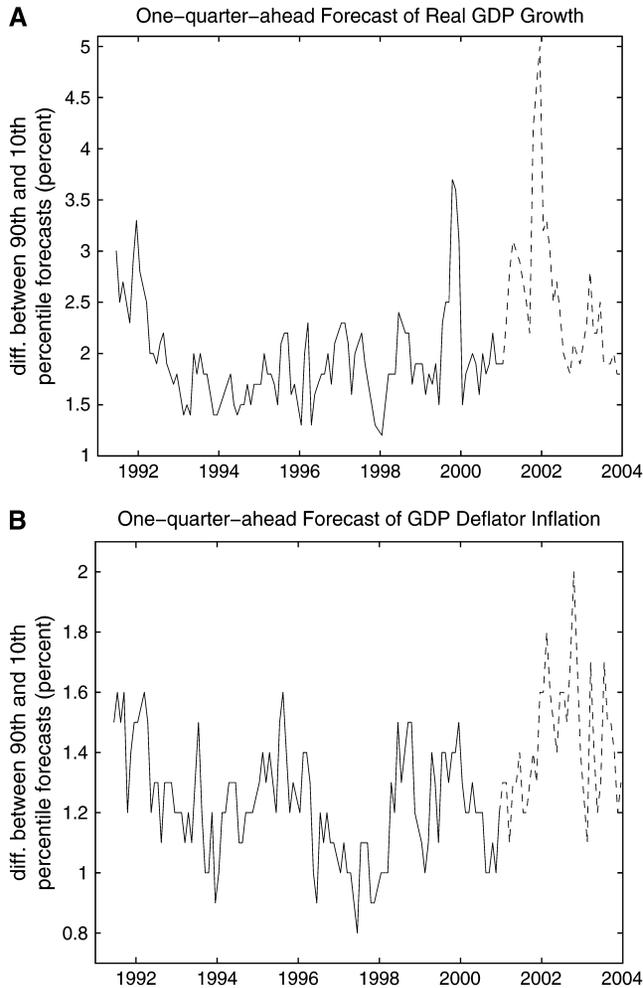


FIG. 6. Cross-sectional Dispersion of Private Sector Macro Forecasts. Solid lines: 1991:6–2000:12; dashed lines: 2001:1–2003:12. Data are monthly. Cross-sectional dispersion is difference between 90th and 10th percentile Blue Chip forecast of real GDP growth (top panel) or GDP Deflator inflation (bottom panel). See text for details.

in uncertainty in 1999Q4 about output growth the following quarter, probably due to some forecasters' concerns about the possible economic effects of the year 2000 date change.

We regress our four measures of interest rate forecast accuracy from the preceding section on the federal funds rate momentum and macroeconomic uncertainty measures described above. In general, we expect estimated coefficients on these variables to be positive, since increases in these variables should tend to raise financial market forecast errors and uncertainty about interest rates. We also include a time trend or post-1994 dummy variable in the regressions to see whether it remains true that

TABLE 6

FEDERAL FUNDS RATE MOMENTUM AND ECONOMIC UNCERTAINTY AS EXPLANATORS FOR VARIATION IN MARKET FORECAST ACCURACY

	Time Trend	Federal Funds Rate Momentum	GDP Forecast Dispersion	Inflation Forecast Dispersion
(a) Federal Funds Futures Forecast Errors (bp):				
1-month-ahead:	-0.52 [-3.51] -0.57 [-2.84] -0.49 [-2.56]	8.19 [4.93]	3.06 [2.33] 0.62 [0.44]	-3.85 [-1.00] -3.01 [-0.82]
3-month-ahead:	-1.50 [-2.05] -1.60 [-2.13] -1.56 [-2.02]	13.93 [2.32]	12.80 [2.96] 11.75 [2.51]	14.33 [1.07] 14.69 [1.11]
5-month-ahead:	-1.82 [-1.03] -3.46 [-2.17] -3.52 [-2.22]	14.47 [1.02] -5.17 [-0.35]	23.55 [3.00] 25.14 [2.51]	23.03 [1.11] 22.49 [1.13]
(b) Surprise Component of FOMC Announcements (bp):				
Fed funds futures:	0.06 [0.50] -0.15 [-0.74] -0.08 [-0.42]	6.53 [5.10]	1.34 [1.01] -2.10 [-1.46]	2.71 [0.59] 4.46 [1.05]
Eurodollar futures:	-0.00 [-0.03] -0.24 [-1.46] -0.18 [-1.19]	5.09 [5.26] 7.18 [4.79]	1.19 [1.14] -1.72 [-1.52]	7.78 [2.12] 9.27 [2.78]
(c) Uncertainty from Eurodollar Options (bp):				
Implied volatility:	-4.22 [-3.85] -3.39 [-3.50] -3.20 [-4.24]	26.15 [3.69]	3.66 [0.57] -6.86 [-1.31]	43.68 [3.16] 50.23 [4.22]
75-25 pctile diff:	-3.38 [-3.92] -2.78 [-3.37] -2.64 [-4.07]	16.95 [2.69] 18.92 [2.47]	0.88 [0.17] -6.51 [-1.27]	37.19 [3.44] 41.79 [4.35]
(d) Cross-sectional Dispersion of Forecasters (pct):				
1-quarter-ahead:	-0.0221 [-3.07] -0.0294 [-4.28] -0.0272 [-4.50]	0.299 [4.57]	0.186 [3.29] 0.121 [2.39]	-0.031 [-0.27] -0.020 [-0.17]
1-year-ahead:	-0.0069 [-0.34] -0.0166 [-1.18] -0.0149 [-1.03]	0.259 [4.59] 0.158 [2.30]	0.108 [1.37] 0.058 [0.89]	0.518 [4.53] 0.527 [4.84]

NOTES: HAC *t*-statistics reported in square brackets; time trend is in years; federal funds rate momentum is in percent; GDP and inflation forecast dispersion are in percent; left-hand side variables are the same as in Tables 2-5; sample period is 1991:6-2003:12 due to availability of GDP and inflation forecast dispersion data; the notes to Tables 2-5 otherwise apply.

private sector interest rate forecasts improved over our sample, controlling for any secular changes in federal funds rate volatility or macroeconomic uncertainty that took place over the period. Results from these regressions are reported in Table 6.¹⁵ Note that these regressions are all estimated over the full sample through December 2003, since the post-2001 deterioration in forecast accuracy is a primary feature of the data we are trying to understand.

The results in Table 6 strongly support the hypothesis that high federal funds rate momentum leads to a deterioration in financial market forecast accuracy and increases in financial market uncertainty. The coefficients on the momentum variable

15. Due to space limitations, only results for regressions including a time trend are reported; results for regressions including the post-1994 dummy variable are qualitatively very similar.

are in virtually all cases positive and highly statistically significant, indicating that a federal funds rate that has moved substantially in the recent past is also more difficult to forecast going forward. Moreover, the fit of the regressions in the critical 2001-2 period is greatly improved: according to the coefficient estimates in Table 6, roughly 40 bp of the 50 bp rise in implied volatility in Figure 3 and 30–45 bp of the 50–100 bp rise in cross-sectional dispersion of forecasts in Figure 4 can be attributed to the rise in federal funds rate momentum at that time. In Figures 1 and 2, the numbers are around 14 bp out of 30–40 bp, still a significant improvement.

Our two measures of macroeconomic uncertainty perform somewhat less well as explanatory variables. Although one measure or the other enters significantly in many of the regressions, it is GDP forecast dispersion that enters significantly in some cases and inflation forecast dispersion that enters significantly in others, and it is not obvious why the preferred measure should flip back and forth. This result corresponds to the intuition one gets just from eyeballing Figures 1–4: the very sharp spike in interest rate forecast errors and uncertainty beginning in early 2001 in those figures suggests a more prominent role for federal funds rate momentum than macroeconomic uncertainty: While macroeconomic uncertainty increased in 2001 and 2002, it does not show the sudden upward spike in early 2001 that both federal funds rate momentum and our earlier interest rate forecast performance figures display.¹⁶

The final and perhaps most interesting observation to take away from Table 6 is the robustness of the underlying time trend to the inclusion of these other explanatory variables in the regressions. Even when all of our interest rate momentum and macroeconomic uncertainty measures are included, the time trend is always negative and almost always highly statistically significant. To be sure, the estimated downward trends in Table 6 are less steep, by about one-third, than those that we estimated (in Section 2) through the end of 2000 without any controls; thus, controlling for momentum and macroeconomic uncertainty does qualify, at least quantitatively, the secular improvements in financial market forecast accuracy we estimated earlier. But the overall existence of the forecast improvements is not overturned by the recent deterioration in private sector forecasts and cannot be explained by a simple secular decline in federal funds rate volatility or macroeconomic uncertainty over our sample.¹⁷

16. Nonetheless, macroeconomic uncertainty does possess some marginal explanatory power beyond federal funds rate momentum, in the sense that when all three variables are included in the regression simultaneously, the hypothesis that the macroeconomic uncertainty variables do not enter can be rejected in almost all cases. Thus, macroeconomic uncertainty does appear to play a contributing, albeit secondary, role in explaining the broad patterns we see in the financial market interest rate forecast data.

17. It is also noteworthy that four-quarter-ahead cross-sectional dispersion of interest rate forecasts shows relatively little improvement compared to one-quarter-ahead forecast dispersion. Although other measures of forecast accuracy at horizons longer than one quarter (e.g., implied volatility from eurodollar options, which have horizons of 2–3 quarters out, and 3- and 5-month-ahead fed funds futures forecasts) show significant declines over our sample, the relative lack of improvement in 4-quarter-ahead forecast dispersion is evidence that these gains are harder to distinguish as we look at forecasts with longer and longer horizons.

3.2 Why Did Interest Rate Forecasts Improve Over Our Sample?

A secular improvement in financial market forecasts of short-term interest rates appears to be a robust feature of the data, but the underlying causes of this improvement are not immediately clear. Thinking of the FOMC's interest rate policy as being given by $i_t = f(X_t)$, as discussed in Section 1, the private sector's forecasts of i_{t+k} could have improved either because of improvements in the private sector's understanding of the policy reaction function f or because of improvements in the private sector's forecasts of the state of the economy X_{t+k} .

To shed some light on which of these two competing explanations fits the data more closely, we compare the behavior of private sector forecasts of interest rates over our sample to the behavior of private sector forecasts of other macroeconomic variables: in particular, real GDP and inflation. In Figure 6, we presented graphs of the cross-sectional dispersion of private sector forecasts of real GDP growth and inflation, and in Figure 7, we present the private sector's *ex post* realized forecast errors for these variables over the same period, defined as the absolute value of the difference between the *ex post* realized value of real GDP growth (top panel) or GDP deflator inflation (bottom panel) for a given quarter minus the one-quarter-ahead Blue Chip Consensus forecast made the previous quarter. Note that, in contrast to the cross-sectional dispersion series in Figure 6, the series in Figure 7 exhibit gaps around the dates of NIPA benchmark revisions (December 1991, January 1996, and October 1999), because revisions to GDP growth rates on these dates—resulting from switching to chain-weighting or reclassifying business and government software purchases as investment, for example—may increase forecast errors simply because private sector forecasters failed to predict the *definition* of GDP rather than the underlying state of the economy. We thus omit forecast errors that would be affected by these benchmark revisions from our analysis.¹⁸

It is immediately clear from Figures 6 and 7 that private sector forecasts of real GDP growth and inflation have not experienced the same degree of improvement as forecasts of short-term interest rates. There is little evidence of a downward trend in any of the graphs, either before 2001 or over the full sample. Although not shown due to space constraints, there is similarly very little evidence of a downward trend in cross-sectional dispersion for four-quarter-ahead macroeconomic forecasts or for four-quarter-ahead macroeconomic forecast errors.¹⁹

Table 7 verifies these observations econometrically. Each of the cross-sectional dispersion and forecast error series in Figures 6 and 7 are regressed on a constant and time trend for the sample through December 2000. We end the estimation in

18. Including observations from around these benchmark revisions does not significantly alter our results. Also, one can avoid the NIPA benchmark revisions for inflation by using an alternative measure of inflation such as the CPI. Blue Chip forecast errors for the CPI (not shown) are very similar to those for the GDP deflator over this period, and our results are qualitatively very similar if we use the CPI instead of the GDP deflator in the analysis.

19. We have also verified that the Blue Chip Consensus forecast errors for short-term interest rates display the same trend and overall patterns as the federal funds futures market forecast errors in Figure 5. Both series behave qualitatively very similarly. For this reason, and to save space, we also do not graph the Blue Chip forecast errors for short-term interest rates.

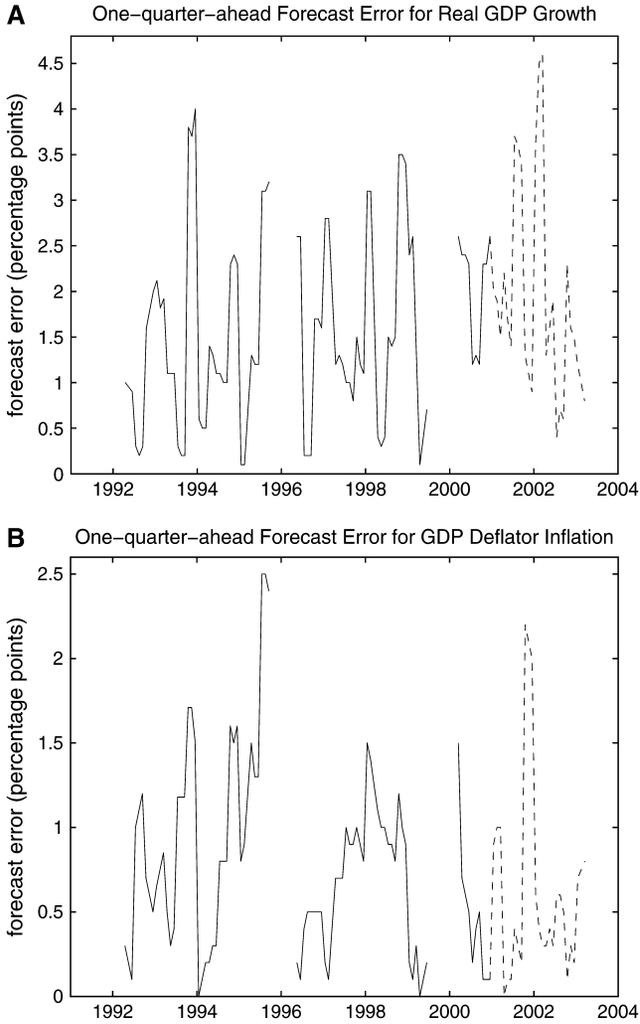


FIG. 7. Private Sector Forecast Errors, Macro Variables. Solid lines: 1991:6–2000:12; dashed lines: 2001:1–2003:12. Data are monthly. Forecast error is realized value minus median Blue Chip consensus forecast of real GDP growth (top panel) or GDP Deflator inflation (bottom panel). Forecast errors that would be affected by NIPA benchmark revisions in Dec. 1991, Jan. 1996, and Oct. 1999 are excluded. See text for details.

2000 so as to maximize the chances of finding a downward trend in the macroeconomic forecast performance measures without having to worry about including any other control variables on the right-hand side. As is clear from the table, there is essentially no evidence of improvement in private sector forecasts of real GDP or inflation over this period, either in terms of *ex post* forecast errors or *ex ante* forecast dispersion. (If anything, the private sector's forecasts of GDP growth actually

TABLE 7

TESTS FOR IMPROVEMENTS IN PRIVATE SECTOR FORECASTS OF MACRO VARIABLES VS. INTEREST RATES

	Constant	Time Trend
(a) Cross-Sectional Dispersion of Forecasts		
Real GDP Growth:		
1-quarter-ahead:	1.959 [8.81]	-0.0052 [-0.13]
1-year-ahead:	1.607 [10.78]	0.0175 [0.59]
GDP Deflator Inflation:		
1-quarter-ahead:	1.314 [21.59]	-0.0182 [-1.59]
1-year-ahead:	1.472 [25.21]	-0.0229 [-1.62]
3-Month Treasury Bill Rate:		
1-quarter-ahead:	0.890 [12.93]	-0.0323 [-3.27]
1-year-ahead:	1.566 [20.46]	-0.0617 [-6.59]
(b) Forecast Errors		
Real GDP Growth:		
1-quarter-ahead:	1.173 [4.63]	0.0819 [1.63]
1-year-ahead:	1.397 [3.14]	0.0636 [0.78]
GDP Deflator Inflation:		
1-quarter-ahead:	0.959 [4.44]	-0.0375 [-1.06]
1-year-ahead:	1.018 [8.27]	0.0136 [1.14]
3-Month Treasury Bill Rate:		
1-quarter-ahead:	0.555 [4.83]	-0.0433 [-2.41]
1-year-ahead:	1.585 [3.55]	-0.1322 [-1.59]

NOTES: Sample period: 1991:6–2000:12; data are monthly; HAC t -statistics reported in square brackets; cross-sectional dispersion of forecasts is 90–10 percentile difference in Blue Chip survey of forecasters, in percent; forecast errors are the ex post realized value of the series minus the 1-quarter-ahead (or 1-year-ahead) median Blue Chip consensus forecast made the previous quarter (or previous year), in percent; time trend is in years.

worsened over this period.) Results over the full sample (through the end of 2003) are very similar.

These results for macroeconomic forecasts stand in sharp contrast to those for interest rate forecasts over the same period, also reported in Table 7 for comparison. The estimated downward trends for interest rate forecasts in Table 7 are both greater in magnitude and much more statistically significant than are those for real GDP and inflation forecasts.

We conclude from this analysis that improvements in forecasting methodology, computing power, and “good luck” have had no discernible impact on private sector forecasts of two of the most important components of the state of the economy X_{t+k} , namely real GDP and inflation. By contrast, private sector forecasts of short-term interest rates $f(X_{t+k})$ have improved dramatically over this same period. Although this evidence is only indirect in that we do not have data on the Fed’s “true” policy response function f or on the private sector’s estimates of f and one could argue that there are other components of the state of the economy X_{t+k} that the private sector could have become better at forecasting, the weight of the evidence presented above strongly suggests that it is the private sector’s understanding of the policy response function f that has improved rather than its ability to forecast the state of the economy X .

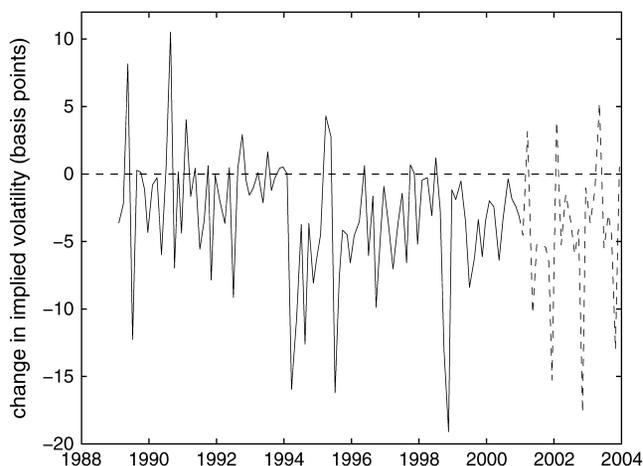


Fig. 8. Change in Market Uncertainty from Day Before to Afternoon after FOMC Announcement, from Eurodollar Options. Solid lines: 1989:1–2000:12; dashed lines: 2001:1–2003:12. Data are sampled at regularly scheduled FOMC meetings. Change in market uncertainty is change in implied volatility (in basis point terms) from Figure 3. See text for details.

3.3 Why Did Understanding of the Policy Response Function Improve?

We finally ask how the public's understanding of the monetary policy reaction function f could have improved over our sample. One possibility, of course, is that the FOMC communicated to the private sector more information about its objectives and the prospective future conduct of monetary policy in response to economic developments. However, a reasonable alternative is that—even in the absence of any meaningful FOMC communication—the private sector gradually learned about the unobserved function f simply through an increase in the number of observed data points over time, just as an econometrician would benefit from having a larger sample of data.

Distinguishing between these two effects is more difficult than for the differences considered in the previous subsection (forecasting X_{t+k} versus understanding f). Nonetheless, Figure 8 presents some evidence that increases in Federal Reserve transparency (i.e., communication about the goals and conduct of monetary policy) have been at least partly responsible for the increase in private sector understanding of f . Here we consider again market uncertainty about interest rates, as measured by implied volatility in basis point terms from eurodollar options (the same series underlying Figure 7), but Figure 8 takes a slightly different perspective, plotting the one-day *change* in financial market uncertainty from the day before to the afternoon after each regularly scheduled FOMC announcement from January 1989 through December 2003. In the framework of Section 1, this corresponds to $\text{Var}_{t,d} \bar{r}_{t+7,t+9} - \text{Var}_{t,d-1} \bar{r}_{t+7,t+9}$, where the monetary policy announcement occurs on day d of month t . Thus, the figure depicts whether and by how much FOMC announcements reduced (or increased) market uncertainty about the future course

TABLE 8
 TEST FOR STRUCTURAL BREAK IN FEB. 1994 IN CHANGE IN IMPLIED VOLATILITY AROUND
 FOMC ANNOUNCEMENTS

Sample Period	Constant	Post-1994 Dummy
1989:1–2003:12	–1.27 [–1.74]	–3.20 [–3.59]

NOTES: Data are sampled at scheduled FOMC meetings; *t*-statistics reported in square brackets; left-hand side variable is change in market uncertainty from Figure 8, in basis points.

of interest rates at a horizon of 6–9 months in the future. There is nothing that requires this market uncertainty to fall in response to FOMC announcements, but over most of our sample this has typically been the case—the mean of the series is negative and a large majority of the observations are also negative.

The most striking feature of Figure 8, however, is the clear break in the series in February 1994, when the Federal Reserve began explicitly announcing and explaining changes in its target for the federal funds rate. A Chow test for a structural break on this date is highly statistically significant (see Table 8). Indeed, prior to 1994, the change in financial market uncertainty around FOMC announcements is not significantly different from zero; it is only after 1994, when the Fed began explaining its policy actions, that we see significant falls in financial market uncertainty in response to FOMC announcements.²⁰

Recall that we already showed in Figure 3 and Table 4 that the *level* of financial market uncertainty just before FOMC meetings fell consistently throughout our sample. What Figure 8 and Table 8 show is that, in addition to the lower level of uncertainty just prior to each meeting, financial market uncertainty also *fell* significantly in response to the FOMC's announcements after 1994. This observation seems difficult to reconcile with a simple model of constant learning on the part of the private sector over time, with no help at all from the increase in communication by the FOMC starting in 1994.

Instead, Figure 8 suggests that the Federal Reserve's shift to explicit monetary policy announcements and explanations for its actions has significantly reduced financial markets' uncertainty about the future course of short-term interest rates, not only for the overnight rate in the immediate future, but even for the level of short-term interest rates at horizons of 6–9 months, the horizon considered in the implied volatility data underlying Figure 8.

4. CONCLUSIONS

Private sector forecasts of short-term interest rates in the U.S. have shown dramatic improvements over the past 15–20 years, as evidenced by (1) a reduction in federal

20. As discussed in the Appendix, our results in all tables carefully take into account the exact timing of when FOMC decisions became known to the markets—in particular, recall that FOMC announcements prior to 1994 implicitly took place through the size and type of the next open market operation following the FOMC's decision.

funds rate forecast errors at horizons out to several months, (2) a fall in financial market surprises in response to FOMC announcements, (3) a reduction in financial market *ex ante* uncertainty about the future course of interest rates, derived from interest rate options, and (4) a fall in the cross-sectional dispersion of private sector forecasts of short-term interest rates. Despite a recent upswing in private sector forecast errors and uncertainty since January 2001, an overall improvement in private sector interest rate forecasts appears to be a robust feature of the data that remains even after controlling for changes in federal funds rate “momentum” and uncertainty about the state of the U.S. economy that took place over the period.

Of course, the underlying causes of the improved forecasting performance cannot be determined with certainty, but two pieces of evidence strongly suggest that increases in Federal Reserve transparency have played a role. First, market forecast errors and cross-sectional forecast dispersion for interest rates have fallen substantially, while those for GDP and inflation generally have not, indicating an improvement in the private sector’s ability to forecast interest rates above and beyond any improvements in forecasting other macroeconomic variables. Second, market uncertainty about the future course of interest rates even 6–9 months ahead typically falls substantially after explicit policy announcements and accompanying explanatory statements by the Federal Reserve—which have been made since February 1994—but shows no significant response to the implicit, unexplained policy announcements that were made by the Fed prior to that date. Although most of the improvement in financial markets’ ability to forecast interest rates over the 1990s appears to have been gradual rather than directly linked to February 1994, it seems reasonable to infer from the above observations that other changes in FOMC transparency, such as those listed in Table 1, have also contributed to the widespread improvement in financial market and private sector forecasts of short-term interest rates that took place over this period.

APPENDIX

Dating of FOMC Announcements

Our dating of FOMC announcements follows Kuttner (2001) and Poole, Rasche, and Thornton (2002) in all respects except as noted below.

Beginning with the February 1994 FOMC meeting, policy announcements on scheduled FOMC meeting dates are assumed to have taken place at 2:15 pm the last day of the FOMC meeting. Prior to 1994, FOMC decisions regarding the federal funds rate are assumed to have been implicitly announced the following morning through the size and type of open market operation.

There are a few exceptions to these dating conventions. The intermeeting policy move on October 15, 1998 was announced at 3:15 pm, after the close of federal funds futures, eurodollar futures, and eurodollar options markets. The 25 bp easing at the November 13, 1990 FOMC meeting was followed by a very volatile federal funds market the following two days; thus, the “Credit Markets” column of *The Wall Street Journal* did not recognize the policy action until two days later than

usual, on November 16.²¹ The 25 bp easing on October 18, 1989, was actually perceived by markets to have taken place on October 16—*before* the actual FOMC decision—as the Desk decided (in consultation with the Chairman) not to offset excess reserves in the market due to stock market turmoil, the SF earthquake, and anticipation of the FOMC’s action two days later (see Kuttner (2003)).

In general, the exact dating of other intermeeting policy moves prior to 1990 is somewhat ambiguous, with alternative series published by the Federal Reserve Bank of New York and unofficially by the FOMC Secretariat’s office. We use the timing of announcements as published by the FRB NY, since we have typically found this to correspond to the date on which the policy action became known to the markets, but we drop changes in the FRB NY federal funds rate target series that do not appear in the Secretariat’s listing of policy changes, since these are typically small (6.25 bp) and were presumably minor technical adjustments in the Desk’s day-to-day targeting operations.

See Kuttner (2001, 2003) and Poole, Rasche, and Thornton (2002) for additional details and a listing of dates.

Federal Funds Futures

Federal funds futures contracts settle based on the average federal funds rate realized over a given calendar month (the contract month). In order to convert this monthly expectation to a forecast for the outcome of the next FOMC meeting, we must assume that market participants assign zero probability to a policy change occurring on any date other than the FOMC meeting date. This assumption is standard in the literature, but to the extent that it is not warranted in a few instances, our forecasts for the outcome of the FOMC meeting will be measured with error. We also make an adjustment for deviations of the federal funds rate from the target rate prevailing on the date of the *ex ante* forecast up through the date of the FOMC meeting, since these deviations would be priced into the federal funds futures contract *ex post*, but would not be forecast errors associated with the outcome of the meeting, because they are confined entirely to the intervening period.

Like Kuttner (2001), we use the same-month federal funds futures contract for each FOMC meeting to calculate the implied forecast for the outcome of the meeting (Poole and Rasche, 2000, and Poole, Rasche, and Thornton, 2002, use the next-month contract). Like Kuttner, we scale up the surprise in the same-month contract (i.e., the *ex post* value of the contract minus the *ex ante* value) by the number of days in the calendar month divided by the number of days remaining after the FOMC meeting, in order to yield the implied surprise in the outcome of the meeting. For late-month meetings (those that occur in the last six days of the month), we use the next-month federal funds futures contract. See Kuttner (2001) for additional description and details.

21. We thank Ken Kuttner for providing us with an unpublished detailed chronology of market knowledge of FOMC actions derived from reading the “Credit Markets” column in the WSJ and biweekly market summaries by the Desk around the time of FOMC meetings and intermeeting moves (Kuttner 2003).

Eurodollar Futures

Eurodollar futures contracts have traded on the Chicago Mercantile Exchange since 1981 and settle based on the spot 90-day LIBOR rate quoted by banks on the day of settlement. They are currently the most actively traded futures contracts in the world. Only the March, June, September, and December eurodollar futures contracts are actively traded, however. Since FOMC meetings occur at various points throughout the quarter, using the next maturing eurodollar contract would introduce variation in the horizon of the forecast, from as little as a few days to settlement, to as much as 3 months. As in Faust et al. (2003), we interpolate between adjacent eurodollar futures contracts to maintain a constant horizon of about 3 months after each FOMC meeting. Thus, if the FOMC meeting occurs on the x th day of the quarter, then we put a weight of $(91 - x)/91$ on the eurodollar futures contract that settles at the end of the quarter containing the FOMC meeting, and a weight of $x/91$ on the eurodollar futures contract that matures at the end of the following quarter. The resulting measure approximates market expectations for a 90-day rate 90 days ahead, which corresponds to the expected federal funds rate from day $t + 90$ to day $t + 180$, where t denotes the date of the FOMC meeting. See Gürkaynak, Sack, and Swanson (2006) for additional description and details.

Eurodollar Options

Eurodollar options have traded on the Chicago Mercantile Exchange since January 1989. A eurodollar call option with strike rate r and expiration date d gives the holder the option of making a 90-day eurodollar deposit on date d at the interest rate r . Using eurodollar *futures* data, we can estimate the expected value of the 90-day eurodollar rate on the expiration date d of the options contract. We then assume that the 90-day eurodollar rate on date d is a lognormally distributed random variable, and use the price of the option to back out the implied volatility of this random variable. Because standardized eurodollar futures and options contracts have expiration dates only near the end of each quarter, we interpolate between the prices of adjacent eurodollar futures contracts, and adjacent eurodollar options contracts, to obtain estimates of a constant horizon (in this case, 6-month-ahead) expected 90-day eurodollar rate and implied volatility for this rate.

A problem with the usual measure of implied volatility, however, is that it is a dimensionless quantity that represents the standard deviation of the *log* of the variable of interest—i.e., if the random variable X is lognormally distributed, with $\log X$ having mean μ and variance σ^2 , then the “implied volatility” of X is σ . Since the *level* of the expected 90-day eurodollar rate has been at all-time lows recently, the recent surge in implied volatility σ may simply reflect the fall in the level of interest rates, rather than any increase in market uncertainty about the eurodollar rate itself.

A more useful measure of uncertainty about interest rates is thus the *implied standard deviation* of the 90-day eurodollar rate (also called the “implied volatility in basis point terms”), which multiplies the usual implied volatility σ by the expected

value $E[X]$ of the 90-day eurodollar rate. Although technically the standard deviation of X is $(e^{\sigma^2} - 1)^{1/2}E[X]$ rather than $\sigma E[X]$, these two measures are so close as to be visually indistinguishable in Figure 7.

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