How Do FOMC Projections Affect Policy Uncertainty?

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I n January 2012, the Federal Open Market Committee (FOMC) began publicly releasing its participants' projections for the future value of the federal funds rate in its quarterly Summary of Economic Projections (SEP). These projections reflect each participant's view of appropriate monetary policy and are thus not unconditional forecasts. Highlighting the release of these projections, former FOMC Chair Ben Bernanke noted that "providing regular information about the future path of policy . . . has aided the public in forming policy expectations, *reduced uncertainty* [emphasis added], and made policy more effective."

However, the individual—and possibly conflicting—nature of these projections may not necessarily lead to lower uncertainty about future policy. A single participant's views about the appropriate future funds rate may not align with the views of the rest of the Committee. If participants notably disagree with each other about the appropriate path of policy, then the release of these projections may actually lead to an *increase* in uncertainty about future interest rates. Indeed, some monetary policy makers have suggested using these projections to communicate their disagreement. For example, in advocating for the release of the projections, Federal Reserve Bank of San Francisco President

John C. Williams stated, "the range of our funds rate forecast would appropriately convey the disagreement and uncertainty we face" (Board of Governors 2017a).

Do these projections decrease or increase uncertainty about future policy? To answer this question, we examine how uncertainty about future interest rates, as measured by options prices from financial markets, changed after the FOMC began releasing its participants' projections for the appropriate federal funds rate. To isolate the releases' effects, we examine our market-based uncertainty measures immediately before and after FOMC meetings.

We find that overall uncertainty about future interest rates fell after the Committee began releasing its participants' interest rate projections. Specifically, we find the level of uncertainty on the day before and the day of an FOMC announcement decreased after the FOMC began releasing interest rate projections. However, we also find that uncertainty is significantly correlated with disagreement across participants' projections. Furthermore, we find changes in participant disagreement are helpful in explaining changes in interest rate uncertainty after an FOMC meeting. In summary, our results provide empirical support for the claims of both Bernanke and Williams.

I.   Measuring Uncertainty Using Options from Financial Markets

To estimate uncertainty about future interest rates and examine how these uncertainty measures changed after the release of FOMC participants' policy projections in the SEP, we use prices from financial markets.[1] Specifically, we use Eurodollar options prices to estimate the probability distribution of possible outcomes for future interest rates (see Appendix for details on how the distribution is constructed). Eurodollar contracts are financial market instruments whose payoff depends on the London Interbank Offer Rate (LIBOR), a short-term borrowing rate for financial firms that closely tracks the federal funds rate. Options on these Eurodollar contracts are additional instruments that have a positive return only under specific outcomes for future interest rates.

The price of a Eurodollar option today reflects financial market participants' beliefs about future short-term interest rates. For example, a given option may have a positive payoff only if the LIBOR rises above 2

percentage points at the end of the next year. A high price for this option suggests financial market participants believe that short-term interest rates are highly likely to be above the 2 percent threshold in a year. In contrast, a price near zero suggests financial market participants believe this event is quite unlikely. One way to think about using options prices to infer the market-implied probabilities is as analogous to the market for automobile insurance: insurance providers charge higher prices to customers they believe are more likely to file a future claim.

Using a variety of Eurodollar options with different interest rate thresholds, we can construct the market-implied distribution of possible outcomes for future interest rates at a given horizon.[2] As an example, the blue bars in Chart 1 illustrate the distribution of possible outcomes for interest rates one year from March 15, 2016, which was the day before an FOMC meeting and the accompanying release of a policy statement and a SEP. The height of each bar shows the market-implied probability of a particular outcome for the LIBOR.[3] On March 15, 2016, the current LIBOR was about 0.6 percent. The tallest bar, which represents the most likely or modal outcome, suggests many financial market participants believed LIBOR would remain roughly unchanged by the end of 2017:Q1. However, the distribution suggests that some market participants believed significantly higher future LIBOR outcomes were also possible.

Using this distribution of possible outcomes, we can estimate the market-implied uncertainty about future interest rates. To measure market-based uncertainty on March 15, 2016, we compute the standard deviation of the market-implied distribution in Chart 1. The standard deviation measures how widely outcomes are dispersed from the average or mean outcome. The day prior to the March 2016 FOMC meeting, the market-implied standard deviation of one-year-ahead interest rates was about 52 basis points.

Measuring uncertainty the day before an FOMC meeting allows us to gauge the market's uncertainty about the future path of interest rates immediately prior to the release of participant projections. For example, if financial market participants are fairly confident about future interest rates, the market-implied distribution of outcomes should be less spread out. Using the level of uncertainty prior to the meeting as a baseline, we can then examine how the distribution changes

Chart 1

Distribution of Outcomes in One Year from Eurodollar Options
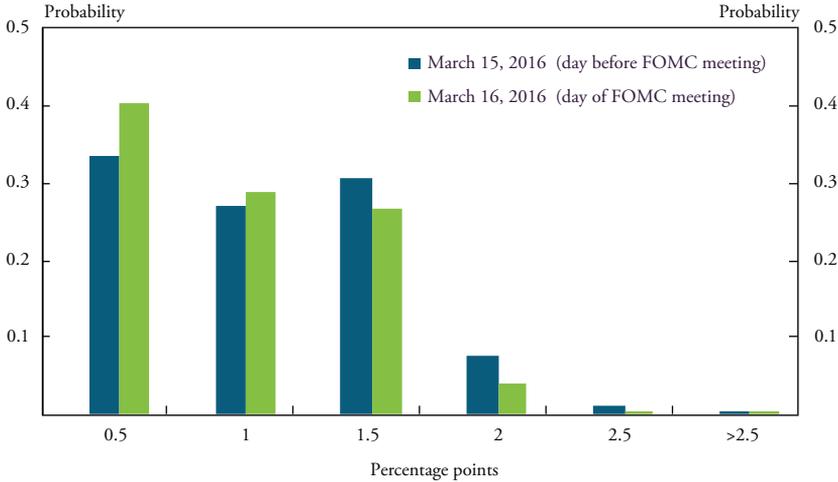
Note: The standard deviation of the distribution was 52 basis points on March 15 and 48 basis points on March 16.
Sources: Chicago Mercantile Exchange and authors' calculations.

immediately after the release of the policy statement and SEP. Typically, there are no significant data releases relevant for monetary policy decisions immediately prior to FOMC meetings. Thus, focusing on the uncertainty around FOMC meetings helps us isolate the role of interest rate projections and their relationship with market-based measures of uncertainty.

Changes in the market-implied distribution of outcomes following the March 16, 2016, FOMC meeting, for example, suggest that the policy announcement and interest rate projections helped resolve some uncertainty about future interest rates. The green bars in Chart 1 show the market-implied distribution of outcomes re-estimated the day of the FOMC meeting on March 16. Following the announcement and release of the SEP, the standard deviation of one-year-ahead future interest rates fell by about 4 basis points.

While this specific policy release appears to have affected market-based measures of uncertainty, we want to understand the connection between FOMC participants' projections and interest rate uncertainty more generally. Thus, building on Bernanke and Williams, we focus our remaining analysis on the following three questions:

1. Did the introduction of these policy projections lower uncertainty about future interest rates the day before and the day of FOMC meetings?
2. Is the disagreement among FOMC participants related to the level of uncertainty regarding future interest rates?
3. Do changes in the degree of disagreement among FOMC participants explain movements in market-based measures of uncertainty around policy announcements?

To answer these questions, we include an additional, alternative measure of uncertainty in our analysis. While the standard deviation is the usual metric for measuring uncertainty, it may not be the best measure if the distribution of future outcomes does not follow a typical bell curve (normal distribution). Thus, we also compute the difference between the 80th and 20th percentiles of the distribution to measure market-implied uncertainty about future interest rates. In general, the 80th minus 20th percentile is approximately two times the standard deviation from the same distribution. This approximation is most accurate if the outcomes are normally distributed. However, the 80th minus 20th percentile may be a more robust measure of uncertainty if the distribution of outcomes is non-normal, which often occurs in financial market data. Using two measures helps ensure our findings are robust.

II. Uncertainty after the Introduction of Interest Rate Projections

By providing additional information to the public, FOMC participant projections might reduce the overall level of uncertainty about future interest rates. Building on the work of Swanson, we examine this idea using the market-implied level of uncertainty the day before FOMC meetings. Measuring the amount of uncertainty prior to the meeting allows us gauge the market's baseline level of uncertainty about future interest rates. If prior interest rate projections provided market participants with more information about the future path of policy rates, then the market-based measures of uncertainty should illustrate a lower baseline level of uncertainty prior to each policy meeting.

We find significant evidence that uncertainty the day before an FOMC meeting declined after FOMC participants' policy projections were included in the SEP. Chart 2 plots our two market-based measures

Chart 2
Uncertainty Prior to Each FOMC Meeting
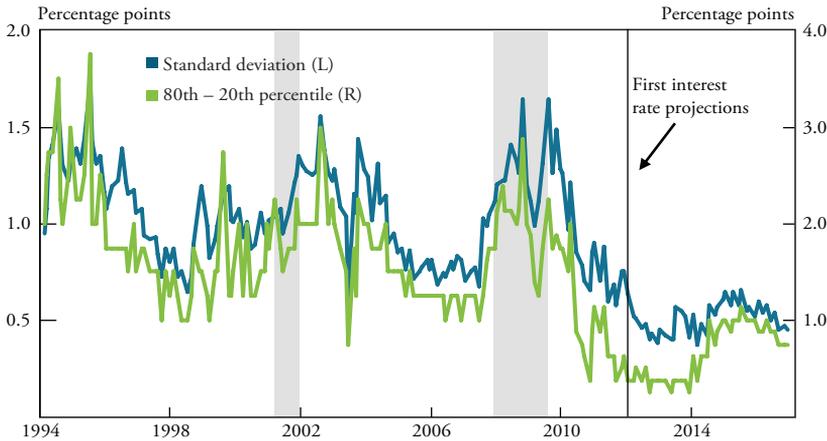
Note: Gray bars denote National Bureau of Economic Research-defined recessions.
Sources: Chicago Mercantile Exchange, National Bureau of Economic Research, and authors' calculations.

of interest rate uncertainty on the day before each FOMC meeting from February 1994 to December 2016.[4] Both the standard deviation and the 80th minus 20th percentile appear lower since the projections of the federal funds rate were introduced in January 2012. To rigorously test this finding, we estimate the following statistical model:

$$\sigma_t = \alpha + \beta_1 I^{FFR\,Proj} + \beta_2 I^{ZLB} + \varepsilon_t.$$

The dependent variable, σ_t, measures the market-implied uncertainty the day before an FOMC meeting. The constant, α, estimates the average level of uncertainty during the February 1994–November 2008 sample period. The variable $I^{FFRProj}$ is an indicator variable that takes on a value of 1 after the introduction of the federal funds rate projections and a value of 0 in all previous periods. The error term, ε_t, captures differences between the level of uncertainty predicted by the model and the actual data. The estimate of β_1 captures how the average level of uncertainty changed after the introduction of interest rate projections in January 2012.

We also incorporate an additional variable, I^{ZLB}, to examine whether the average level of uncertainty changed prior to 2012, when the federal funds rate was constrained by the zero lower bound (ZLB). Uncertainty about future interest rates may have been mechanically

lower at the ZLB. Since interest rates cannot fall below their effective lower bound, the left side of the distribution of possible outcomes is compressed, lowering measures of uncertainty by construction. To ensure this phenomenon is not driving our key findings, we allow for a different average level of uncertainty, measured by β_2, during the ZLB period but prior to the introduction of interest rate projections. Accordingly, the variable I^{ZLB} takes on a value of 1 during the December 2008–December 2011 sample period and 0 all other times.

The level of uncertainty prior to an FOMC announcement was about half as large in the 2012–16 period as it was in the other sample periods. Table 1 shows the estimates for the average level of uncertainty in all three sample periods. Prior to 2009, the standard deviation of one-year-ahead interest rates right before a policy announcement was about 1 percentage point. After the federal funds rate projections were introduced, pre-meeting uncertainty fell by over 0.5 percentage point. The 80th minus 20th percentile measure of uncertainty declined by a similar margin. While we cannot draw any causal links from these results, our findings support Bernanke's statement that these projections may have reduced uncertainty. Over the past few years, providing the public with additional information about the future path of policy has indeed coincided with a lower level of uncertainty about future interest rates.

In addition, we find some weak evidence that uncertainty may also have been lower after the onset of the ZLB but prior to the introduction of interest rate projections. When we measure uncertainty using the standard deviation, we find that the coefficient on I^{ZLB} is near zero, which suggests no change in the typical level of uncertainty the day before an FOMC meeting during the ZLB period relative to the previous period. However, when we measure uncertainty using the 80th minus 20th percentile, the coefficient is negative and statistically significant, which does suggest lower uncertainty during the ZLB period. While our two alternative measures of uncertainty yield different interpretations for the December 2008–December 2011 period, both illustrate a robust decline in uncertainty after the introduction of interest rate projections in January 2012.

As an additional check on the robustness of our conclusions, we repeat our previous empirical exercise using data from the day of an FOMC meeting rather than the day before.[5] Table 2 contains the

Table 1

Average Level of Uncertainty the Day before an FOMC Meeting

Dependent variable	Standard deviation (1)	80th − 20th percentile (2)
Average during pre-ZLB period	1.07*** (0.02)	1.76*** (0.05)
Change during ZLB but prior to introduction of funds rate projections	−0.08 (0.06)	−0.53*** (0.13)
Change after introduction of funds rate projections	−0.56*** (0.03)	−1.09*** (0.07)
Observations	185	185

*   Significant at the 10 percent level
**   Significant at the 5 percent level
*** Significant at the 1 percent level
Notes: Robust standard errors are in parentheses. The pre-ZLB sample period is February 4, 1994, through October 29, 2008. The ZLB without federal funds rate (FFR) projections sample period comprises the FOMC meetings from December 16, 2008, through December 13, 2011. The FFR projections period is January 30, 2012, through December 14, 2016.
Sources: Chicago Mercantile Exchange and authors' calculations.

Table 2

Average Level of Uncertainty the Day of an FOMC Meeting

Dependent variable	Standard deviation (1)	80th − 20th percentile (2)
Average during pre-ZLB period	1.04*** (0.02)	1.72*** (0.05)
Change during ZLB but prior to introduction of funds rate projections	−0.09 (0.06)	−0.58*** (0.13)
Change after introduction of funds rate projections	−0.54*** (0.02)	−1.09*** (0.07)
Observations	185	185

*   Significant at the 10 percent level
**   Significant at the 5 percent level
*** Significant at the 1 percent level
Notes: Robust standard errors are in parentheses. The pre-ZLB sample period is February 4, 1994, through October 29, 2008. The ZLB without federal funds rate (FFR) projections sample period comprises the FOMC meetings from December 16, 2008, through December 13, 2011. The FFR projections period is January 30, 2012, through December 14, 2016.
Sources: Chicago Mercantile Exchange and authors' calculations.

estimated regression coefficients, which are nearly identical to our previous findings in Table 1. Thus, our choice of a particular day on which to measure uncertainty is not driving our key findings. Overall, our results suggest that financial markets' uncertainty about short-term interest rates one year ahead is lower after the introduction of interest rate projections.

## III. Disagreement among FOMC Participants and the Level of Uncertainty

While overall uncertainty appears to have declined after the introduction of interest rate projections, the specific quantitative information in these projections may be helpful in understanding financial market uncertainty around FOMC meetings. As Williams suggested, policymakers may wish to use these projections to communicate their uncertainty about the outlook for future interest rates.

To assess whether forecast disagreement among FOMC participants is related to our market-based measures of uncertainty, we construct a measure of policy disagreement among FOMC participants.[6] Using individual participants' projections for the one-year-ahead federal funds rates, we compute the width of the central tendency as the difference between the maximum and minimum projections after dropping the top and bottom three observations.

We find that the level of disagreement among FOMC participants is positively related to the level of market-implied uncertainty. Using data from each FOMC meeting with policy rate projections over the 2012–16 period, Chart 3 plots the width of the central tendency against both measures of market-implied uncertainty—the standard deviation (Panel A) and the 80th minus 20th percentile (Panel B).[7] The scatter plots in both panels illustrate that greater disagreement among FOMC participants is correlated with increased uncertainty about future interest rates. To assess the quantitative strength of this correlation, we compute the best-fit linear regression model relating the width of the central tendency to each measure of uncertainty. The lines in Chart 3 show the estimates from that statistical model. The slope of the line for the standard deviation is approximately 0.3, while the slope for the 80th minus 20th percentile is approximately 0.6. Thus, the statistical model suggests that if the central tendency were 1 percentage point wider, the

Chart 3

Disagreement among FOMC Participant Projections and Market-Based Uncertainty

Panel A: Standard Deviation

Width of central tendency

Panel B: 80th – 20th Percentile

Width of central tendency
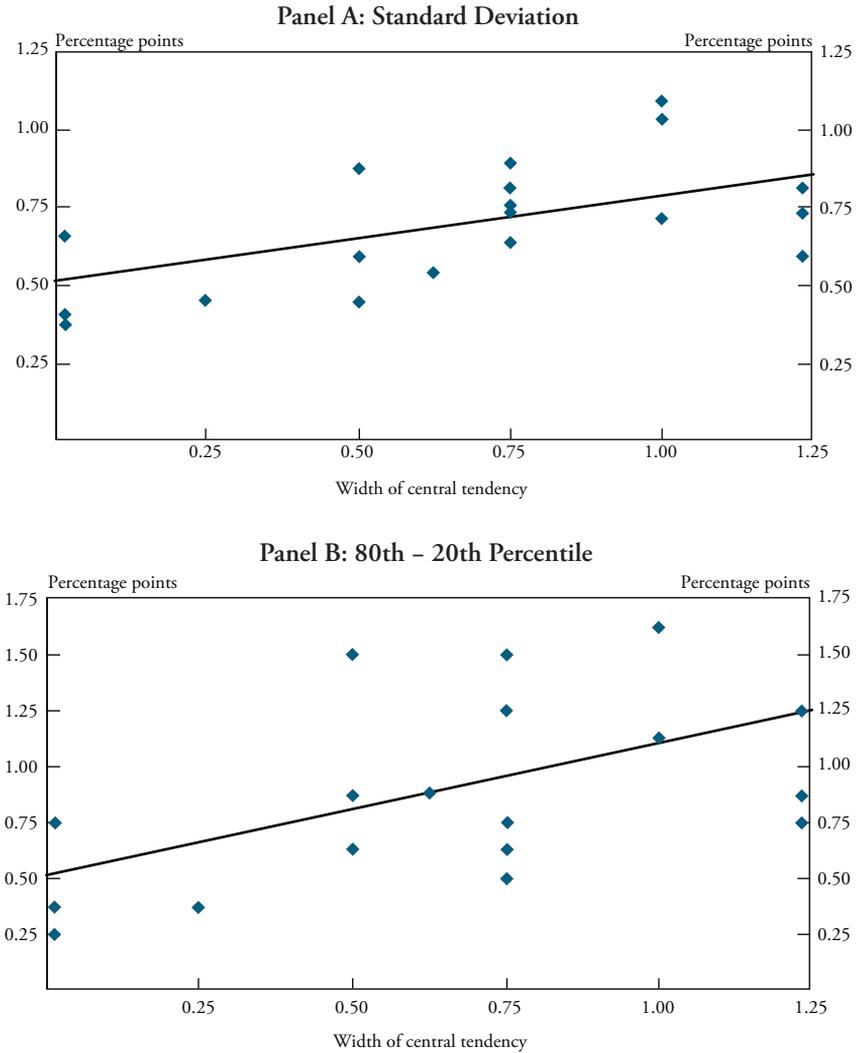
Note: The black lines denote the best-fit linear regression model.
Sources: Board of Governors of the Federal Reserve System, Chicago Mercantile Exchange, and authors' calculations.

standard deviation of market-implied uncertainty would be about 30 basis points higher on average.

For both measures of uncertainty, the estimated slopes are significantly positive and statistically different from zero. Although we cannot draw any causal conclusions from these statistical results, our findings suggest that disagreement among FOMC participants is highly correlated with measures of uncertainty about the future path of interest rates. This high correlation suggests that both financial markets and policymakers are likely responding to a common set of macroeconomic fundamentals. Moreover, since our options-based uncertainty measures require significant computations and non-publicly available data, our results suggest that disagreement among FOMC participants may be an easily observable proxy for uncertainty about future interest rates.

Finally, we examine whether changes in the width of the central tendency are helpful in understanding changes in market-implied uncertainty after an FOMC meeting. As Chart 1 illustrated, market-based measures of uncertainty can change around FOMC meetings.[8] To assess whether changes in FOMC policy projections help explain these movements, we estimate the following regression model:

$$\Delta\sigma_t = \alpha + \gamma\Delta WCT_t + \varepsilon_t,$$

where $\Delta\sigma_t$ is the change in a measure of market-implied uncertainty from one day before to the day of a SEP release, ΔWCT_t is the change in the width of the central tendency from the last projection release, and ε_t is an error term.[9] The estimated coefficient, γ, illustrates whether changes in the width of the central tendency are related to changes in the market-implied measures of uncertainty.

We find some suggestive evidence that changes in the FOMC's policy projections help explain changes in market-implied uncertainty around FOMC announcements. Table 3 shows the estimation results for both measures of uncertainty. Using the standard deviation, we find that an increase in the width of the central tendency is associated with higher market-implied uncertainty about the future path of rates. On average, a 100 basis point reduction in the width of the central tendency is associated with about a 5 basis point decline in the market-implied standard deviation. Moreover, the statistical model suggests that changes in the width of the central tendency explain over 40 percent of

Table 3

Changes in the Width of the Central Tendency and Changes in Uncertainty

Dependent variable	Standard deviation (1)	80th – 20th percentile (2)
Width of central tendency	0.047*** (0.02)	0.09 (0.10)
Constant	–0.008 (0.004)	0.01 (0.02)
Observations	20	20
R^2	0.48	0.11

*   Significant at the 10 percent level
**   Significant at the 5 percent level
*** Significant at the 1 percent level
Note: Robust standard errors are in parentheses.
Sources: Board of Governors of the Federal Reserve System, Chicago Mercantile Exchange, and authors' calculations.

the variation in daily changes in market-implied uncertainty. We also find a positive relationship between changes in the central tendency and uncertainty when we measure uncertainty using the 80th minus 20th percentile. While the coefficient on the width of the central tendency is less precisely estimated using this alternative measure of uncertainty, the model still explains about 10 percent of the variation in the changes in uncertainty around FOMC announcements.

IV. Conclusions

Overall, our results support the claims of both Bernanke and Williams about the relationship between funds rate projections in the SEP and uncertainty about future interest rates. Market-based measures of uncertainty fell after the FOMC began releasing participant projections. Although the degree of uncertainty continues to fluctuate around FOMC meetings, disagreement among participants about appropriate future policy—as measured in the SEP—appears to be correlated with market-based measures of uncertainty about the future path of interest rates. In addition, we find that a decline in disagreement among FOMC participants' projections is associated with lower market-implied measures of uncertainty.

Taken together, these results suggest that the FOMC's policy projections may be an effective tool for communicating the future path of policy and its uncertainty, a form of forward guidance. Indeed,

former Federal Reserve Bank of Philadelphia President Charles Plosser said in an FOMC meeting that "the best way to do forward guidance at this point is to publish our policy paths in the SEP" (Board of Governors 2017b).[10] Thus, our results suggest that policy projections in the SEP could play an important role in implementing the FOMC's desired guidance going forward.

Appendix

Computing the Market-Implied Distribution of Outcomes for Future Interest Rates

This Appendix provides further details on Eurodollar contracts and the estimation of their options-implied probability density function. For the calculations in the main text, we use data purchased from the Chicago Mercantile Exchange. To illustrate our method using publicly available data from a particular day, we use data from October 1, 2012, which is available at http://www.cmegroup.com/confluence/display/EPICSANDBOX/End+of+Day

A Eurodollar is a dollar-denominated deposit in a bank outside of the United States that earns the current LIBOR. Eurodollar futures are financial market contracts that pay off based on the value of the LIBOR at a given point in the future. For example, consider a Eurodollar futures contract purchased October 1, 2012, that would expire in December 2013. The payoff for the holder of this futures contract would be 100 – *R,* where *R* is the actual three-month LIBOR at the December settlement date. Thus, a futures price of 98.75 on October 1, 2012, implies the LIBOR was expected to be 100 – 98.75 = 1.25 percent in December 2013.

Options on Eurodollar futures are financial market contracts that give the owner the right, but not the obligation, to buy or sell a Eurodollar future at a pre-specified strike price at a given point in the future. A call option allows the owner to buy a given asset, while a put option allows the owner to sell it. Consider, for example, a call option on the December 2013 Eurodollar future purchased on October 1, 2012, with a strike price of K = 99. This option had a positive payoff only if the December 2013 futures price rose above the strike price, because the option owner had the right to buy the future contract for less than its October 1, 2012, market value. Thus, we can write the price of this four-quarter-ahead call option today as $C_t^4 = max\left(f_t^4 - K, 0\right)$, where f_t^4 is the price of the four-quarter-ahead Eurodollar futures contract. A high price for this option suggests that financial market participants believed the price of the December 2013 Eurodollar future was likely to be above the strike price.

To estimate the options-implied density function, we follow Swanson and use the prices of multiple Eurodollar options with the same

expiration but different strike prices. Further, we estimate the function under the assumption of risk-neutrality. Except where otherwise noted, we assume that the density function follows a step function, with the steps centered on all available strike prices.

As an illustration of this method, we calculate the options-implied density using four-quarter-ahead Eurodollar options on October 1, 2012. On that date, we have settlement prices for 11 call options and 23 put options. The strike prices and settlement prices appear in Table A-1.

For this example, we assume that that the density function has 14 steps that are 25 basis points wide and centered at values ranging from 96.50 to 99.75.

We can define the matrix of call payoff under these six different interest rate outcomes as follows:

$$
max\left(1_{11} * X_{14} - K_{11} * 1_{14}{}',0\right) = \begin{pmatrix} max(99.75 - 98.75,0) & \cdots & max(96.50 - 98.75,0) \\ \vdots & \ddots & \vdots \\ max(99.75 - 100,0) & \cdots & max(96.50 - 100,0) \end{pmatrix},
$$

where 1_{11} is a column vector of ones equal to the number of calls, X_{14} is a row vector with the interest rate outcomes, K_{11} is a column vector of the strike prices, and $1_{14}{}'$ is a row vector of ones equal to the number of interest rate outcomes. Similarly, we can define a matrix of put payoffs: $max(K_{23} * 1_{14}{}' - 1_{23} * X_{14},0)$. We then stack the resulting call and put payoffs in a matrix followed by a row of ones. We label the resulting matrix A. The row of ones ensures that the estimated probabilities sum to one.

Similarly, we take the vectors of calls and puts prices, stack them in a vector, and append an additional row that contains a scalar one. We label the resulting vector b. To determine the probability associated with each interest rate outcome, we solve the following system:

$$Ax = b,$$

where A and b are defined as above. The resulting solution in x provides an estimate of the probabilities of each interest rate outcome. Again, including the additional row of ones in A and b implies that the resulting solution satisfies that the element in x sums to one ($x_1 + x_2 + \ldots + x_{14} = 1$). We solve the system in Matlab, using nonlinear least squares to ensure no probabilities are negative.

Table A-1
Eurodollar Options Prices with December 2013 Settlement

Calls		Puts	
Strike price	Settlement price	Strike price	Settlement price
98.75	0.8975	96.50	0.0025
98.87	0.7750	97.00	0.0050
99.00	0.6550	97.25	0.0050
99.12	0.5375	97.37	0.0050
99.25	0.4225	97.50	0.0075
99.37	0.3100	97.75	0.0100
99.50	0.2050	97.87	0.0125
99.62	0.1125	98.00	0.0150
99.75	0.0450	98.12	0.0175
99.87	0.0175	98.25	0.0200
100.00	0.3800	98.37	0.0225
		98.50	0.0250
		98.62	0.0275
		98.75	0.0300
		98.87	0.0325
		99.00	0.0375
		99.12	0.0450
		99.25	0.0525
		99.37	0.0650
		99.50	0.0850
		99.62	0.1175
		99.75	0.1750
		99.87	0.2725

Source: Chicago Mercantile Exchange.

Endnotes

[1]See Kahn and Palmer for a detailed history of the SEP.

[2]Technically, we compute the market-implied probability distribution under the assumption of risk neutrality.

[3]In constructing the market-implied probability distributions, we assume that the probability density follows a step function where the steps are centered on the available strike prices. For Chart 1 only, we assume a coarser step function to make the resulting plot easier to read and interpret.

[4]While data are available prior to 1994, Swanson shows that the introduction of press releases during that year reduced uncertainty on average compared with prior years. For this reason, we omit pre-1994 meetings in order to focus the analysis.

[5]Specifically, we use end of day data from the last day of an FOMC meeting, which should incorporate any new information released in the policy announcement or SEP projection.

[6]In theory, forecast disagreement and uncertainty surrounding a future outcome are distinct concepts. However, Bloom and many others document that many measures of uncertainty about the future are correlated with the disagreement in private-sector forecasts.

[7]We match the one-year-ahead projections with the appropriate horizon measure of uncertainty. For example, a one-year-ahead interest rate projection in March 2013 refers to the level of the funds rate at the end of 2014. Therefore, we would use a seven-quarter-ahead measure of uncertainty for this observation. The left-hand side reflects the level of uncertainty at the end of the day of an FOMC announcement.

[8]Using selected FOMC dates from 2008 to 2012, Bauer also shows that market-based measures of uncertainty can change after policy announcements.

[9]Ideally, we would like to have information about market participants' expectations about changes in the FOMC's projections the day prior to the FOMC announcement. However, these data are unavailable. Our statistical model assumes that market participants' expectations about future FOMC projections of appropriate policy follow a random walk. Since part of the change in the projections over the past quarter may be anticipated, our coefficient estimate is likely biased towards zero, since the options prices the day prior to the FOMC announcement should already reflect those expectations.

[10]Rudebusch and Williams also argue that central banks should publish interest rate projections.

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