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Abstract

Between August 2011 and December 2012 the Federal Open Market Committee (FOMC) used date-based forward guidance to help stimulate the U.S. economy and promote its objectives of maximum employment and price stability. Some have argued that the formulation of the guidance that the FOMC used may have reduced interest rates primarily by signaling a weak economic outlook rather than by signaling a more accommodative stance of monetary policy. I examine the impact of the date-based guidance, with the principal goal of discerning the extent to which it altered investors' views of the FOMC's policy reaction function. I show that one seemingly straightforward way to address this question—using estimates of the sensitivity of money market futures rates to macroeconomic data surprises—is confounded by the zero lower bound on nominal interest rates, a point that has more general implications for the analysis of the effects of monetary policy at the zero bound. I demonstrate that the problem can be overcome using distributions of investors' short-term interest rate expectations derived from interest rate options. Using PDFs constructed from these options, along with survey measures of macroeconomic surprises, I find the date-based guidance led to a statistically significant and economically meaningful change in investors' perceptions of the FOMC's reaction function. This finding is robust to various regression specifications and the use of alternative options contracts and PDF fitting methodologies.

Keywords: monetary policy, zero lower bound, forward guidance, economic surprises

JEL Classification: E43, E44, E52, E58

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1 Introduction

In the statement released following its August 2011 meeting, the Federal Open Market Committee (FOMC) announced that it "currently anticipates that economic conditions—including low rates of resource utilization and a subdued outlook for inflation over the medium run—are likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013." Although the FOMC had provided some form of forward guidance regarding the future path of its policy rate in each statement since late 2008, this was the first time the language included explicit reference to a calendar date.

The revised guidance prompted significant declines in implied rates on money market futures rates, as market participants revised lower their expected path for the target federal funds rate over the next several years. It also appears to have reduced uncertainty regarding that path, as implied volatilities on options on Eurodollar futures contracts and short-tenor swaptions expiring over the next several years declined substantially following the statement's release. In January 2012, the Committee extended "mid-2013" to "late-2014". As shown in Figure 1, this extension also led to declines in futures rates and interest rate implied volatilities.

As Woodford (2012) highlights, the reaction of futures rates to the announcements could be interpreted in two very different ways. The "date-based" guidance may have been taken as an indication that the Committee expected the economy to remain weak for longer than market participants had been anticipating, leading them to revise down their own expectations for future economic conditions and thus short-term interest rates. Indeed, the August statement included a more pessimistic assessment of the economic outlook than the prior statement had, and stated that that "downside risks to the economic outlook have increased." Alternatively, the guidance

may have led investors to expect a more accommodative stance of monetary policy for a given set of economic conditions—that is, it may have been interpreted as a signal of some change in the FOMC's so-called reaction function. Eggertson and Woodford (2003) discuss why a central bank might wish to adopt an alternative reaction function when near the zero lower bound (ZLB) on short-term nominal interest rates.

The reaction of implied volatilities to the announcements is also consistent with either interpretation. The revelation of information about the FOMC's economic outlook might have reduced market participants' uncertainty about their own forecasts for the economy and short-term rates. Moreover, as highlighted below, at the ZLB a weaker outlook might reduce uncertainty about short-term interest rates by increasing the probability the ZLB will be a binding constraint at future dates. Alternatively, by signaling a change in the FOMC's likely reaction to future economic conditions, the guidance might have reduced uncertainty about the future path of short-term rates, also leading to lower implied volatilities.

Whether the date-based guidance signaled a weaker economic outlook or a change in the FOMC's reaction function has important implications for the likely efficacy of the policy. Perceptions that the Committee's outlook was weaker than previously believed might lower rates but also lead broader financial conditions to tighten in a counterproductive way. On the other hand, perceptions that the Committee would be likely to respond in a different way to economic outcomes and forecasts might ease broad financial conditions, helping to stimulate aggregate demand and promote the FOMC's employment and price stability objectives. Of course, the details of the perceived change in the FOMC's reaction function would determine its precise effect on expectations regarding the future path of the federal funds target rate and Federal

Reserve asset purchases; these expectations would, in turn, would determine the ultimate effect on longer-term interest rates and other asset prices.

This paper examines the extent to which the date-based guidance altered perceptions of one key ingredient in the FOMC's reaction function—the change in policy for a given change in economic conditions. To make this more concrete, think of the FOMC's reaction function as being reasonably well described by a function of the form:

$$i_t = i_t^* + \alpha_t Z_t \qquad (1)$$

where i_t is the nominal policy rate, i_t^* is the neutral policy rate, and Z_t is a vector of state variables that summarize economic conditions. This is just a generalized version of a so-called Taylor rule, in which Z_t would commonly include the (actual or expected) unemployment or output gap and the deviation of (actual or expected) inflation from its target. I try to estimate how the date-based guidance affected market participants' perceptions of α_t. To do so, I estimate the time-varying sensitivity of short-term interest rate expectations to macroeconomic data surprises.

I start by illustrating that a perceived change in α_t should, under "normal" circumstances, change the sensitivity of futures rates to these surprises. However, this identification channel is confounded by the ZLB. In particular, as shown in Swanson and Williams (2013), as the ZLB becomes more binding—in the sense that the perceived probability that the FOMC would set a negative target rate if it could do so increases—futures rates should become less sensitive to economic surprises independent of any change in perceptions of the FOMC's desired policy reaction to evolving economic conditions. Thus, if the date-based guidance or accompanying language in the statements led to a worsened outlook and increased probability of being

constrained by the ZLB at future dates, inference based on the sensitivity of futures rates is likely to be misleading.

Fortunately, the issue posed by the ZLB can be circumvented by using distributions of short-term interest rate expectations derived from interest rate options. In particular, under a plausible set of assumptions, the sensitivity of sufficiently high percentiles of these distributions—for example, the 85th percentile—are not directly affected by the ZLB. Intuitively, the high percentiles allow us to focus on short-term interest rate expectations associated with future states in which the ZLB is not a binding constraint, and thus to cleanly read expectations for the Committee's desired policy response to evolving conditions. Using risk-neutral probability density functions (PDFs) constructed from interest rate caps, along with measures of the surprise components of key U.S. macroeconomic data releases, I estimate the effects of the date-based guidance on perceptions of the FOMC's reaction function. My empirical model uses dummy variables to capture the effects of the introduction and extension of the date-based guidance, controlling for other factors, such as monetary policy uncertainty and the state of the business cycle, which might generate time-variation in the sensitivity to economic surprises.

I find that the introduction of the date-based guidance in August 2011 did indeed lead to a significant reduction in the sensitivity of the risk-neutral percentiles to economic surprises. In particular, the regression point estimates indicate that the "mid-2013" language reduced the sensitivity of rate expectations 6-months to 3-years ahead by 65 to 100 percent. I consider all possible dates for a break in the sensitivity in recent years; the evidence strongly favors August 2011 as the most likely timing of such a break. Moreover, the finding of reduced sensitivity is robust to the inclusion of various control variables and to the use of PDFs derived using alternative options contracts and fitting methodologies. I conclude that the "mid-2013" guidance

substantially altered market participants' views of the FOMC's reaction function. Interestingly, however, I find that the extension from "mid-2013" to "late-2014" at the January 2012 FOMC meeting had no statistically significant effect.[1] One explanation for this is that an extension of the guidance at the January meeting was anticipated by market participants—making its effects difficult to isolate—and the expected timing of the first target rate increase was, at that time, already relatively close to late-2014.[2] It may also be the case that when the referenced date is sufficiently distant, the FOMC's willingness to provide date-based guidance at all matters more than the specific horizon that the guidance covers.

These findings support the view that the FOMC's date-based guidance did more than signal a weaker outlook—it altered perceptions of the Committee's likely reaction to evolving conditions. The resulting reduction in the sensitivity of short-term interest rate expectations might have helped to keep longer-term interest rates anchored at low levels, and perceptions of a changed reaction function may have boosted business and consumer confidence and stimulated demand. On the other hand, the reduced sensitivity might also have lessened the probability that market reactions to economic developments moved longer-term interest rates in a manner consistent with the Committee's view regarding the likely future path of short-term rates. Whether the date-based guidance also affected perceptions of the intercept of the FOMC's reaction function, i_t^*, is beyond the scope of this paper; for analysis of this see Campbell et al. (2012) and Eusepi et al. (2013).

[1] In September 2012 the FOMC extended "late-2014" to "mid-2015". For reasons discussed below I do not include this extension in my empirical analysis. The replacement of the date-based guidance with economic thresholds in December 2012 obviously offers potentially valuable information into the effects of the date-based guidance, but as of the initial writing of this paper in January 2013 it is premature to use my methodology to identify the effects of this change.

[2] Though supported by available survey data, this stands in some contrast to observed declines in futures rate and implied volatilities around the January 2012 statement.

This paper proceeds as follows: Section 2 briefly highlights related research. Section 3 reviews the evolution of the forward rate guidance used by the FOMC since reaching the ZLB in December 2008. Section 4 shows how the sensitivity of futures rates to economic surprises normally reveal information about perceptions of the FOMC's reaction function, highlights how the ZLB clouds that signal, and illustrates how percentiles of distributions derived from interest rate options can be used to circumvent this problem. Section 5 describes the risk-neutral PDFs and economic surprises data used in the analysis. Section 6 presents estimations and results. Section 7 discusses the estimation results and concludes.

2 Related Research

Eggertson and Woodford (2003) show how communicating more explicitly about the future path of short-term interest rates can help to promote a central bank's stabilizations goals when the ZLB is a meaningful constraint. Following on the analysis of Krugman (1998), they consider the consequences of the ZLB for the optimal conduct of monetary policy in the context of an explicit intertemporal equilibrium model. They find that the ZLB represents an important constraint on what monetary policy can achieve, and show that the key to dealing with it is to create the right expectations regarding the way in which monetary policy will be used subsequently, at a time when the ZLB is no longer a binding constraint. They characterize the kind of expectations regarding future policy that it would be desirable to create, and discuss a form of a price-level targeting rule that should bring about the constrained-optimal equilibrium. A key feature of this policy is that, over some period when a standard policy rule would prescribe a positive short-term interest rate, the rate is instead held at zero and is thus relatively less responsive to changes in the outlook than the reaction function in the absence of the ZLB constraint would dictate.

A number of researchers have studied the financial market effects of unconventional monetary policy at the ZLB. However, the overwhelming majority of this research has focused on the effects of the Federal Reserve's large-scale asset purchases. Important papers in this literature include D'Amico and King (forthcoming), Gagnon et al. (2011), Hamilton and Wu (2012), Joyce et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), Li and Wei (2012), and Swanson (2011). Wright (2012) looks at the asset price effects of U.S. monetary policy at the ZLB more generally—without attempting to distinguish between the effects of forward guidance and large-scale asset purchases—using a structural VAR identified by the assumption that monetary policy shocks are heteroskedastic.

Swanson and Williams (2013) use a novel method to estimate time-varying effects of economic surprises on interest rates at the ZLB. Using rolling 1-year window regressions, they find that 1- and 2-year Treasury yields were surprisingly sensitive to economic news throughout 2008-11, despite the federal funds rate being stuck at zero during that period. They also present evidence that time-variation in the effects of economic surprises is related to measures of monetary policy uncertainty. This paper adopts their basic methodology for identifying time-varying effects with a limited number of macroeconomic news observations, but differs from theirs in several key respects. Most fundamentally, I focus on estimating the effects of a particular policy—the date-based guidance used by the FOMC between August 2011 and December 2012—rather than characterizing the change in sensitivity more generally. To isolate the policy's effect from the more general impact of the ZLB, I use interest rate options-implied

PDFs instead of Treasury yields, and regression specifications designed to capture time-varying effects specifically related to the guidance.[3]

Campbell et al. (2012) study the FOMC's forward guidance. They distinguish between two types of forward guidance, which mirror the two interpretations of the reaction to the date-based guidance outlined in the previous section. In particular, they discuss "Odyssean" guidance, which changes private expectations by publicly committing the FOMC to future deviations from its underlying policy rule, and "Delphic" guidance, which encompasses statements that describe only the economic outlook and typical monetary policy stance. They develop a new methodology based on a traditional interest rate policy rule that uses data on federal funds futures and market participants' expectations of future economic conditions to measure Odyssean forward guidance. Their empirical evidence suggests that the public has experience with Odyssean forward guidance, and they investigate the consequences of providing that form of forward guidance in the current environment. My analysis supports the view that the FOMC's date-based guidance was not simply taken by market participants as a declaration of the FOMC's policy intentions based on some fixed reaction function; instead, it altered perceptions of the way the Committee would respond to changes in the outlook.

Moessner and Nelson (2008) examine various aspects of the response of financial markets to forward guidance in the U.S. in an earlier period and in other countries. Using an empirical model similar to mine, they find that the guidance used by the FOMC between 2003 and 2005—guidance which did not include reference to calendar dates—was accompanied by an increase in the sensitivity of 1-year-ahead Eurodollar futures rates to economic surprises.

[3] The interest rate options—like futures rates—provide measures of expected policy rates at fixed future dates, whereas Treasury yields reflect the average expected policy rates over longer horizons. The former afford a clearer view of the effects of monetary policy.

My analysis also connects to an extensive literature on the asset price effects of macroeconomic data surprises, including Beechey (2007), Faust et al. (2007), Gürkaynak et al. (2005), and Rigobon and Sack (2008). However, to my knowledge, mine is the first to examine the impact of economic surprises on measures of the distributions of short-term interest rate expectations derived from interest rate options.

3 Recent Evolution of the FOMC's Forward Guidance

A brief review of the evolution of the FOMC's use of forward guidance on the target federal funds rate provides useful context for the analysis in this paper. The following are the changes the Committee has made to the guidance since the ZLB was reached in December 2008:[4]

- December 2008: Along with reducing the target rate to the ZLB, stated that "weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time".
- March 2009: Changed "some time" to "an extended period".
- November 2009: Elucidated the conditions likely to warrant exceptionally low rates, stating that "economic conditions, including low rates of resource utilization, subdued inflation trends, and stable inflation expectations, are likely to warrant exceptionally low levels of the federal funds rate for an extended period".
- June 2011: Modified the description of conditions likely to warrant low rates, to "including low rates of resource utilization and a subdued outlook for inflation over the medium run".
- August 2011: Replaced "for an extended period" with "at least through mid-2013". This was the Committee's first use of date-based forward guidance.
- January 2012: Replaced "mid-2013" with "late-2014".

[4] All of the language changes came in a statement released at the conclusion of an FOMC meeting. The statements can be found at http://www.federalreserve.gov/monetarypolicy/fomccalendars.htm.

- September 2012: Replaced "late-2014" with "mid-2015". The FOMC also stated that it "expects that a highly accommodative monetary policy will remain appropriate for a considerable time after the recovery strengthens".
- December 2012: Replaced the date-based guidance with thresholds linked to the unemployment rate and projected inflation. In particular, the FOMC stated that it "anticipates that this exceptionally low range for the federal funds rate will be appropriate at least as long as the unemployment rate remains above 6-1/2 percent, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2 percent longer-run goal, and longer-term inflation expectations continue to be well anchored".

While there were three statements in which date-based guidance was introduced or modified—August 2011, January 2012, and September 2012—there is substantial variation in the extent to which market participants anticipated the language changes. Based on news reports, market commentaries and available surveys, the introduction of the date-based guidance in August 2011 appears to have come as a near-complete surprise to market participants. In contrast, as shown in Table 1, surveys of primary dealer economists conducted by the Open Market Desk of the Federal Reserve Bank of New York indicate that respondents assigned very high odds to some strengthening of the forward guidance at the January 2012 and September 2012 meetings.[5,6]

Another key distinguishing feature of the September 2012 statement is that it also announced that the Federal Reserve would purchase agency mortgage-backed securities (MBS) at a pace of $40 billion per month, and that in the absence of a substantial improvement in the labor market

[5] The survey questionnaires and results can be found at http://www.newyorkfed.org/markets/primarydealer_survey_questions.html.
[6] The probability of date-based guidance being introduced at the next meeting was not asked about on the primary dealer survey ahead of the August 2011 meeting, likely a reflection of the fact that it was not a possibility being discussed by market participants at that time.

outlook the Committee would continue its agency MBS purchases and undertake additional purchases. That is, the Committee announced purchases that were explicitly linked to economic conditions, unlike the fixed-size purchase programs with specified end-dates that it had undertaken to that point. Because the extension of the guidance came at the same time as this explicitly state-dependent asset purchase program, I don't include the September 2012 meeting in my regression analysis, and rely instead on the changes made in August 2011 and January 2012 to illuminate the effects of date-based guidance.[7]

In framing my analysis and interpreting the results, it is also worth highlighting the large number of other policy announcements and communications that came contemporaneously with the communications described above. For example, the December 2008 statement was the first official FOMC communication to reference the possibility of purchases of longer-term Treasury securities.[8] The March 2009 statement announced a significant expansion in the Federal Reserve's agency debt and MBS purchases and announced its first round of Treasury purchases. FOMC participants' economic projections were published—as part of the Summary of Economic Projections (SEP)—and Chairman Bernanke held press conferences following the release of a number of the statements. The day of the January 2012 statement was the first time that FOMC participants published projections for the target federal funds rate as part of the SEP, and marked the first publication of the Committee's "Statement on Longer-Run Goals and Policy Strategy". Finally, the September 2012 and December 2012 statements announced open-ended purchases of agency MBS and Treasury securities, respectively.

[7] There are also relatively few observations on economic surprises available following the September 2012 meeting.

[8] Agency debt and MBS purchases had been announced in November 2008, and the possibility of purchases of longer-term Treasury securities had been referenced in a speech by the Chairman on December 1, 2008.

4 Identifying Shifts in the Perceived Reaction Function at the ZLB

In this section I present a stylized model designed to: (1) demonstrate how, in the absence of the ZLB, the sensitivity of futures rates to economic surprises can reveal information about perceptions of the FOMC's reaction function, (2) highlight how the ZLB clouds this signal, and (3) illustrate how percentiles of distributions derived from options prices can be used to circumvent the problem posed by the ZLB.

Identifying Shifts in the Perceived Reaction Function Using Futures Rates

As in the introduction, let i_t denote the time-*t* target for the federal funds rate, given by:

$$i_t = i_t^* + \alpha_t Z_t \qquad (2)$$

where i_t^* is the FOMC's perception of the neutral nominal policy rate, Z_t is a vector of state variables that summarizes the FOMC's perception of current or future economic conditions, and α_t is a vector of coefficients that governs how the FOMC adjusts the target in response to changes in Z_t. This specification takes the form of simple policy rules—often called Taylor rules—that are frequently used in monetary policy analysis. In these rules, the vector Z_t typically includes measures of the unemployment or output gap and of the deviation of inflation from the central bank's target. For simplicity, I assume Z_t and α_t are scalars, and $\alpha_t > 0$.[9]

Let $f'_{j,t}$ denote the time-*t* rate on a futures contract that settles based on the target federal funds rate at *t+j*, where the prime superscript denotes that this is a hypothetical futures rate that would prevail if the ZLB were not a binding constraint or the possibility of reaching it were

[9] For example, Z_t might be the level or growth rate of the nominal GDP gap.

sufficiently remote so as to have no impact on the contract's pricing. If the marginal investor is risk-neutral, this futures rate will equal the mean of the distribution of target rate expectations:

$$f'_{j,t} = E_t\left[i_{t+j}\right] \tag{3}$$
$$= E_t\left[i^*_{t+j} + \alpha_{t+j} Z_{t+j}\right]$$

where $E_t[\cdot]$ is the conditional expectations operator.

Under the plausible assumption that investors' beliefs about i^*_{t+j} are not affected by changes to $E_t\left[Z_{t+j}\right]$, the sensitivity of the futures rate to economic surprises is given by:

$$\frac{\partial f'_{j,t}}{\partial E_t\left[Z_{t+j}\right]} = \hat{\alpha}_{t+j} \tag{4}$$

where $\hat{\alpha}_{t+j}$ is the marginal investor's time-*t* perception of α_{t+j}.[10] A seemingly straightforward way to assess whether perceptions of the FOMC's reaction function were affected by the date-based guidance would be to test for breaks in $\hat{\alpha}_{t+j}$, using observable variables to proxy for changes in $E_t\left[Z_{t+j}\right]$ and controlling or other factors that might generate time-variation.

The Confounding Effects of the ZLB

The ZLB confounds the identification strategy suggested just above. To see how, let i^S_t denote the so-called "shadow rate"—the target rate that the FOMC would set in the absence of a ZLB—which reflects the Committee's desired policy setting. Assume the shadow rate is given by:

[10] The assumption that investors' beliefs about i^*_{t+j} are not affected by changes to $E_t\left[Z_{t+j}\right]$ can be relaxed. As long as the effect of changes in $E_t\left[Z_{t+j}\right]$ on $E_t\left[i^*_{t+j}\right]$ is time-invariant, the results carry through.

$$i_t^s = i_t^* + \alpha_t Z_t \tag{5}$$

Let i_t continue to denote the *actual* target rate. Reflecting the effects of the ZLB, i_t is:

$$i_t = \max(0, i_t^s) \tag{6}$$

Now assume that, conditional on information at time-*t*, the shadow rate i_{t+j}^s is perceived to be normally distributed:

$$i_{t+j|t}^s \sim N(\mu_{j,t}, \sigma_j^2) \tag{7}$$

where $\mu_{j,t} = E_t[i_{t+j}^*] + \hat{\alpha}_{t+j} E_t[Z_{t+j}]$.

Let $f_{j,t}$ denote the futures rate once the assumption that the ZLB can be safely ignored is relaxed; note that the prime superscript has been dropped to distinguish this from the hypothetical futures rate considered above, which ignored the effects of the ZLB. Because of the ZLB, $f_{j,t}$, which is the mean of the distribution of the actual target rate, will be given by:

$$f_{j,t} = [1 - \Phi(\lambda_{j,t})] \cdot \left[\mu_{j,t} + \sigma_j \frac{\varphi(\lambda_{j,t})}{1 - \Phi(\lambda_{j,t})}\right] \tag{8}$$

where $\varphi(\cdot)$ is the probability density function of the standard normal distribution and $\Phi(\cdot)$ is its cumulative distribution function, and $\lambda_{j,t} = -\mu_{j,t}/\sigma_j$.[11]

It can be shown that under the assumptions outlined above, $\partial f_{j,t}/\partial E_t[Z_{t+j}] \in [0, \hat{\alpha}_{t+j}]$ and is monotonically increasing in $\mu_{j,t}$. That is, in the presence of the ZLB, the sensitivity of futures rates to changes in the outlook declines with the mean of the shadow rate distribution. Figure 2

[11] This follows from the fact that the probability that $i_t > 0$ is given by $1 - \Phi(\lambda_{j,t})$, and, conditional on $i_t > 0$, i_t follows a truncated normal distribution.

illustrates these points, plotting $f_{j,t}$ and $\mu_{j,t}$ as functions of $E_t[Z_{t+j}]$ for the values $\hat{\alpha}_{t+j} = 1$, $\sigma_j^2 = 1$, and $E_t[i^*_{t+j}] = 0$.[12] These features of the sensitivity of futures rates to economic surprises mean that, in the presence of the ZLB, communications from the FOMC that prompt declines in $E_t[Z_{t+j}]$ or $E_t[i^*_{t+j}]$ will tend to dampen the sensitivity of futures rates to economic surprises independent of any effect on $\hat{\alpha}_{t+j}$. That is, declines in sensitivity may come about simply because the ZLB becomes a "more binding" constraint. As noted above, the August 2011 statement included a more pessimistic economic assessment than the previous statement, and stated that "downside risks to the economic outlook have increased". Thus, the possibility that one might mistakenly attribute a decline in the sensitivity driven by a more pessimistic outlook to the effects of the date-based guidance seems material.[13]

Using Distribution Percentiles to Identify Shifts

This limitation of futures rates can be overcome using interest rate options, from which percentiles of the perceived distributions of future federal funds rates can be derived. To see how, let $p^s_{x,j,t}$ and $p_{x,j,t}$ denote the *x*'th percentiles of the time-*t* distributions of the *j*-period-ahead shadow and actual rates, respectively. Due to the ZLB:

$$p_{x,j,t} = max(0, p^s_{x,j,t}) \tag{9}$$

[12] There is nothing special about these parameter values; the points hold more generally. Moreover, the same chart could be drawn as a function of $E_t[i^*_{t+j}]$ for given values of $E_t[Z_{t+j}]$ and other parameters.

[13] Separately, the guidance may have been taken as a signal that the FOMC had revised down its collective judgment of the neutral nominal policy rate. This, too, would be problematic for identification based on futures rates.

Because i_t^s is, by assumption, normally distributed, ceteris paribus, an increase (decrease) in its mean, $\mu_{j,t}$ will increase (decrease) any percentile of the distribution by an equal amount:[14]

$$\frac{\partial p_{x,j,t}^s}{\partial \mu_{j,t}} = 1 \tag{10}$$

If x is selected to be sufficiently high, so that $p_{x,j,t} > 0$ over the sample period of interest:

$$\begin{aligned} \frac{\partial p_{x,j,t}}{\partial E_t[Z_{t+j}]} &= \frac{\partial p_{x,j,t}}{\partial \mu_{j,t}} \cdot \frac{\partial \mu_{j,t}}{\partial E_t[Z_{t+j}]} \\ &= \frac{\partial p_{x,j,t}^s}{\partial \mu_{j,t}} \cdot \frac{\partial \mu_{j,t}}{\partial E_t[Z_{t+j}]} \\ &= \hat{\alpha}_{t+j} \end{aligned} \tag{11}$$

where the last equality follows from the fact that $\partial \mu_{j,t} / \partial E_t[Z_{t+j}] = \hat{\alpha}_{t+j}$. As a result, one can identify shifts in $\hat{\alpha}_{t+j}$ by examining how percentiles of the perceived distributions of future rates respond to incoming economic news that alters the outlook. The intuition behind this is that, by looking at the distribution percentiles, one can focus on short-term interest rate expectations associated with states in which the ZLB is not binding and thus can cleanly read market participants' expectations for the Committee's desired policy response to evolving conditions. Figure 3 illustrates the point, plotting $p_{85,j,t}$ and $\mu_{j,t}$ against $E_t[Z_{t+j}]$ for the values of $\hat{\alpha}_{t+j}$, σ_j^2, and $E_t[i_{t+j}^*]$ considered in Figure 2. As long as the 85th percentile is positive, its derivative with respect to $E_t[Z_{t+j}]$ does not depend on the level of $E_t[Z_{t+j}]$ or $E_t[i_{t+j}^*]$.

To preview the core empirical analysis that follows in Section 6, I estimate regression models of the form (I have dropped the *j* subscripts for simplicity):

[14] This depends on the assumption that σ_j^2 is time-invariant.

$$\Delta p_{x,t} = f(X_t)\beta s_t + \varepsilon_t \quad (12)$$

where measures of $p_{x,t}$ are derived from interest rate options prices and s_t are measured surprises for several economic data releases, meant to proxy for changes in $E_t[Z_{t+j}]$. My baseline strategy is to include dummy variables for the introduction of the date-based guidance in August 2011 and its extension in January 2012 within the vector X_t, along with other factors that may generate time-varying sensitivity.

5 Risk-Neutral Percentiles and Economic Surprises Data

Two key data elements are used in the empirical analysis in this paper: (1) percentiles of distributions of expectations regarding future federal funds rates, constructed from interest rate options prices, and (2) measures of macroeconomic surprises—the difference between the expected and actual values for various data releases—constructed using survey forecasts.

Risk-Neutral PDFs

The baseline PDFs used are constructed by staff at the Federal Reserve Board. The measure is non-parametric and is derived from out-of-the-money interest rate caps and floors; for robustness, I also use PDFs constructed from options on Eurodollar futures using an alternative methodology. However, prior to August 2011 the available expiries on Eurodollar futures options generally extended out only two years, and so these contracts provide more limited information on changes in sensitivity at horizons of interest.

An interest rate cap is a portfolio of European call options, or "caplets", on 3-month LIBOR rates. These options provide protection against rising interest rates and as a result the prices at

which caplets with different expiry dates and strike rates trade reveal information about the probabilities investors assign to different interest rate outcomes.

With enough caps one can recover pricing information on the constituent caplets, in a manner similar in spirit to extracting forward interest rates from a yield curve. Following Breeden and Lizenberger (1978) one can then construct the risk-neutral PDF for a given expiry, *j*, by twice differentiating the function for the price of the caplets expiring at *j* with respect to strike. In order to generate a twice differentiable price function the Board staff follows Shimko (1993). In particular, for each expiry, implied volatility is regressed on a quadratic function of strikes, and the fitted values from this regression are substituted into Black's formula for pricing caplets.[15]

It is worth emphasizing that the resulting PDFs are risk-neutral and, in addition to revealing information about the actual probabilities market participants assign to future short-term interest rate outcomes, are affected by the demand for exposure to those outcomes for hedging or speculation. As a result, they do not generate pure measures of the percentiles. Nonetheless, if the sensitivity of options risk premiums to economic surprises is time-invariant—or at least was unaffected by the date-based guidance—the fact that the risk-neutral and actual, or "physical", PDFs differ should not present problems for the analysis in this paper. Moreover, long-term yields are affected by both short-term interest rate expectations and risk premiums, and so policymakers may care as much about the effects of their policy on risk-neutral measures as on physical measures.

This analysis uses distributions derived from interest rate caps with horizons from 1 to 4 years and strikes ranging from 1 to 14 percent. The data are available from Bloomberg starting

[15] The procedure described produces PDFs of future 3-month LIBOR rates. To generate PDFs of federal funds rates, Svensson LIBOR and federal funds rate curves are fit and the difference between them is used to adjust the strikes on the interest rate caps.

in 2005. However, because there are significant gaps in the price data prior to January 2007, I start my estimation samples in January 2007.[16]

Figure 4 plots the risk-neutral probabilities of the federal funds rate being less than ½ percent 4, 8, 12, and 16 quarters ahead. These probabilities have risen significantly in recent years, and increased notably following the August 2011 FOMC statement. Their high levels and the sharp increases around the introduction of the date-based guidance affirm the relevance of the identification challenge posed by the ZLB that was discussed in the previous section.

Figure 5 plots the risk-neutral 85th percentiles of the federal funds rate 4, 8, 12, and 16 quarters ahead. The 85th percentiles have remained significantly above 0 at horizons beyond 4 quarters, which, in light of the discussion in the previous section, suggests they can be used to identify changes in perceptions of the FOMC's reaction function. The baseline analysis of changes in sensitivity uses these 85th percentiles at quarterly horizons from 2 to 16 quarters ahead.[17]

Economic Surprises

The measure of economic surprises used is derived from the expected and actual values for a set of key U.S. macroeconomic data releases. I measure surprises as the difference between the published value of a given economic release and the median expectation for the release taken from Bloomberg surveys of financial market institutions and professional forecasters. A key feature of the Bloomberg survey is that forecasts can be updated until the night before the release, so the forecasts should incorporate essentially all available information at the time the data are published. For robustness, I also conduct the analysis using expectations taken from

[16] Data is missing in certain spots thereafter; for example, a 3-month period in fall/winter 2008.
[17] For technical reasons I exclude the 1-quarter-ahead percentiles.

Action Economics (formerly Money Market Services) surveys and find the key results described in the next section hold. Further details on both surveys can be found in Swanson and Williams (2013) and in Gürkaynak et al. (2005). The actual values are the real-time (i.e., unrevised) vintage of the data. Following the literature on economic surprises, in the regressions I normalize the surprises by dividing each by its sample standard deviation, and on dates on which a particular variable is not released I set the surprise for that variable that day to zero.[18]

The regressions include surprises related to 13 economic releases that have been used extensively in analysis of the asset price effects of economic surprises—for example, Beechey (2007), Gürkaynak et al. (2005), Rigobon and Sack (2008), Faust et al. (2007), and Swanson and Williams (2013). The releases are: capacity utilization, consumer confidence, core CPI, durable goods, industrial production, initial claims for unemployment benefits, ISM manufacturing, leading economic indicators, new home sales, nonfarm payrolls, core PPI, real GDP, and retail sales excluding autos. Table 2 presents summary statistics on the surprises for these releases over various sample periods relevant to the analysis.

6 Estimation and Results

Unconditional Volatility

As a preliminary step, I first examine the effects of the date-based guidance on the unconditional volatility of the 85th percentiles, using the following regression equation:

$$\Delta p^2_{85,j,t} = \psi_j(1 + \gamma_{1,j} dum_{t,2013} + \gamma_{2,j} dum_{t,2014}) + \varepsilon_{j,t} \quad (13)$$

[18] The normalization facilitates comparison of the relative effects of surprises across releases, since the resulting regression coefficients capture the effects of a one-standard deviation surprise for each release.

where $\Delta p^2_{85,j,t}$ is the squared daily change in the 85th percentile ("percentile volatility"), $dum_{t,2013}$ and $dum_{t,2014}$ are dummy variables that take the value one following the FOMC's introduction of the "mid-2013" and "late-2014" guidance, and $\varepsilon_{j,t}$ is an error term. The coefficient ψ_j captures the average squared daily change in the period preceding the introduction of the date-based guidance. The coefficients $\gamma_{1,j}$ and $\gamma_{2,j}$ capture the effects of the date-based guidance, expressed as percentages of the pre-guidance volatility.[19] A value of -1 implies the guidance fully damped the pre-guidance volatility, whereas a value of 0 implies no effect. I estimate the equation for $j = 2, 3, \ldots, 16$, over the period January 1, 2007 to December 12, 2012, using nonlinear least squares with Newey-West standard errors.

Table 3 displays the results. The pre-guidance 85th percentile volatilities lie between 27 and 492 basis points—indicating standard deviations between 5 and 22 basis points—and are increasing in j and always highly significant. With the introduction of the mid-2013 guidance, the percentile volatilities for horizons out to 4 years fell by 30 to 100 percent, with the magnitude of the decrease generally declining in j. Following the late-2014 guidance, percentile volatility for horizons of 10 quarters and beyond was further reduced by roughly 20 to 40 percent.

Sensitivity to Economic Surprises

The regression results above clearly indicate that the unconditional volatilities of the 85th percentiles were significantly lower following the date-based guidance. However, these declines may in part reflect the effects of a reduction in the variance of economic shocks. Indeed, as seen in Table 2, the standard deviation of surprises for almost all of the 13 releases considered here was lower in the periods following the introduction of the date-based guidance than before.

[19] In this regression equation the impact of the late-2014 guidance relative to the volatility in the period immediately preceding its first use is given by $\gamma_{2,j}/(1+\gamma_{1,j})$.

To control for this effect, I next estimate the sensitivity to economic surprises ("percentile sensitivity") using the following regression model:

$$\Delta p_{85,j,t} = \delta_j + f(X_{j,t}) \sum_{i=1}^{I} \beta_{i,j}\, s_{i,t} + \varepsilon_{j,t} \tag{14}$$

$$f(X_{j,t}) = 1 + \gamma_{1,j} dum_{t,2013} + \gamma_{2,j} dum_{t,2014}$$

where $\Delta p_{85,j,t}$ is the daily change in the 85th percentile, $dum_{t,2013}$ and $dum_{t,2014}$ are as described above, and $\varepsilon_{j,t}$ is again an error term. The variable $s_{i,t}$ denotes the surprise component of the *i*'th economic release at time-*t*, constructed as described in the previous section. Recall that these surprises are normalized to have unit standard deviation, so the coefficient $\beta_{i,j}$ captures the effect of a one-standard deviation shock to the *i*'th economic surprise on the *j*-quarter-ahead percentile in the pre-guidance period. Importantly these effects are allowed to vary across economic releases and horizons. As in the unconditional volatility regressions, $\gamma_{1,j}$ and $\gamma_{2,j}$ capture the effects of the date-based guidance, expressed as percentages of the pre-guidance sensitivity. Importantly, in this set-up the effects of economic releases are restricted to scale up or down by a common proportion, though that proportion can vary with the expectations horizon. This restriction is useful since, with the relatively short sample, identifying changes in sensitivity for individual releases may be difficult to do with any precision. The basic formulation is taken from Swanson and Williams (2013), who provide further justification for the restriction and test it empirically, finding that it is very consistent with the response of Treasury yields to surprises.

I estimate the equation for $j = 2, 3, \ldots, 16$, over the period January 1, 2007 to December 12, 2012, using non-linear least squares with Newey-West standard errors. Following convention in the literature on the asset price effects of economic surprises, the sample is now limited to days

on which data on at least one of the macroeconomic variables was released.[20] Table 4 displays results for *j = 4, 8, 12,* and *16*; results are broadly similar for the other horizons, not shown. Figure 6 plots the point estimates and 90 percent confidence intervals for $\gamma_{1,j}$ and $\gamma_{2,j}$ for all horizons.

The effects of the mid-2013 guidance are clear. The estimated coefficient at each horizon is negative, and the estimates are significant at the 5 percent level out to 3 years. The point estimates for horizons out to 3 years are between -0.66 and -1, and for each of these the hypothesis that the coefficient is equal to -1 cannot be rejected at standard significance levels. That is, one cannot reject the hypothesis that the introduction of the date-based guidance in August 2011 led the percentiles at these horizons to become completely unresponsive to incoming macroeconomic news.

On the other hand, none of the estimates of the late-2014 coefficient are statistically significant. The point estimates are small and positive at horizons out to 3 years (between 0.01 and 0.14), and negative thereafter. It is somewhat unsurprising that there was no further decline in percentile sensitivity with the extension of the guidance in January 2012, as the estimates of the coefficient on the mid-2013 dummy variable imply that for many horizons there was no sensitivity left to be reduced. I discuss other possible interpretations of this result in Section 7.

As seen in Table 4, when statistically significant the $\beta_{i,j}$ coefficients have the expected sign, in that surprises that reflect stronger-than-expected real activity or higher-than-expected inflation lead to an increase in the 85th percentiles. Similar to findings from other studies of economic surprises, nonfarm payrolls generally has the largest effects: a one-standard deviation surprise to

[20] Limiting the sample in this manner does not have any material impact on the results.

nonfarm payrolls tends to increase the 85th percentile of the distributions out to 3 years by 6 to 9 basis points. Initial claims and retail sales ex autos are significant at each horizon, while capacity utilization, consumer confidence, core CPI, and core PPI are significant for some horizons. These results, and in particular the estimates on mid-2013 that lie near -1, imply that monetary policy was expected to violate the Taylor principle that, to stabilize the economy, central banks must raise short-term nominal interest rates more than one-for-one in response to higher inflation. As Davig and Leeper (2007) show, however, stabilizing policy can satisfy the Taylor principle in the long run even while deviating from it substantially for brief periods, or modestly for prolonged periods.

Other Possible Break-dates

The structural break dates in the regressions above were selected based on the timing of key Federal Reserve policy communications. Nevertheless, it is possible that the significance of the mid-2013 dummy variable is picking up a break in the sensitivity that occurred at some other point in the sample. To consider this possibility, I estimate the following regression model:

$$\Delta p_{85,j,t} = \delta_j + f(X_{j,t}) \sum_{i=1}^{I} \beta_{i,j}\, s_{i,t} + \varepsilon_{j,t} \tag{15}$$

$$f(X_{j,t}) = 1 + \gamma_{j,\tau} dum_{t,\tau}$$

where $dum_{t,\tau}$ is a dummy variable that takes the value one on all dates after τ. I estimate the model for all τ within the middle 80 percent of the sample running from January 1, 2007, to December 12, 2012.

Figure 7 plots the F-statistics for $\gamma_{j,\tau}$ for $j = 2, 4, 8,\ldots, 16$. For j between 4 and 10—that is, the horizons for which there are statistically significant breaks in sensitivity in the regressions presented above—the maximum value for the F-statistic is for a break right around August 2011. For more distant horizons, the maximum occurs between August 2011 and January 2012. Put differently, when I allow for a single break in the sensitivity at some *unknown* date, I find that the most likely date for this break for horizons between 1 year and 2½ years is almost precisely at the time the "mid-2013" guidance was introduced. Based on the critical values from Andrews (1993), if one were searching for a break at an unknown date one would reject the null hypothesis of no break at the 1 percent significance level for all horizons out to 16 quarters.

Additional Robustness Checks

Next, I control for other possible sources of time-variation in the percentile sensitivities by incorporating two additional factors into the regression model above. The first is a proxy for uncertainty about future monetary policy, which among other things could capture uncertainty about the parameter $\hat{\alpha}_{t+j}$ from Section 4. Swanson and Williams (2013) show that monetary policy uncertainty explains some of the time-varying effects of economic surprises on Treasury yields. I measure this uncertainty as the difference between the 85th and 50th percentiles of the risk-neutral PDFs. I use this rather than the variance of the risk-neutral distribution or implied volatility of at-the-money interest rate options for the same reason that I use percentiles rather than futures rates—to avoid the mechanical effects of the ZLB. The second additional factor is meant to capture possible business cycle variation in percentile sensitivity. I measure the state of the business cycle using the Aruoba-Diebold-Scotti (ADS) business conditions index, which

tracks real business conditions at a daily frequency.[21] To isolate the effects of these variables unrelated to the date-based guidance, I first regress each on a constant and the two guidance dummy variables and then include the residuals in the extended regression, so that:

$$f(X_{j,t}) = 1 + \gamma_{1,j} dum_{t,2013} + \gamma_{2,j} dum_{t,2014} + \gamma_{3,j} \overline{width}_{85,j,t} + \gamma_{4,j} \overline{ads}_t \qquad (16)$$

where $\overline{width}_{85,j,t}$ and $\overline{ads}_t$ are the orthagonalized measures of monetary policy uncertainty and the business cycle.[22]

Table 5 displays the results of these regressions for *j = 4, 8, 12,* and *16*; again, the results are broadly similar for other horizons, not shown. The newly incorporated variables are often significant, with an increase in monetary policy uncertainty associated with an increase in percentile sensitivity at horizons out to 2½ years, and the results indicate some pro-cyclicality in percentile sensitivity at medium-term horizons. Most importantly, all of the key results regarding the effects of the date-based guidance and of individual economic surprises that are described above also hold in this extended model.

Finally, I examine the robustness of the results described above to the use of a different set of interest rate options and a different PDF fitting methodology. In particular, I construct risk-neutral PDFs from options on Eurodollar futures using an alternative non-parametric fitting technique.[23] These options have fixed settlement dates, generally out to 2 years. In constructing

[21] The ADS incorporates data from the following (seasonally adjusted) economic indicators: weekly initial jobless claims; monthly payroll employment, industrial production, personal income less transfer payments, manufacturing and trade sales; and quarterly real GDP. For details, see http://www.philadelphiafed.org/research-and-data/real-time-center/business-conditions-index/. This draft of the paper uses the current vintage of the ADS index, rather than the real-time vintages.

[22] At present the standard errors presented do not account for the fact that generated regressors are used in the second-stage regression.

[23] The underlying on these options are Eurodollar futures contracts. The payoff on the futures contract depends on the level of 3-month LIBOR on the contract's settlement date.

the PDFs for a given settlement date I apply the butterfly portfolio method described in Kitsul and Wright (2012), using price data for call options on all available strikes and assuming that the support of the distribution is the set of mid-points between available strikes. The price data is from Bloomberg, with the range of available strikes extending from 0.25 to 8 percent. For comparison to the cap-implied distributions, I linearly interpolate the fixed-settlement date PDFs to construct a time series of the 85th percentile of the 6-quarter-ahead Eurodollar option-implied PDF. Figure 7 plots this against the 6-quarter-ahead cap-implied 85th percentile. The two series are broadly similar, though there is a notable level difference which arises from the fact that Eurodollar option-implied PDF is for 3-month LIBOR, which has different term, credit, and liquidity characteristics than federal funds. Regardless, Table 6 shows that the key results for the cap-implied 6-quarter-ahead PDF also hold for the Eurodollar option-implied PDF.

7 Discussion and Summary

This paper examined the impact of the date-based forward guidance on the path of the target federal funds rate that the FOMC used between August 2011 and December 2012. I showed that one seemingly straightforward way to evaluate how this formulation of the guidance altered market participants' views on the Committee's reaction function is confounded by the zero lower bound (ZLB) on nominal interest rates, which makes it difficult to separate the mechanical constraints of the ZLB from changing views about the Committee's desired policy setting. I showed, however, that this problem can be overcome using PDFs of investors' short-term interest rate expectations constructed from interest rate options.

Using regression analysis with dummy variables to capture the effects of the FOMC's changing date-based guidance and controlling for other relevant factors, I found that the

introduction of the date-based guidance in August 2011 led to a statistically significant and economically meaningful reduction in the sensitivity of the risk-neutral percentiles to economic surprises. In particular, my point estimates indicate that the "mid-2013" language reduced the sensitivity of expectations 6 months to 3 years ahead by 75 to 100 percent. This finding stands up to the consideration of structural breaks on other dates, and is robust to the use of alternative options contracts and PDF construction methodologies and to alternative model specifications. I conclude that the date-based guidance did indeed substantially alter investors' views about the FOMC's reaction function.

However, I find that the extension from "mid-2013" to "late-2014" in January 2012 had no significant effect on investor perceptions of the FOMC's reaction function. The most obvious explanation for this is that the "mid-2013" language had already almost fully damped the sensitivity of short-rate expectations at fairly distant horizons. Separately, as shown in Table 1, the survey of primary dealer economists conducted ahead of the January 2012 meeting shows that market participants placed a median probability of 70 percent on some strengthening of the forward guidance at the meeting, with written comments provided indicating that some dealers explicitly noted their expectation that the calendar date referenced by the FOMC would be pushed out. Moreover, as shown in Figure 9, respondents at that time assigned an average probability of 56 percent to the first target rate increase occurring in the second half of 2014 or later—that is, they were already pricing in a significant probability that the federal funds rate would remain within its current target range "at least through late-2014". In contrast, in the survey conducted ahead of the August 2011 meeting, respondents assigned an average probability of only about 30 percent to the first target rate increase occurring in the second quarter of 2013 or later. A third explanation comes from FOMC participants' interest rate

projections, which were published for the first time on the day of the January 2012 FOMC meeting. These projections showed that, while the FOMC collectively anticipated that the federal funds rate would remain at exceptionally low levels at least through late 2014, 8 of the 17 participants (there were 2 vacant spots at that time) judged that, under appropriate policy, the target at year-end 2014 would be 1 percent or higher. Only 6 participants judged that under appropriate policy the federal funds rate would still be within the 0 to ¼ percent range at that point. These projections prompted a lot of rumination among market participants over the date-based guidance—for example, about the Committee's commitment to the guidance, the differences between individual and collective judgments, whether "exceptionally low" included rates as much as a percentage point above the current target range, and how quickly the FOMC would raise the target once it started to tighten. A final, intriguing possible explanation for the apparently limited effect of the extension to late-2014 is that, when the referenced date is sufficiently distant, the willingness to provide date-based guidance at all may matter more than the specific horizon that the guidance covers.

Separately, some might think that it is critical to allow for the possibility that the date-based guidance introduced some asymmetry into the FOMC's reaction function, muting the response to stronger-than-expected but not weaker-than-expected macroeconomic surprises. It is true that there should be asymmetry in the sensitivity of *futures rates* to macroeconomic surprises because of the ZLB, as Figure 2 and the discussion in Section 4 make clear. But it is less obvious that there should be an asymmetry in the sensitivity of percentiles. Indeed, naïve incorporation of asymmetry is illogical, as it implies that positive and negative surprises that exactly offset each other are expected to alter the stance of monetary policy. Instead, there would need to be some

interaction between the asymmetric sensitivity and the prevailing level of rates; estimating a model which allows for this over the relatively short sample available would be challenging.

My findings confirm that the FOMC's date-based forward guidance did more than signal a weaker outlook—it altered perceptions of the Committee's likely reaction to evolving conditions. The resulting reduction in the sensitivity of short-term interest rate expectations might have helped to keep longer-term interest rates anchored at low levels, and perceptions of a changed reaction function may have boosted business and consumer confidence and stimulated demand. On the other hand, the reduced sensitivity might also have lessened the probability that market reactions to economic developments moved longer-term interest rates in a manner consistent with the Committee's view regarding the likely future path of short-term rates, raising the risk of sharp adjustments in longer-term rates when these views converge.

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Table 1: Median Probability Assigned to a Change in the Forward Guidance

Meeting Survey	At the Next FOMC Meeting	Within the Next 3 Meetings	Within 1 Year	Within 2 Years
Used to signal future policy easing or to ease policy				
August 2011	n/a	n/a	20%	25%
January 2012	70%	n/a	80%	90%
September 2012	75%	n/a	85%	90%
Used to signal future policy tightening or to tighten policy				
August 2011	n/a	n/a	37%	80%
January 2012	0%	n/a	15%	50%
September 2012	0%	n/a	5%	30%

Note: From surveys of primary dealer economists conducted by the Open Market Desk of the Federal Reserve Bank of New York the week prior to FOMC meetings. "n/a" indicates that a question was not included on the survey. Results are published at http://www.newyorkfed.org/markets/primarydealer_survey_questions.html

Table 2: Economic Surprises Summary Statistics

		1/1/2007 to 8/9/2011			8/10/2011 to 1/25/2012			1/26/2012 to 12/12/2012		
Economic Release	**Unit**	**Mean**	**Std Dev**	**Obs**	**Mean**	**Std Dev**	**Obs**	**Mean**	**Std Dev**	**Obs**
Capacity Utilization	percent	-0.1	0.4	55	0.1	0.2	6	-0.2	0.4	10
Consumer Confidence	index	-0.6	5.4	55	0.4	9.1	5	0.0	4.8	11
CPI ex Food & Energy	percent	0.0	0.1	55	0.0	0.1	6	0.0	0.1	10
Durable Goods	percent	-0.4	2.2	55	0.9	0.8	5	-0.5	3.3	11
Industrial Production	in percent	-0.1	0.5	55	0.1	0.3	6	-0.3	0.5	10
Initial Claims	in thousands	2.7	21.2	235	-2.3	13.9	24	0.8	16.3	46
ISM Manufacturing	index	0.4	2.2	56	0.6	1.1	5	-0.4	1.5	11
Leading Indicators	in percent	0.0	0.2	55	0.2	0.2	5	0.0	0.2	11
Nonfarm Payrolls	in thousands	-17.5	71.7	54	-4.2	58.5	5	-2.5	59.8	11
New Home Sales	in thousands	-11.8	50.0	55	-0.8	10.9	5	-0.5	14.3	11
PPI ex Food & Energy	in percent	0.0	0.2	55	0.0	0.2	6	0.0	0.2	10
Real GDP (Advanced)	in percent	0.1	0.7	19	0.1		1	-0.1	0.2	4
Retail Sales ex Autos	in percent	-0.1	0.6	55	0.0	0.4	6	0.0	0.3	10
Total Obs				859			85			166

Note: Surprises are measured as the actual release value minus the median expectation taken from the last MMS/Action Economics survey conducted ahead of the data release.

Table 3: Volatility of Cap-Implied 85th Percentiles

Dep Var:	Cons		Mid-2013		Late-2014			
Quarters Ahead	Coef	StdErr	Coef	StdErr	Coef	StdErr	Adj-R	Obs
2-quarters	27.10 ***	4.27	-0.97 ***	0.01	0.00	0.01	0.02	1145
3-quarters	43.94 ***	6.92	-0.96 ***	0.01	-0.01	0.01	0.02	1145
4-quarters	63.15 ***	9.86	-0.96 ***	0.01	-0.01	0.01	0.02	1145
5-quarters	83.84 ***	12.25	-0.95 ***	0.01	-0.01	0.01	0.02	1145
6-quarters	104.64 ***	13.60	-0.93 ***	0.02	-0.01	0.02	0.03	1145
7-quarters	123.79 ***	13.97	-0.91 ***	0.02	-0.02	0.02	0.03	1145
8-quarters	139.46 ***	13.80	-0.87 ***	0.03	-0.04	0.03	0.04	1145
9-quarters	151.79 ***	13.50	-0.81 ***	0.05	-0.07	0.05	0.05	1145
10-quarters	161.08 ***	13.23	-0.73 ***	0.06	-0.11 *	0.06	0.05	1145
11-quarters	166.94 ***	12.95	-0.62 ***	0.08	-0.17 **	0.08	0.04	1145
12-quarters	170.30 ***	12.89	-0.49 ***	0.10	-0.25 **	0.10	0.04	1145
13-quarters	187.42 ***	14.77	-0.37 ***	0.12	-0.33 ***	0.12	0.03	1145
14-quarters	238.65 ***	21.90	-0.31 ***	0.12	-0.39 ***	0.12	0.02	1145
15-quarters	337.45 ***	36.76	-0.33 ***	0.11	-0.39 ***	0.11	0.02	1145
16-quarters	492.07 ***	61.53	-0.42 ***	0.11	-0.33 ***	0.10	0.02	1145

Note: The dependent variables are the squared daily changes in the 85th percentiles of the risk-neutral PDFs of federal funds rates, measured in basis points. Mid-2013 is a dummy variable that takes the value one in the period after August 9, 2011. Late-2014 is a dummy variable that takes the value one in the period after January 25, 2012. The sample period is January 1, 2007 to December 12, 2012. Regression use Newey-West standard errors. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. See the text for further details.

Table 4: Effects of Forward Guidance on Sensitivity to Economic Surprises

Baseline Model

	4-quarters		8-quarters		12-quarters		16-quarters	
Explanatory Variable	**Coef**	**Std Err**	**Coef**	**Std Err**	**Coef**	**Std Err**	**Coef**	**Std Err**
Constant	0.04	0.27	0.42	0.40	0.77	0.46	0.94	0.75
Capacity Utilization	2.89	3.01	8.51	6.82	8.04 *	4.74	1.05	4.20
Consumer Confidence	-0.29	1.36	0.59	1.96	1.62	2.16	5.67 **	2.67
CPI ex Food & Energy	1.40	1.14	2.28	1.58	2.04	1.90	4.50 *	2.38
Durable Goods	1.71	1.78	0.28	2.04	-0.84	1.92	5.16	3.22
Industrial Production	0.54	3.32	-5.10	5.70	-6.93	4.82	0.24	5.83
Initial Claims	-1.72 ***	0.50	-2.06 **	0.86	-2.53 ***	0.93	-3.50 **	1.51
ISM Manufacturing	1.66 *	0.91	2.67	1.80	1.55	2.45	2.00	2.71
Leading Indicators	1.03	0.92	2.01	1.77	0.90	1.93	-2.60	5.35
Nonfarm Payrolls	7.82 **	3.12	8.80 ***	2.75	5.78 ***	2.22	0.16	3.99
New Home Sales	0.47	1.02	-0.25	1.48	-1.24	1.31	-3.87 *	2.22
PPI ex Food & Energy	0.23	1.25	2.59 *	1.46	3.16 **	1.43	3.49	2.46
Real GDP (Advanced)	1.98	1.73	-0.54	2.08	0.66	2.50	5.90	3.73
Retail Sales ex Autos	2.30 ***	0.53	2.45 **	1.10	5.40 ***	1.80	6.21 ***	2.11
Mid-2013	-0.99 ***	0.11	-0.91 ***	0.13	-0.66 *	0.34	-0.40	0.68
Late-2014	0.05	0.12	0.04	0.17	0.12	0.39	-0.89	0.73
Adj-R	0.12		0.08		0.04		0.02	
Obs	599		599		599		599	

Note: The dependent variables are the daily changes in the 85th percentiles of the risk-neutral PDFs of federal funds rates, measured in basis points. Economic surprise variables are constructed using Bloomberg median expectations, and are normalized to have unit standard deviation. Mid-2013 is a dummy variable that takes the value one in the period after August 9, 2011. Late-2014 is a dummy variable that takes the value one in the period after January 25, 2012. The sample period is January 1, 2007 to December 12, 2012. Regression use Newey-West standard errors. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. See the text for further details.

Table 5: Effects of Forward Guidance on Sensitivity to Economic Surprises

Extended Model

	4-quarters		8-quarters		12-quarters		16-quarters	
Explanatory Variable	**Coef**	**Std Err**	**Coef**	**Std Err**	**Coef**	**Std Err**	**Coef**	**Std Err**
Constant	-0.07	0.25	0.32	0.40	0.74	0.45	0.65	0.74
Capacity Utilization	1.08	2.59	6.18	5.57	6.52 *	3.95	1.03	2.42
Consumer Confidence	0.32	1.76	0.35	2.16	-0.48	2.25	0.71	1.64
CPI ex Food & Energy	1.41	1.09	2.86 *	1.54	2.75	1.77	0.38	0.92
Durable Goods	2.39	1.48	0.66	1.76	-1.50	1.79	0.04	0.27
Industrial Production	4.46	3.39	-1.04	4.89	-2.62	4.16	-1.64	3.83
Initial Claims	-1.92 ***	0.57	-1.91 **	0.94	-2.72 ***	0.88	-0.29	0.69
ISM Manufacturing	2.51	1.55	3.66 **	1.69	2.98	1.85	-0.49	1.28
Leading Indicators	0.77	1.16	0.50	1.82	0.20	1.80	0.94	2.02
Nonfarm Payrolls	8.10 ***	2.91	8.49 ***	2.31	5.26 **	2.08	0.42	1.07
New Home Sales	0.77	1.07	0.49	1.32	-0.34	0.77	0.08	0.27
PPI ex Food & Energy	-0.17	1.39	1.81	1.34	2.13	1.42	0.81	1.89
Real GDP (Advanced)	3.00	2.51	-1.87	2.62	-0.16	4.47	0.26	0.62
Retail Sales ex Autos	2.58 ***	0.51	2.73 ***	1.03	6.79 ***	2.11	0.55	1.27
Mid-2013	-0.95 ***	0.10	-0.89 ***	0.14	-1.04 ***	0.35	3.94	11.84
Late-2014	0.01	0.12	0.07	0.18	0.45	0.40	-2.16	6.35
Width	2.51 ***	0.40	1.16 ***	0.40	0.63	0.54	19.89	48.09
ADS Index	0.04	0.11	0.22 **	0.11	0.28 ***	0.07	-3.93	9.36
Adj-R	0.19		0.10		0.05		0.03	
Obs	599		599		599		599	

Note: The dependent variables are the daily changes in the 85th percentiles of the risk-neutral PDFs of federal funds rates, measured in basis points. Economic surprise variables are constructed Bloomberg median expectations, and are normalized to have unit standard deviation. Mid-2013 is a dummy variable that takes the value one in the period after August 9, 2011. Late-2014 is a dummy variable that takes the value one in the period after January 25, 2012. Width is the difference between the 85th and 50th percentiles of the risk-neutral PDFs, measured in percentage points and orthogonalized to the dummy variables. ADS is the Aruoba-Diebold-Scotti business conditions index, orthagonalized to the dummy variables. The sample period is January 1, 2007 to December 12, 2012. Regression use Newey-West standard errors. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. See the text for further details.

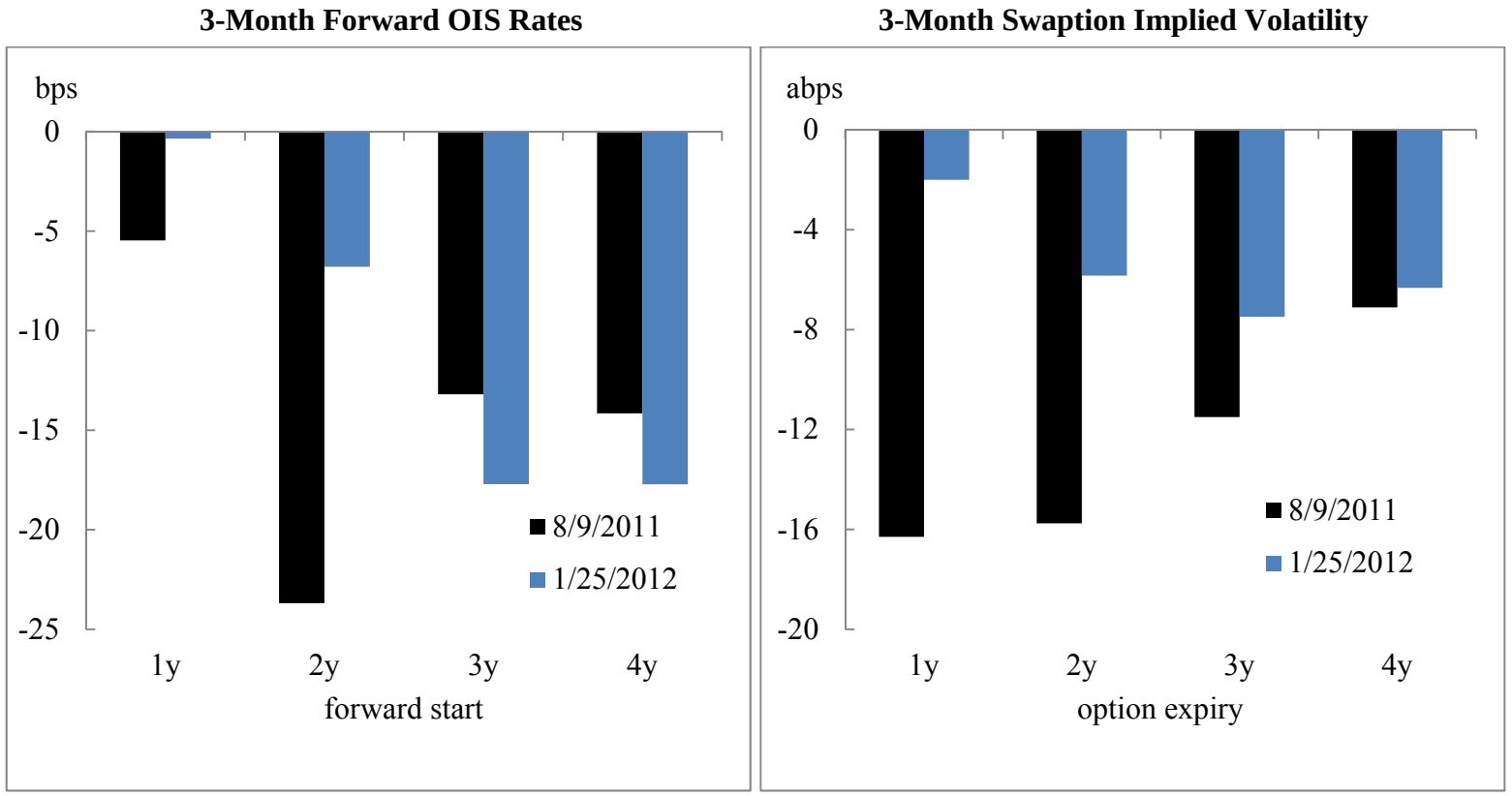
Table 6: Effects of Forward Guidance on Sensitivity to Economic Surprises

Cap-Implied vs. ED Options-Implied 85th Percentiles

	Cap-Implied				ED Futures Options-Implied			
	Baseline Model		Extended Model		Baseline Model		Extended Model	
Explanatory Variable	Coef	Std Err	Coef	Std Err	Coef	Std Err	Coef	Std Err
Constant	0.20	0.35	0.07	0.33	0.00	0.37	0.01	0.38
Capacity Utilization	6.52	5.80	4.73	4.93	6.51 *	3.51	6.23	3.84
Consumer Confidence	-0.09	1.68	0.39	1.91	-2.13	2.96	-1.89	4.50
CPI ex Food & Energy	1.73	1.43	2.02	1.31	2.99	1.91	2.70	2.13
Durable Goods	1.46	2.02	1.92	2.06	-4.49	2.96	-4.95	3.15
Industrial Production	-2.37	5.07	1.17	4.67	2.74	3.25	-0.54	4.61
Initial Claims	-2.07 ***	0.68	-1.89 **	0.75	-3.27 ***	0.97	-3.56 ***	1.29
ISM Manufacturing	2.45 *	1.30	3.08 *	1.61	2.77 **	1.41	2.80	2.01
Leading Indicators	1.66	1.39	0.51	1.49	1.35	1.35	1.32	1.83
Nonfarm Payrolls	9.47 ***	3.35	9.70 ***	2.89	7.93 ***	2.65	9.64 ***	2.95
New Home Sales	0.10	1.32	0.45	1.25	0.02	1.12	0.25	1.12
PPI ex Food & Energy	1.22	1.47	0.68	1.41	0.94	1.67	1.90	2.24
Real GDP (Advanced)	0.63	1.84	0.15	2.46	1.60	4.08	0.31	3.27
Retail Sales ex Autos	2.28 ***	0.78	2.41 ***	0.74	5.14 **	2.12	5.55 **	2.69
Mid-2013	-0.95 ***	0.10	-0.91 ***	0.10	-0.62 ***	0.22	-0.71 ***	0.21
Late-2014	0.02	0.12	0.00	0.13	-0.28	0.24	-0.23	0.22
Width			1.56 ***	0.42			0.44	0.36
ADS Index			0.11	0.12			-0.17	0.36
Adj-R	0.11		0.15		0.16		0.12	
Obs	599		599		599		599	

Note: The dependent variables are the daily changes in the 85th percentiles of the 6-quarter-ahead risk-neutral PDFs of federal funds rates, constructed from either interest rate caps or from options on Eurodollar futures, measured in basis points. Economic surprise variables are constructed Bloomberg median expectations, and are normalized to have unit standard deviation. Mid-2013 is a dummy variable that takes the value one in the period after August 9, 2011. Late-2014 is a dummy variable that takes the value one in the period after January 25, 2012. Width is the difference between the 85th and 50th percentiles of the risk-neutral PDFs, measured in percentage points and orthogonalized to the dummy variables. ADS is the Aruoba-Diebold-Scotti business conditions index, orthagonalized to the dummy variables. The sample period is January 1, 2007 to December 12, 2012. Regression use Newey-West standard errors. ***, **, and * denote significance at the 1, 5, and 10 percent levels, respectively. See the text for further details.

Figure 1: One-Day Changes around Date-Based Guidance



Source: JPMorgan

Figure 2: Shadow Rate Mean and Futures Rate

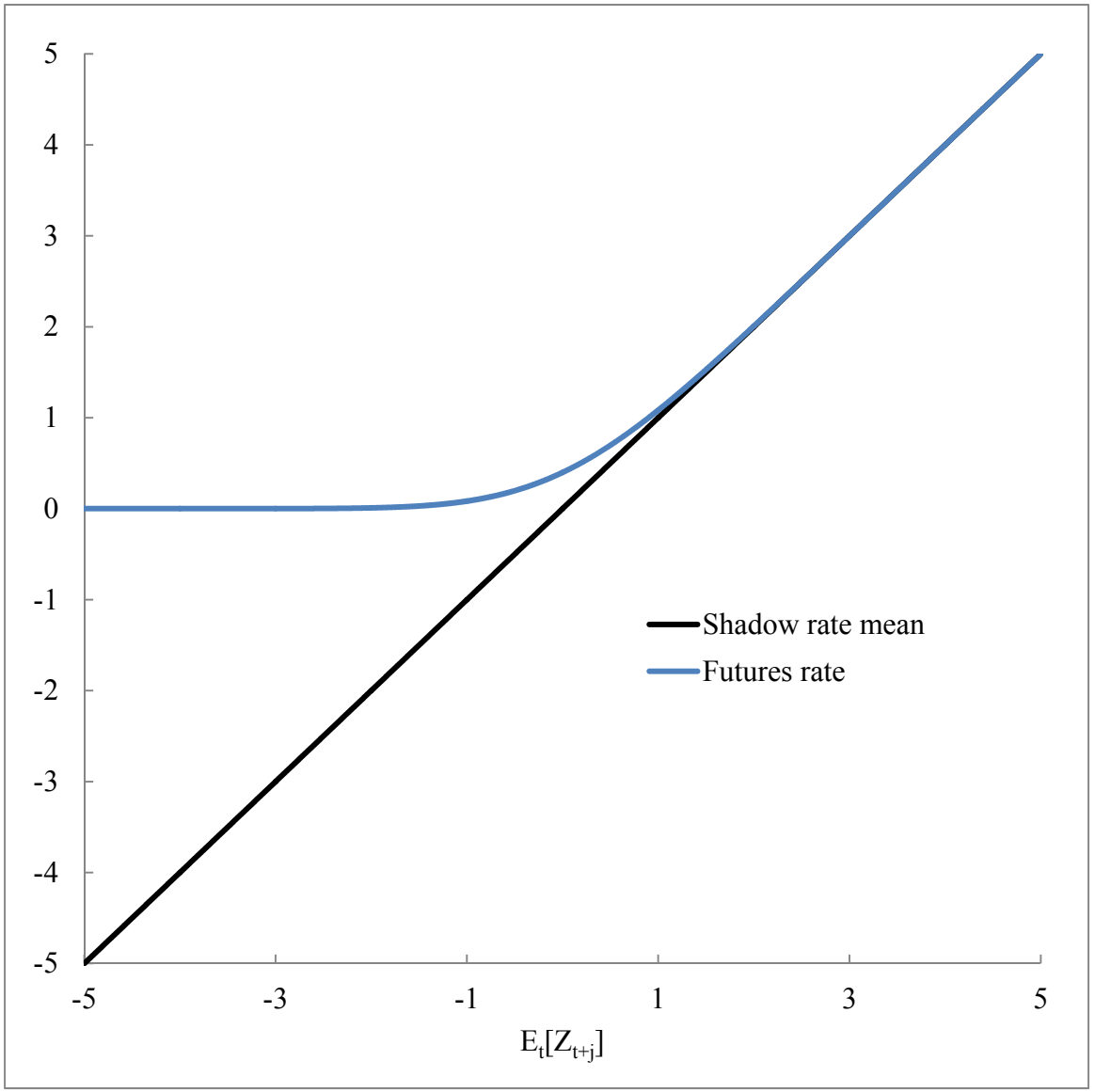


Figure 3: Shadow Rate Mean and 85th Percentile

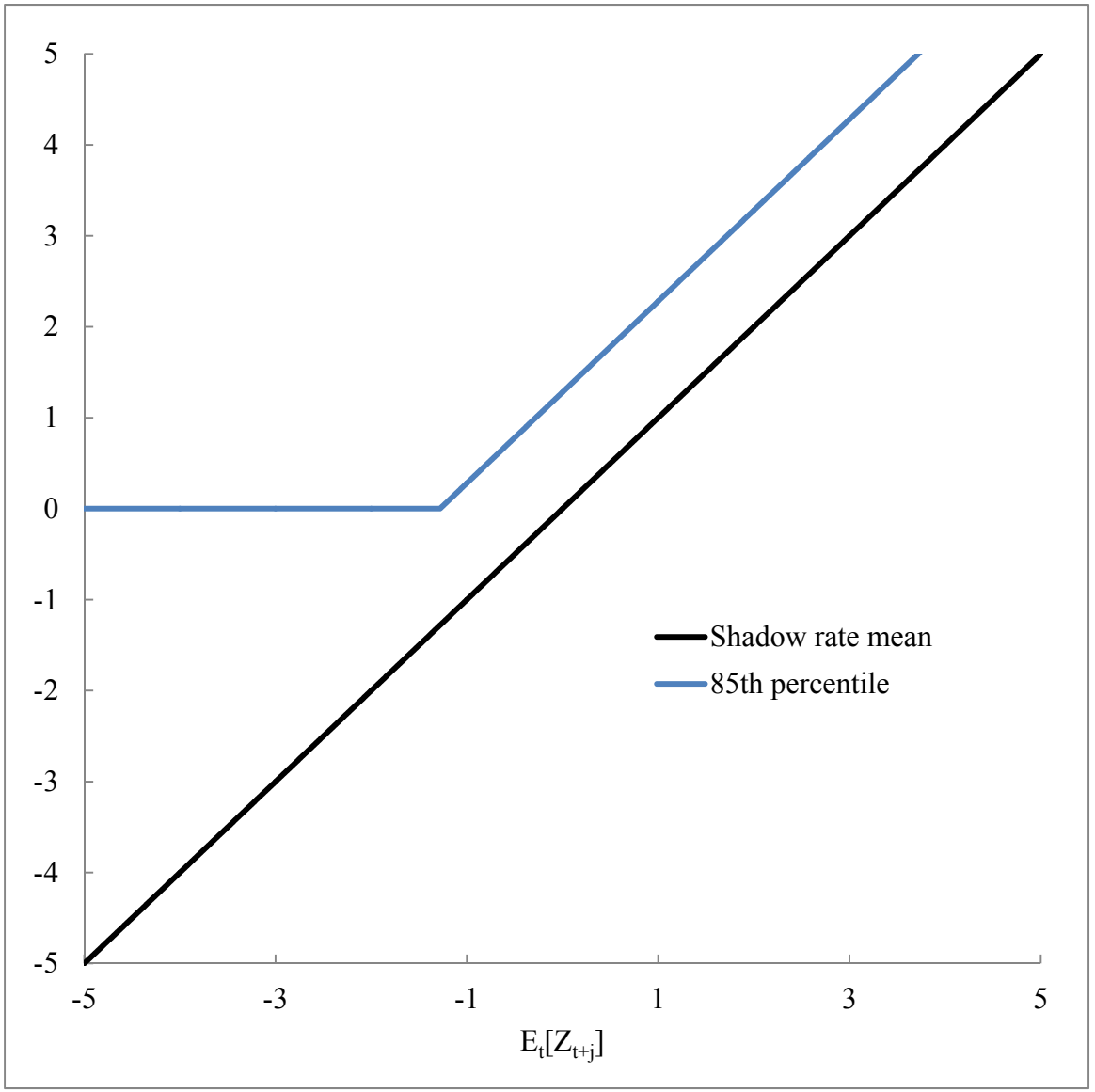
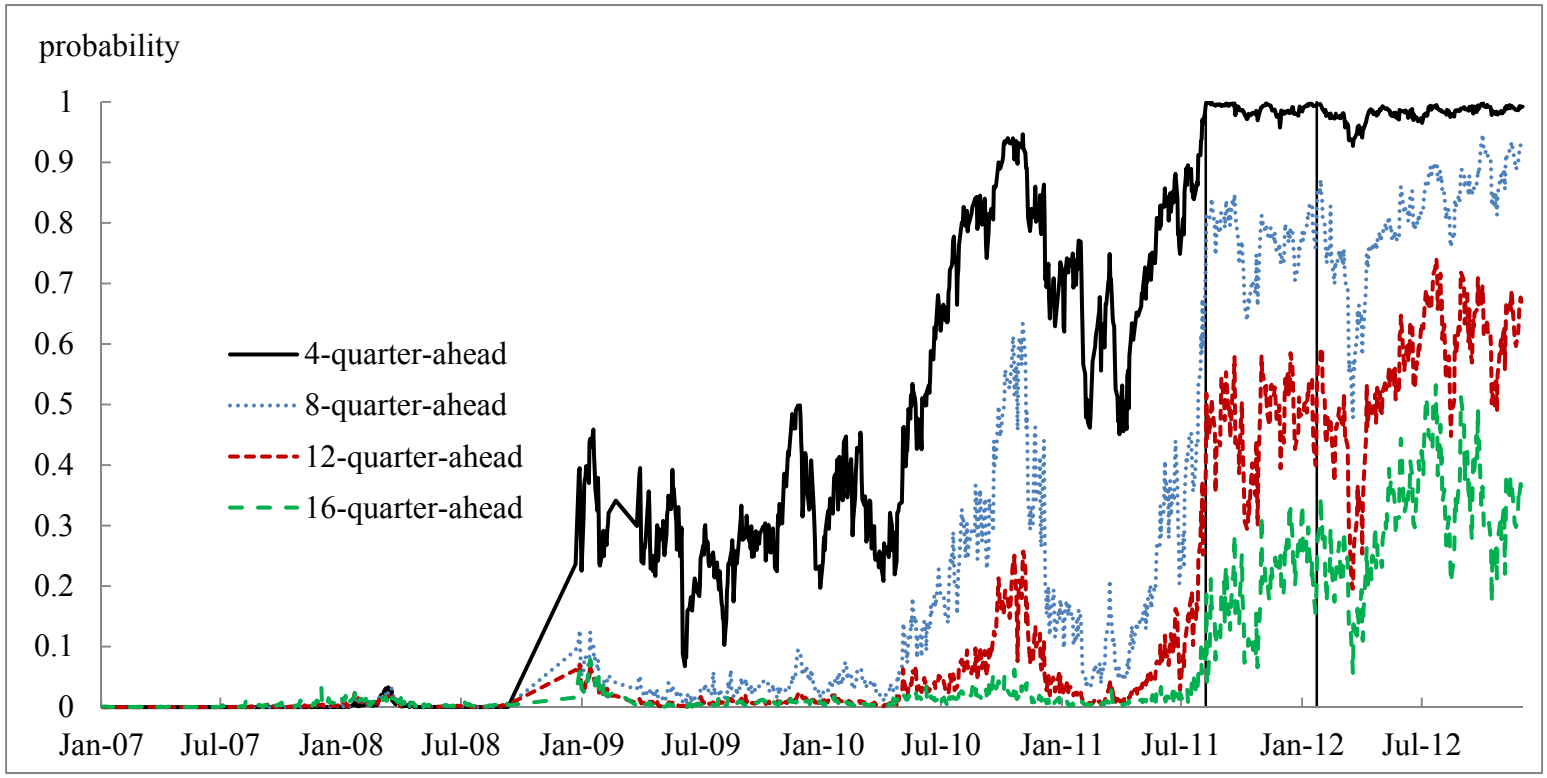
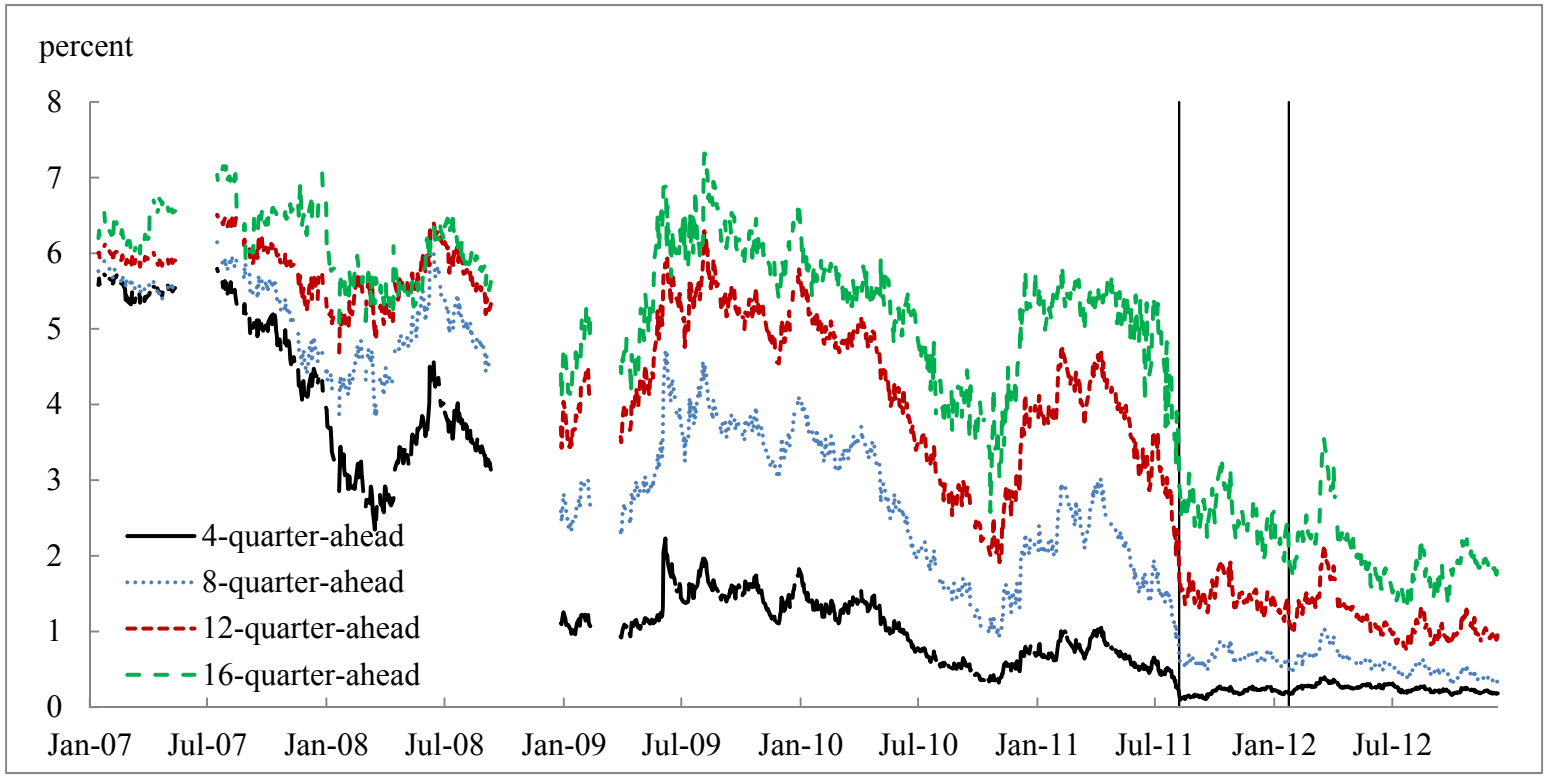


Figure 4: Cap-Implied Probabilities of Federal Funds Rates Below ½ Percent



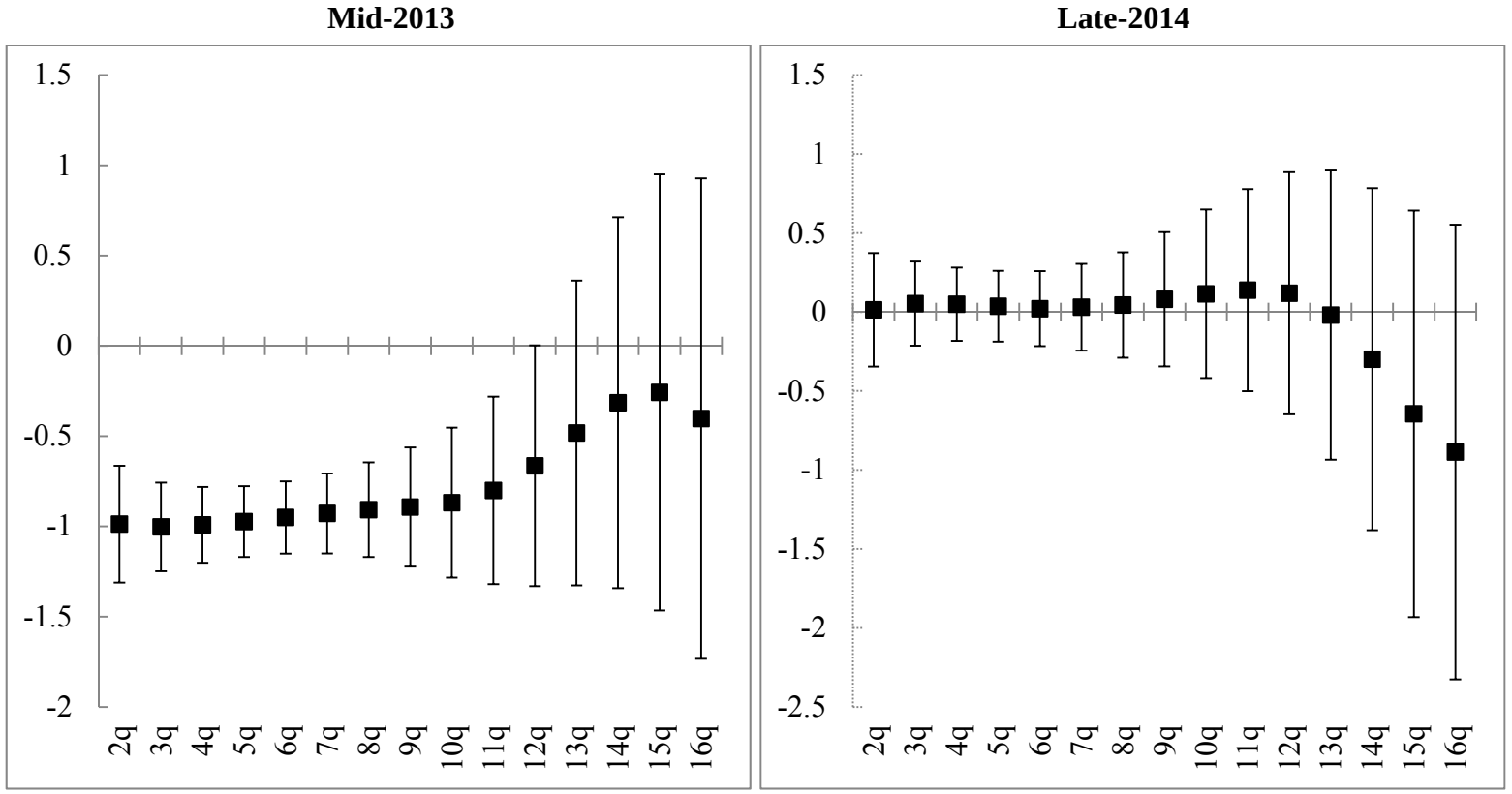
Note: The black vertical lines denote the timing of the FOMC's initial use of the "mid-2013" and "late-2014" forward guidance, respectively.

Figure 5: 85th Percentiles of Cap-Implied Distributions



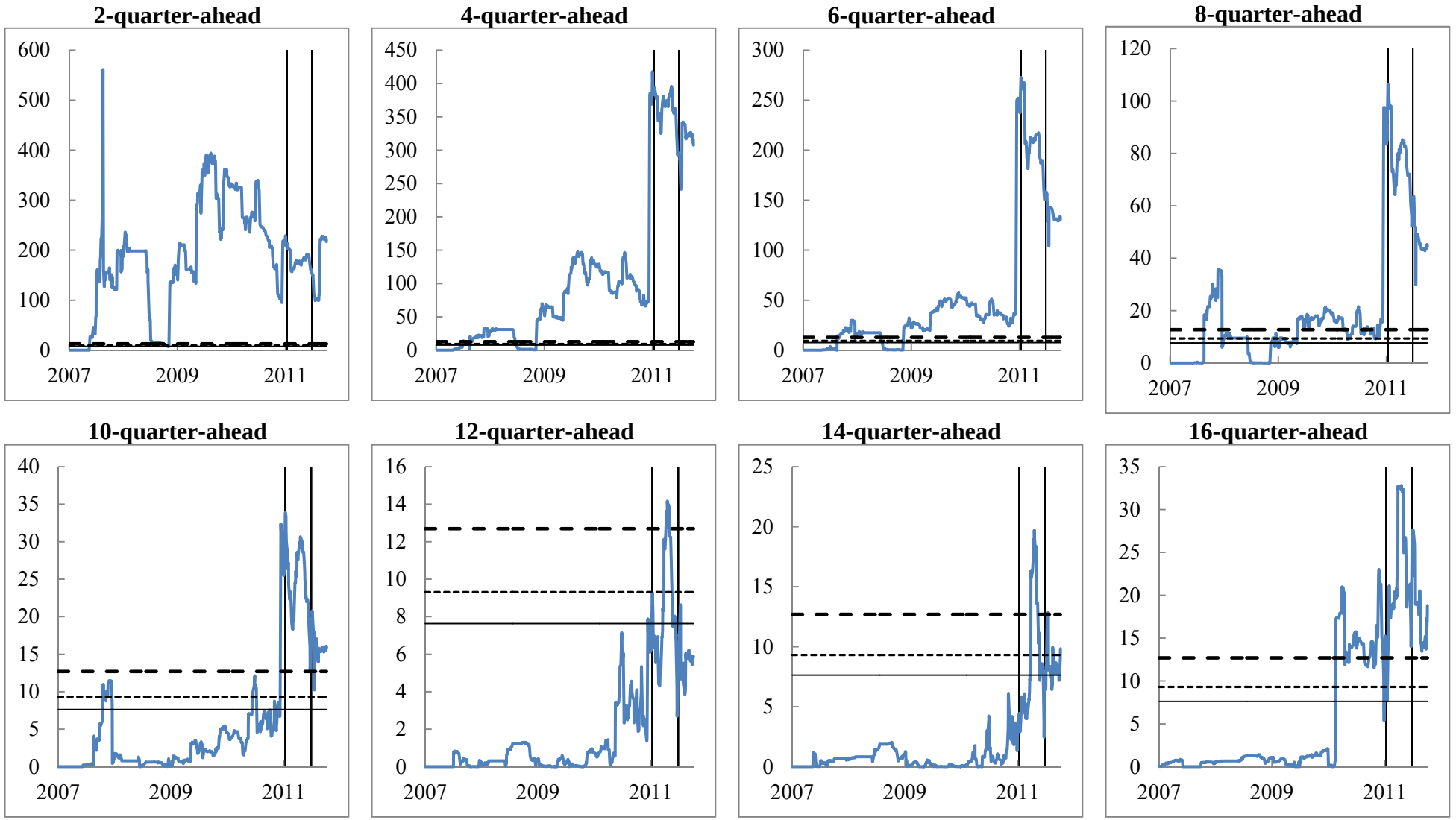
Note: The black vertical lines denote the timing of the FOMC's initial use of the "mid-2013" and "late-2014" forward guidance, respectively.

Figure 6: Coefficient Point Estimates and 90 Percent Confidence Intervals



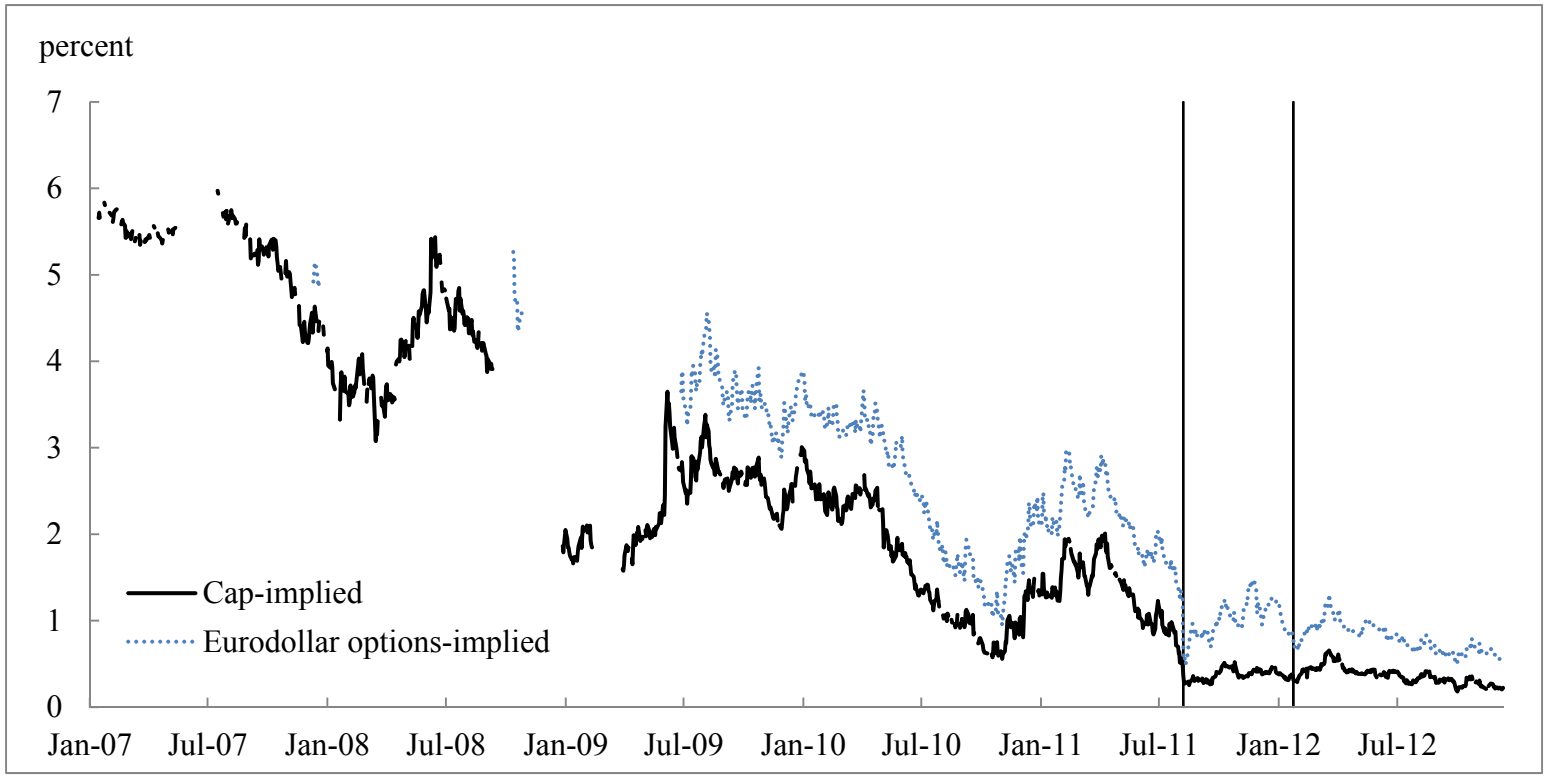
Note: Point estimates and 90 percent confidence intervals from regressions of the daily changes in the 85th percentiles of the risk-neutral PDFs of federal funds rates, allowing for a break in the sensitivity with the introduction of the mid-2013 and late-2014 guidance in August 2011 and January 2012, respectively. X-axis is the horizon of the risk-neutral distribution, in quarters. The sample period is January 1, 2007 to December 12, 2012. Newey-West standard errors. See the text for details.

Figure 7: Percentile Sensitivity Break-date Search



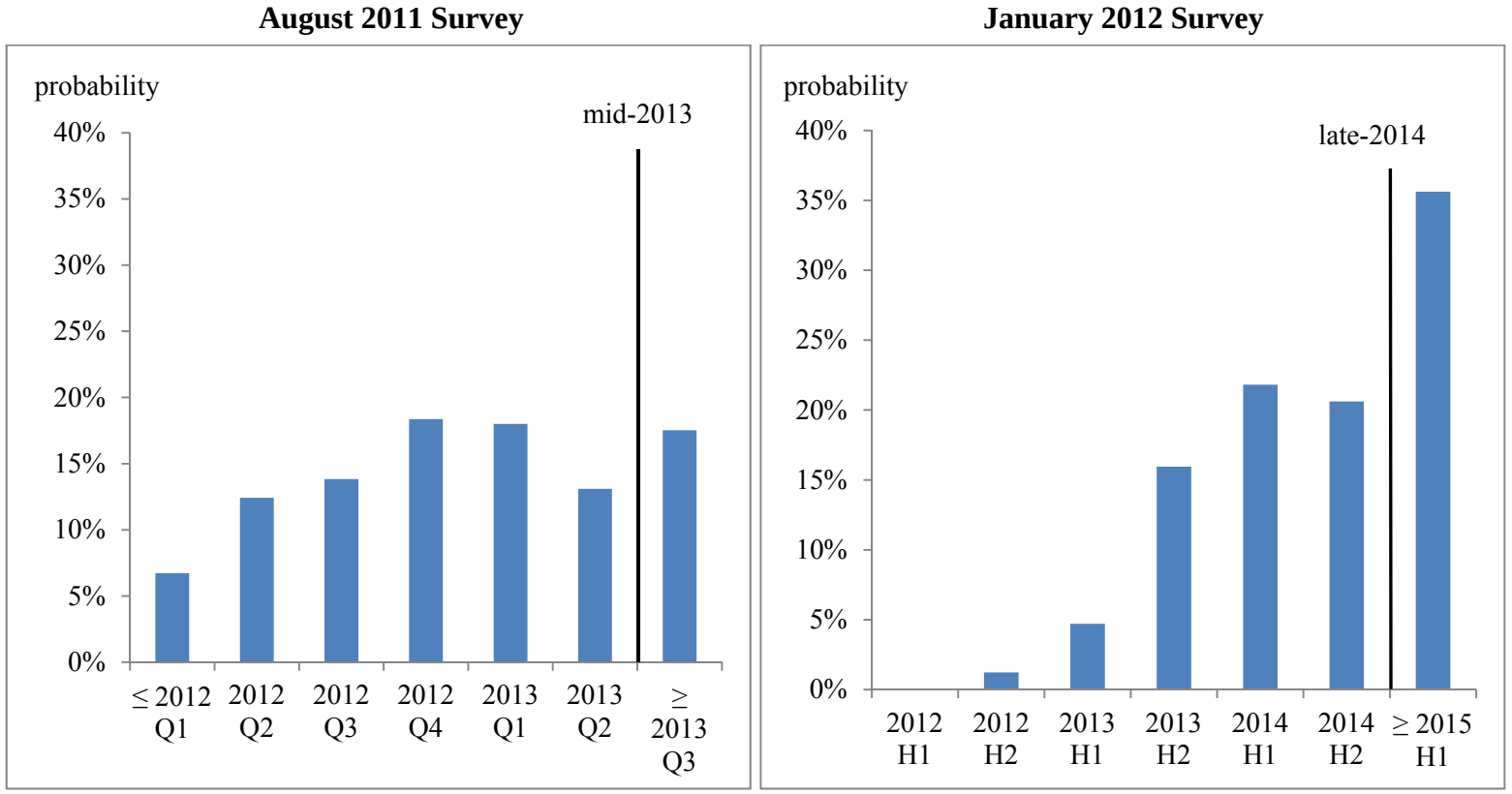
Note: Plots show the F-statistic from the test of a structural break in the percentile volatility on each date in the middle 80 percent of the sample period January 1, 2007 to December 12, 2012. The black vertical lines denote the timing of the FOMC's initial use of the "mid-2013" and "late-2014" forward guidance, respectively. Newey-West standard errors. See the text for details. The black horizontal lines denote the 1, 5, and 10 percent significance levels based on Andrews (1993).

Figure 8: Cap-Implied vs. Eurodollar Options-Implied 85th Percentiles 6-Quarters Ahead



Note: The black vertical lines denote the timing of the FOMC's initial use of the "mid-2013" and "late-2014" forward guidance, respectively.

Figure 9: Average Probability of Timing of the 1st Increase to the Target Funds Rate



Note: The black lines are meant to roughly denote "mid-2013" and "late-2014". From surveys of primary dealer economists conducted by the Open Market Desk of the Federal Reserve Bank of New York the week prior to FOMC meetings. Results are published at http://www.newyorkfed.org/markets/primarydealer_survey_questions.html