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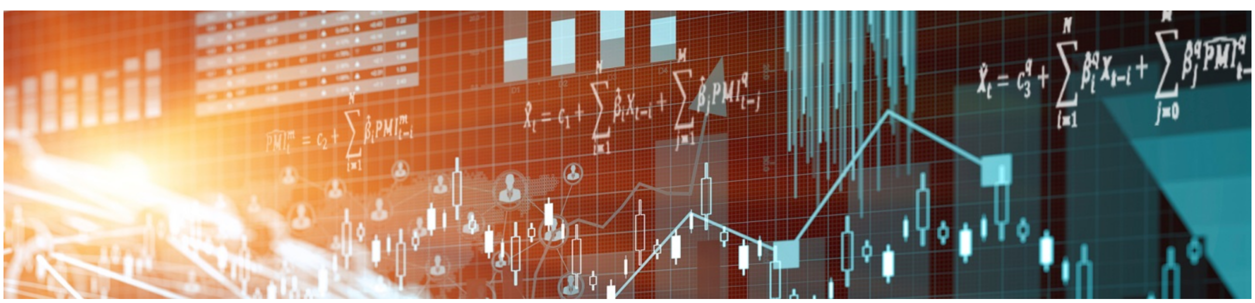
Monetary Policy Uncertainty: A Tale of Two Tails



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Bank of Canada Staff Working Paper 2018-50

September 2018

Monetary Policy Uncertainty: A Tale of Two Tails

by

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ISSN 1701-9397

Acknowledgements

The views expressed in this paper are those of the authors and do not represent the views of the Bank of Canada. We thank Philippe Andrade, Michael Bauer, Efrem Castelnouvo, Laurent Ferrara, Bruno Feunou, Marc Giannoni, Alejandro Justiniano, Oleksiy Kryvtsov, Andy Levin, Barbara Rossi, Dongho Song, Stephen Williamson, Jonathan Wright, and participants of seminars at the Bank of Canada, Banque de France, Reserve Bank of Australia, National Science Foundation, and University of Girona and at the 2018 Barcelona GSE Summer Forum on Uncertainty in Macroeconomics and Finance; 2018 FRB Conference on Risk, Uncertainty, and Volatility; 2017 Barcelona GSE Summer Forum on Time Series Econometrics and Applications for Macroeconomics and Finance; 2017 Melbourne Institute Macroeconomic Policy Meetings; 2017 St. Louis Fed Central Bank Forecasting Conference; and 2017 Midwest Econometrics Group for useful comments and suggestions. Alexander Lam provided excellent research assistance. Former versions of the paper were circulated under "Asymmetries in Monetary Policy Uncertainty: New Evidence from Financial Forecasts."

Abstract

We document a strong asymmetry in the evolution of federal funds rate expectations and map this observed asymmetry into measures of monetary policy uncertainty. We show that periods of monetary policy tightening and easing are distinctly related to downside (policy rate is higher than expected) and upside (policy rate is lower than expected) uncertainty. Downside monetary policy uncertainty decreases over time, while upside uncertainty remains rather stable, reflecting the asymmetry in the behavior of the expectational errors—a finding that we attribute to changes in the conduct of monetary policy. We show that this behavior cannot be entirely explained by uncertainty in macroeconomic fundamentals: the asymmetry remains even when we control for macroeconomic uncertainty, emphasizing the importance of monetary policy implementation. Finally, we assess the macroeconomic effects of monetary policy uncertainty. We find that the effects are non-linear and conditional on the economy being in an easing or tightening regime. Though uncertainty is, in general, recessionary, its effects are stronger in a monetary easing regime relative to a tightening one.

Bank topics: Transmission of monetary policy; Monetary policy communications; Econometric and statistical methods; Business fluctuations and cycles; Uncertainty and monetary policy
JEL codes: C18; C32; E02; E43; E52

Résumé

Dans cette étude, nous rendons compte d'une forte asymétrie dans l'évolution des attentes à l'égard du taux des fonds fédéraux, asymétrie que nous faisons correspondre à des mesures de l'incertitude concernant la politique monétaire. Nous montrons que les périodes de resserrement monétaire sont liées à une incertitude « négative » (taux directeur supérieur aux attentes) et celles d'assouplissement monétaire, à une incertitude « positive » (taux directeur inférieur aux attentes). L'incertitude négative concernant la politique monétaire diminue au fil du temps, tandis que l'incertitude positive reste plutôt stable. Cette constatation reflète le comportement asymétrique des erreurs de prévision, que nous attribuons aux modifications de la conduite de la politique monétaire. Nous montrons que l'incertitude liée aux fondamentaux macroéconomiques ne permet pas à elle seule d'expliquer ce comportement : l'asymétrie demeure, même lorsque nous tenons compte de l'incertitude macroéconomique, ce qui fait ressortir l'importance de la mise en œuvre de la politique monétaire. Enfin, nous évaluons les effets macroéconomiques de l'incertitude entourant la politique monétaire. Selon nos résultats, les effets, non linéaires, dépendent de la phase de détente ou de resserrement de la politique monétaire. Même si, en général, l'incertitude a des effets récessifs, ces derniers sont plus sensibles en période d'assouplissement qu'en période de resserrement monétaire.

Sujets : Transmission de la politique monétaire; Communications sur la politique monétaire; Méthodes économétriques et statistiques; Cycles et fluctuations économiques; Incertitude et politique monétaire
Codes JEL : C18; C32; E02; E43; E52

Non-Technical Summary

During the last few decades, central banks across the globe came to recognize the potentially valuable role that transparency can play in stabilizing the economy. For example, the Federal Reserve in the US started releasing a statement describing policy actions regarding the effective policy interest rate. Further, forward guidance, an explicit communication from the Federal Reserve about the likely future course of monetary policy, has been one of the important tools of unconventional monetary policy in the post-financial crisis zero lower bound (ZLB) period of policymaking.

It has been established that interest rate predictability has improved with increasing central bank transparency and better communication strategies, as the public could form more accurate expectations about the current and future path of interest rates (as a function of economic conditions). This, in turn, is thought to translate into lower levels of monetary policy uncertainty, which typically has an expansionary effect as it encourages investment and spending.

Motivated by the distinct link of interest rate predictability and monetary policy uncertainty, we rely on the accuracy of expectations of the policy rate to characterize monetary policy uncertainty. As a basis for our analysis, we employ federal funds rate forecast errors for several horizons implied by the Blue Chip Financial Forecasts (BCFF). For robustness, we also consider revisions in federal funds futures prices around Federal Open Market Committee (FOMC) announcement dates – the so-called "surprise." It turns out that positive and negative forecast errors occur in clusters and are tightly linked to the behavior of the policy rate. Namely, negative (positive) forecast errors dominate during the episodes of monetary easing (tightening). Moreover, the conditional (historical) forecast error distributions become tighter over time indicating that the forecast error dispersions decreased over time. Strikingly, this decline is nearly entirely driven by the fact that the right tail (associated with positive forecast errors and tightening episodes) shortens over time, while the left tail (associated with negative forecast errors and easing episodes) shows no apparent downward trend and exhibits mainly cyclical variations. We attribute this behavior to increasingly better-communicated policy actions from the Federal Reserve during monetary tightenings.

To measure monetary policy uncertainty, we summarize the asymmetry in the forecast error evolution using a metric that quantifies uncertainty in terms of probabilities and, therefore, allows us to take the asymmetric tail behavior into account. More specifically, the proposed measure quantifies the ex-ante likelihood of the observed outcome, measured by the probability associated with being below or above the realized forecast error, at every point in time. Moreover, our metric of monetary policy uncertainty combines both left- and right-tail behaviors of forecast errors to a single joint measure. This simplifies the analysis of the economic effects of monetary policy uncertainty. Since our uncertainty measure is based on the forecast errors, it inherits all the documented asymmetries and time-varying properties associated with the forecast errors.

Lastly, we investigate whether there is non-linear propagation of monetary policy uncertainty shocks and whether it matters for macroeconomic dynamics. We assess the macroeconomic implications of monetary policy uncertainty by analyzing its effects conditional on the economy being in a monetary tightening or easing cycle. We find recessionary effects that are stronger in easing relative to tightening. After purging our measure for macroeconomic uncertainty, effects generally get dampened, but non-linearities remain.

"Central Banking [has been] traditionally surrounded by a peculiar mystique... The mystique thrives on a pervasive impression that Central Banking is an esoteric art. Access to this art and its proper execution is confined to the initiated elite. The esoteric nature of the art is moreover revealed by an inherent impossibility to articulate its insights in explicit and intelligible words and sentences." Karl Brunner, 1981[1]

1 Introduction

Monetary policy currently markedly differs in its conduct relative to the quote above. Nowadays, monetary policy is more transparent in its implementation, as central banks across the globe have come to recognize the potentially valuable role that transparency can play in stabilizing the economy. For example, in the US, the Federal Reserve started releasing a statement describing policy actions in regards to the federal funds rate (FFR) after the Federal Open Market Committee (FOMC) meetings in 1994, which was followed by a number of changes in the communication strategy in the subsequent years. A notable example of these new strategies is (various forms of) forward guidance: an explicit communication from the Federal Reserve about the likely future course of monetary policy, which has been one of the important tools of unconventional monetary policy in the post-financial crisis zero lower bound (ZLB) period of policymaking.[2]

It has been established that interest rate predictability has improved with increasing central bank transparency and innovative communication strategies (e.g., Poole and Rasche, 2003; Swanson, 2006), as the public has been able to form more accurate expectations about the current and future path of interest rates (as a function of economic conditions). This, in turn, is thought to translate into lower levels of monetary policy uncertainty (see Bernanke, 2004), which typically has an expansionary effect as it encourages investment and spending.

A large empirical literature focuses on measuring macroeconomic uncertainty and its effects on the economy, see for instance Bloom (2009), Jurado et al. (2015), Rossi and Sekhposyan (2015), Scotti (2016), and Jo and Sekkel (2017), among others. Monetary policy uncertainty is peculiar, since, relative to other sources of uncertainty, the central bank could be one of the main drivers behind it. There is a nascent and much narrower

[1]This quote is taken from Blinder (2002).

[2]See Blinder et al. (2008) and Feroli et al. (2017) for a discussion of central bank communication over time.

literature concerned with measuring monetary policy uncertainty directly. Some recent contributions on this are Sinha (2015), Baker et al. (2016), Creal and Wu (2017), Fontaine (2016), Husted et al. (2016), and Istrefi and Mouabbi (2017).

Our approach differs from this scarce but growing literature measuring US monetary policy uncertainty by providing several original contributions. First, we thoroughly analyze survey-based as well as market-based expectations of the policy rate and their conditional (historical) distributions. In doing so, we find a strong asymmetry in the evolution of these expectations, which we show to be related to the conduct of monetary policy.[3] Second, in contrast to symmetric measures of uncertainty, we map the observed asymmetry in the accuracy of these expectations to obtain measures of monetary policy uncertainty. Third, we quantify the importance of macroeconomic conditions for monetary policy uncertainty. As such, we decompose the sources of monetary policy uncertainty into two components: a component associated with systematic monetary policy and a component associated with discretionary monetary policy actions. We show that the observed asymmetry is preserved. Lastly, we identify non-linearities in the transmission of monetary policy uncertainty to the macroeconomy.

More specifically, to analyze monetary policy uncertainty we start from the premise that whether monetary policy is more or less uncertain depends on the predictability of the policy rate.[4] We use survey-based and market-based forecasts of the FFR to measure expectations about current and future monetary policy decisions. In our benchmark specification we rely on FFR forecast errors for several horizons implied by the Blue Chip Financial Forecasts (BCFF) survey as a basis for our analysis. As robustness, we also consider revisions in federal funds futures prices around FOMC announcements dates – the so-called "surprise" (Kuttner, 2001).

We start by uncovering interesting and novel facts about the asymmetric dynamics of the forecasts errors from the BCFF and the market-based surprises. Positive and negative forecast errors occur in clusters and are tightly linked to the behavior of the policy rate. Namely, negative (positive) forecast errors dominate during the episodes of monetary eas-

[3]Therefore, we also add to the recent literature highlighting the importance of asymmetric risks in macroeconomic forecasts. Adrian et al. (2018) analyze the time-varying asymmetric behavior of GDP growth, while Andrade et al. (2012) do so for inflation.

[4]Jurado et al. (2015), Rossi and Sekhposyan (2015), Scotti (2016), and Jo and Sekkel (2017) have a similar approach to characterizing macroeconomic uncertainty.

ing (tightening). Moreover, the conditional (historical) forecast error distributions become tighter over time, indicating that the forecast error dispersions decreased over time. Strikingly, this decline in volatilities is nearly entirely driven by the right side of the conditional distributions, as there is asymmetric time-varying behavior in the tails of the forecast error distributions. In particular, the right tail (associated with positive forecast errors and tightening episodes) shortens over time, while the left tail (associated with negative forecast errors and easing episodes) shows no apparent downward trend and exhibits mainly cyclical variations. We attribute this behavior to increasingly better-communicated policy actions from the Federal Reserve during tightenings.

To measure monetary policy uncertainty, we summarize the asymmetry in the forecast error evolution using a metric that quantifies uncertainty in terms of probabilities and, therefore, allows us to take the asymmetric tail behavior into account. More specifically, the proposed measure quantifies the ex-ante likelihood of the observed outcome, measured by the probability associated with being below or above the realized forecast error, at every point in time. It is similar to measures such as Value at Risk (VaR) and tail risk but does not rely on arbitrary thresholds: it rather relies on a realization. Moreover, our metric of monetary policy uncertainty combines both left- and right-tail behaviors of forecast errors to a single joint measure (instead of having a time-varying measure for the right-tail and left-tail risks, for example). This simplifies the analysis of the economic effects of monetary policy uncertainty.

Since we quantify monetary policy uncertainty based on federal funds forecast errors, it could potentially pick up macroeconomic uncertainty. One could argue that forecasts are less accurate in monetary policy easing cycles since macroeconomic fundamentals are harder to forecast in recessions, and that this may drive the observed asymmetric behavior of FFR forecasts. In order to address this issue we also consider two alternative ways to quantify monetary policy uncertainty. These alternatives allow us to separate the uncertainty associated with the discretionary monetary policy from the uncertainty associated with the systematic component of monetary policy. We purge monetary policy uncertainty of macroeconomic uncertainty using the underlying "key assumptions" provided by the survey participants in the BCFF. First, we construct uncertainty measures for output growth and inflation and obtain a measure of monetary policy uncertainty not explained by those (a residual-based measure). Second, we assume that agents form their interest rate expectations based on a Taylor rule and, consequently, can purge the forecast errors directly of the expectational errors in output and inflation. We then construct an uncertainty measure based on these "Taylor rule residuals." We show that the asymmetry in the evolution of forecast errors remains, regardless of the method used to purge monetary policy uncertainty of macroeconomic uncertainty. We note that our conclusions are derived using the real-time data for macroeconomic fundamentals (as interest rates are not revised); thus they incorporate the natural information flow of the economy and are not contaminated by data revisions.

We further investigate whether there is non-linear propagation of monetary policy uncertainty shocks and whether it matters for macroeconomic dynamics. We assess the macroeconomic implications of monetary policy uncertainty by analyzing its effects conditional on the economy being in a monetary tightening or easing cycle. We find recessionary effects that are stronger in easing relative to tightening. After purging our measure of macroeconomic uncertainty, effects generally get dampened, but non-linearities remain. Moreover, the results are robust to the various forecast horizons used to calculate the forecast errors and the associated uncertainty indices. However, we find significant recessionary effects only for the longer expectations horizons in the case of tightening episodes.[5]

This suggests that uncertainty about discretionary monetary policy appears to have an important role when monetary policy is both easing and tightening (for the latter case at the longer expectational horizons). Although macroeconomic uncertainty (i.e., uncertainty about macroeconomic fundamentals) seems to be relevant for macroeconomic transmission, it is not the main driver of monetary policy uncertainty. Further, clearer communication in tightening could be linked to better anchored expectations about the path of the monetary policy, which in turn makes monetary policy uncertainty less relevant for macroeconomic dynamics at the short horizons. However, expectations are less anchored at the longer horizons given that we observe significant contractionary macroeconomic effects at those horizons during tightening, suggesting that monetary policy communication might aim at pinning down shorter-term expectations better.

[5]Non-linear effects of macroeconomic (as opposed to monetary policy) uncertainty have been documented in Caggiano et al. (2014) and Mumtaz and Theodoridis (2018). However, in our setup we not only have a way to assess asymmetric propagation, but also understand the relative importance of alternative sources of monetary policy uncertainty, i.e., discretionary versus systematic.

Though our analysis focuses on the FFR expectations and uncertainty in regards to conventional monetary policy, we also look at the longer-term interest rate expectations (10-year treasury bond yields) to gain insights about unconventional monetary policy uncertainty at the effective ZLB. We provide some evidence on how the uncertainty evolves over time. We should note, however, that given the small sample size, these results are merely suggestive. To assess the role of unconventional monetary policy tools for uncertainty at the ZLB we need more observations, and expanding the analysis in a cross-sectional dimension might be helpful.

The paper proceeds as follows. In Section 2, we describe the data and discuss the dynamics of FFR forecasts and their relation to monetary policy. In Section 3, we present our measure of monetary policy uncertainty. We then assess the role of uncertainty stemming from macroeconomic fundamentals and compare our monetary policy uncertainty indices with other measures. Section 4 discusses the non-linear macroeconomic impact of monetary policy uncertainty, and Section 5 briefly introduces a measure of (unconventional) monetary policy uncertainty at the effective ZLB based on 10-year government bond yield forecasts. Section 6 concludes.

2 Federal Funds Rate Forecasts and Monetary Policy

We employ survey-based expectations of the FFR taken from the BCFF. This survey works well for our purposes since it provides forecasts of the whole yield curve including the FFR.[6] Below we discuss the data and forecast properties and dynamics.

2.1 Data

Since 1982, the BCFF survey is conducted monthly, covering approximately 50 analysts ranging from broker-dealers to economic consulting firms. The BCFF is published on the first day of each month and presents forecasts from a survey conducted during two consecutive business days one to two weeks earlier. The precise dates of the survey vary and are not generally noted in the publication. Since April of 1983, each month the BCFF provides the forecasts of the average interest rate over a particular quarter, beginning with the

[6] For instance, the US Survey of Professional Forecasters (SPF) contains only forecasts for the 3-month treasury bill and 10-year treasury bond rates, starting from 1984:Q3 and 1992:Q1, respectively.

current quarter and up to four or five quarters into the future.[7] For example, in January, the forecast of the current quarter captures the average expected outcome over January, February, and March, and the one-quarter-ahead forecast pertains to the average expected outcome of April, May, and June.

Therefore, the monthly BCFF forecasts are fixed-event forecasts of interest rates over the quarter, implying that their forecast horizon changes with each month in the quarter. We construct fixed-horizon forecasts by weighting the two given fixed-event forecasts following Chun (2011) (or see Dovern et al., 2012, for an application to survey forecasts of GDP and prices). In order to obtain, for instance, a six-months-ahead (fixed-horizon) forecast, we look at one-quarter- and two-quarters-ahead (fixed-event) forecasts. In the first month of the quarter, the six-months-ahead forecast is simply the forecast of the one-quarter-ahead forecast. In the second month of the quarter, the six-months-ahead forecast is obtained by taking the average of the one-quarter- and two-quarters-ahead forecasts with weights equal to 2/3 and 1/3, respectively. The six-months-ahead forecast for the final month of the quarter is the weighted average of the one-quarter- and two-quarters-ahead forecasts, with weights equal to 1/3 and 2/3. Nine-months-ahead forecasts are calculated as the weighted average of the two-quarters- and three-quarters-ahead forecasts given by the survey, with weights similar to the ones discussed above.[8]

We obtain forecast errors by subtracting the consensus forecasts (mean across the 50 analysts) from the realizations that are available from the Federal Reserve Board's H.15 website. In Section 3.4, we use the difference between top-10-average and bottom-10-average forecasts to obtain a measure of disagreement, as in Andrade et al. (2016). Our sample period is from 1983:04 to 2018:04, though the effective sample size depends on the forecast horizon.

2.2 Key Features of Federal Funds Rate Forecasts

Figure 1 plots the forecast errors for the FFR obtained from the BCFF over time. Forecast errors are shown for several forecast horizons, i.e., three-months-, six-months-, nine-months- and twelve-months-ahead. A few characteristics stand out. First, forecast errors across

[7] Before 1983, forecasts exist only for the current and then every other quarter.

[8] We could conduct a robustness exercise by looking at the end-of-quarter forecasts from BCFF. This would enable us to obtain fixed-horizon forecasts directly from the surveys at the expense of moving to a lower, quarterly frequency analysis.

different horizons co-move strongly and move in cycles. Not surprisingly, errors are small during the ZLB period. Second, forecast errors are generally larger for longer-horizon forecasts.

Furthermore, by looking at Figure 1, it is apparent that forecast errors in the FFR are tightly linked to the federal funds target rate (depicted with dashed lines). Errors are generally negative when the target rate is decreasing, i.e., during easing cycles, and positive when the target rate is increasing, i.e., during tightening cycles. Thus, it appears that the Fed policy rate is commonly lower than expected during easing cycles and higher than expected in periods of tightening. Interestingly, there seems to be one exception to this relationship related to the lift-off of policy rates following the ZLB. Surrounding the Federal Reserve's first rate hike, forecast errors of the FFR were negative, but have turned positive for the subsequent hikes. This suggests that analysts expected the Fed to depart from the ZLB sooner.

Moreover, positive forecast errors appear to be smaller in magnitude than negative forecast errors. In addition, the magnitude of positive forecast errors seems to be decreasing over time, while the magnitude of the negative forecast errors seems to be stable over time. This essentially implies that though the analysts typically underestimate the policy decision, they underestimate more so in easing (when interest rates are going down) relative to tightening (when interest rates are going up), and there has been a change in how agents (forecasters, central bank, etc.) behave in interest rate tightening.

These findings are supported by Table 1, which reports the sample moments of the BCFF forecast errors across easing and tightening subsamples. There are no well-established definitions of easing and tightening cycles in the literature. We resort to identifying easing cycles by looking at periods where the one-month lag of the change in the federal funds target rate is negative and tightening cycles by looking at periods after positive monthly changes in the federal funds target rate.[9] Consistent with the visual inspection of Figure 1, the sample mean of forecast errors in easing cycles is negative, while the average forecast error in a tightening cycle is positive. Moreover, the forecast errors are, in absolute value, less in tightening relative to the ones in easing: Analysts, on average, underestimate the interest rate movements by the Federal Reserve; however, they are less surprised in tightening than

[9] It should be noted that tightening and easing subsamples do not sum to the overall sample used for analysis since there are many periods where the FFR target does not change.

in easing. The same patterns emerge when looking at the conditional distributions of the forecast errors (see Figure 23 in the Appendix).

Table 2 conducts formal unbiasedness and rationality tests for the forecast errors.[10] As the full-sample unbiasedness results suggest, the forecast errors overall are biased at all conventional significance levels. However, subsample analysis suggests that the bias is mainly driven by easing episodes, and there is not much evidence for forecast biasedness in monetary policy tightenings. As far as the rationality (joint test for unbiasedness and efficiency) of the forecasts goes, the forecasts predominantly fail rationality both in a full-sample as well as in subsamples, suggesting that high and low values of the FFR are treated differently by the forecasters.[11]

The analysis above shows that positive and negative forecasts errors are concentrated during episodes of monetary policy tightening and easing, respectively, with errors being on average smaller and decreasing over time in tightening episodes. To assess these time-varying dynamics of federal funds forecasts errors further, we calculate time-varying distributions of the forecast errors. We use five years of monthly data (from 1983:04 to 1988:03) to approximate the conditional distribution of forecast errors in the beginning of the sample period. We further update the distribution with monthly observations as they become available; i.e., we use an expanding time window. Figure 2 shows the evolution of the forecast error distributions over time.

The distributions become tighter over time, indicating that the forecast error dispersions decreased over time. Strikingly, this decline in volatilities is nearly entirely driven by the right side of the conditional distributions, as there is asymmetric time-varying behavior in the tails of the forecast error distributions. In particular, the right tail (associated with positive forecast errors and tightening episodes) shortens over time while the left tail (associated with negative forecast errors and easing episodes) shows mainly cyclical

[10] The Wald test statistics is constructed with a Newey and West (1987) HAC-estimator, with a truncation parameter of $P^{1/4}$, P being the effective sample size.

[11] Some preliminary evidence on the dependence of the forecast errors on monetary tightening and easing regimes is provided by the New York Fed economists on the Liberty Street Economics blog at `http://libertystreeteconomics.newyorkfed.org/2011/08/a-look-at-the-accuracy-of-policy-expectations-1.html`. Cieslak (2018) provides evidence of ex-post predictability of the FFR forecast errors by macroeconomic fundamentals, for instance employment growth, and shows its further importance for bond return predictability. Though, in theory, the documented behavior of the forecast errors could be consistent with the rationality of the forecasts under a noisy information setting, it is rejected in Cieslak (2018).

variations. Figure 3 makes that point even clearer by showing the probabilities associated with forecasts errors one standard deviation below and above the mean – the so-called tail risk. Since the mid-1990s the right-tail risk has declined steadily. This is also consistent with the decline in the magnitude of positive forecasts errors as described previously. But the left-tail risk does not have such an apparent trend and exhibits only cyclical time variations. By visual inspection these movements seem to be related to the monetary policy cycle. In an easing cycle, the risk associated with the left tail seems to increase. This cyclical variation could be also related to the business cycle, an issue that we analyze later.

2.3 Relation to the Fed Communication Strategies

The natural question that follows after observing the dynamics of the FFR forecast error distributions is whether they are related to the Federal Reserve's communication strategies. More specifically, one could ask whether the asymmetric time-varying behavior of forecast errors is in any way related to the type and intensity of the communication coming from the Federal Reserve. In order to answer these questions, we look for some narrative evidence coming from the post-FOMC-meeting releases. The analysis in this section is mainly related to the evidence provided in Feroli et al. (2017).

Before February of 1994, there were no FOMC announcements and the public was left to infer policy actions from the developments in the FFR markets. FOMC communication via post-meeting statements started in February of 1994, with the onset of the 1994–95 tightening cycle. The evolution of the distributions seems to be in line with the introduction of post-meeting statements. For example, one can observe a shift in the time-varying distributions in the mid-1990s and the right-tail risks started to decline steadily.

Initially, post-meeting statements accompanied only policy changes and were not regular. Regular post-meeting statements started in May of 1999, with their initial intent being threefold: (a) to announce and explain policy changes, if any; (b) to provide information about the committee's view on current and future economic developments; and (c) to provide (some) guidance on future policy actions. From the onset of the release of the regular statements, the FOMC has been using language embedding guidance on future policy actions.

Feroli et al. (2017) provide an index (varying from 0 to 5) of relative strength of FOMC's forward guidance in post-meeting statements since 1999 (see their chart 2.3). In general, their index is higher (in absolute value) in the tightening cycles relative to the easing ones: dynamics that are in line with the observed BCFF forecast patterns. Moreover, it appears that over the tightening cycles, the Fed uses more "time-based" forward guidance, where it commits to set policy rate at specific levels for specific future dates. This is in contrast to the "data-based" forward guidance, where a state-contingent policy rate is communicated. Given their methodology, the period from 2003 to 2006 is a strong time-based guidance period, where communication involved terms such as "policy accommodation can be removed at a pace that is likely to be measured" and the like. That seems to coincide closely with the noticeable decline of the forecast errors in the first tightening episode of the early 2000s. However, given the small set of occurrences (two easing and two tightening cycles), this provides a narrative for only the asymmetric behavior of forecast errors.

Summing up, we attribute the decreasing dispersion of forecast errors to the decline in the upside risk to federal funds forecast errors, which, following the above narrative, may be associated with improvements in the Federal Reserve's communication strategies during tightening episodes. One could argue that forecasts are less accurate in easing cycles since easing episodes may coincide with recessions and are, therefore, harder to communicate. We shed light on the role of business cycle fluctuations for the asymmetric time variations of the conditional distributions in Section 3.3.

3 Measuring Monetary Policy Uncertainty

In this section, we first lay down the framework in which we construct our measure of monetary policy uncertainty. Second, we present the uncertainty index obtained from the FFR survey-based forecast errors. Third, we purge our index of uncertainty about macroeconomic conditions and we compare it with alternative measures of monetary policy uncertainty. Finally, for robustness, we construct a market-based measure of monetary policy uncertainty based on federal funds future surprises.

3.1 The Uncertainty Index

When thinking of measuring monetary policy uncertainty, it would be preferable to have an index that summarizes the asymmetry and the tail behavior of the forecast error distribution. Dispersion measures, such as variance or volatility, will be unable to do so since they would penalize positive forecast errors as much as negative ones. The uncertainty index we introduce for monetary policy quantifies uncertainty in terms of probabilities and, therefore, allows us to take the asymmetric tail behavior into account. More specifically, it measures the probability associated with being below or above the realized forecast error.[12] The proposed index is similar to measures such VaR and tail risk (for instance, the measure depicted in Figure 3). However, it does not require the choice of an arbitrary threshold criteria (such as a probability value for VaR or one/two standard deviation cutoffs for the tail risk).

To emphasize, we think about monetary policy being more uncertain when there is less predictability at any given point in time. In particular, the uncertainty index is based on the conditional distribution of the forecast errors and captures the ex-ante probability that one would assign to the forecast error, given the historical distribution of the forecast errors. The further away from the (theoretical) mean–i.e., 0.5–the higher the uncertainty. Most importantly, we can distinguish between upside and downside uncertainty, i.e., identify situations where a forecast error is above or below the mean of the distribution. A similar approach is applied in Rossi and Sekhposyan (2015) to assess macroeconomic uncertainty.

More formally, let the forecast error at time $t+h$ be denoted by $e_{t+h} = y_{t+h} - E_t(y_{t+h})$, i.e., this is the forecast error associated with the h-step-ahead forecast formed with all the available information at time t, and t refers to the forecast origin date. Let $f\left(e\right)$ denote the probability density function (PDF) of the forecast errors, e_{t+h}. Given e_{t+h} and $f\left(e\right)$, the index at time $t+h$ is defined as $U_{t+h} = \int_{-\infty}^{e_{t+h}} f\left(e\right) de$. In order to capture upside and downside uncertainty and have them directly comparable to each other in magnitude, we consider the index $U_{t+h}^{+} = \frac{1}{2} + \max\left\{U_{t+h} - \frac{1}{2}, 0\right\}$ for upside uncertainty and $U_{t+h}^{-} = \frac{1}{2} + \max\left\{\frac{1}{2} - U_{t+h}, 0\right\}$ for downside uncertainty. $U_{t+h}^{*} = \frac{1}{2} + \left|U_{t+h} - \frac{1}{2}\right|$, on the other hand, would be the measure of overall uncertainty. Note that, by construction, the overall

[12] To the extent that forecast errors seem to be correlated over time, one could obtain our index based on the predicted forecast error, thus making the index useful for economists in real time.

measure of uncertainty as well as the upside and downside ones fluctuate between 0.5 and 1. In general, the overall measure of the uncertainty will account for the probability mass associated with outcomes above and below the realization.

We provide an illustrative example below. Consider Figure 4, which has three panels. Let us consider two distinct episodes. The first one is in February of 2006 (labeled as 2006:02), when Chairman Bernanke assumed the chairmanship of the Federal Reserve, while the second episode pertains to August of 2008 (labeled as 2008:08), i.e., a month before Lehman declared bankruptcy. The first panel shows the probability densities of the forecast errors associated with the six-months-ahead FFR forecasts provided by BCFF. The red PDF uses forecast errors up to 2006:01, while the blue PDF is obtained from data up to 2008:07. Since the probability distribution is based on the historical forecast errors, it evolves over time. By looking at the figure, one could notice that the left tail of the distribution has been moving, showcasing the fact that most of the forecast error realizations have been in the left tail between these two time periods. Moreover, the figure in the first panel shows that the forecast error associated with the change in the Fed chairmanship is positive. On the other hand, the forecast error associated with August of 2008 is negative and much more unlikely ex-ante than that associated with February of 2006. The second panel shows the CDFs corresponding to the PDFs, i.e., U_{t+h}. The last panel shows the resulting upside and downside uncertainty indices: there is high positive uncertainty associated with 2008:8, while the uncertainty associated with 2007:2 is a downside one and lower.

Thus, our measure of uncertainty successfully captures the dynamics of the distribution of the forecast errors documented previously and quantifies the realization with a probability measure that could have been attributed to it ex-ante. An implied feature of our uncertainty index is that a smaller forecast error (in absolute value) could be associated with the same level of uncertainty as a larger error (in absolute value), when the forecast error distribution becomes tighter (a fact that we have documented earlier).

In constructing the figure and throughout the paper we follow the notion that interest rates above expectations constitute downside uncertainty, since higher interest rates are typically deterrents for growth. On the other hand, forecast errors below expectations are linked to upside uncertainty, since they typically stimulate economic activity. As apparent from the example, we obtain the monetary policy uncertainty indices from the distributions in real time. More specifically, at each t (point in time), the distribution is constructed using up to t period forecasts and time $t + h$ realizations. The initial distribution is constructed using 15% of the sample data. The distribution is further updated based on an expanding window scheme, i.e., incorporating additional observations as they become available through time (as mentioned in Section 2.2).

Needless to say, we could also choose to construct the distributions based on a fixed rolling window of observations, i.e., by truncating one initial observation as we include a new one. This strategy would increase the overall level of uncertainty at the end of the sample relative to what is reported. Given the strategy we adopt, we have uncertainty indices available from 1988:07 to 2018:01. The effective sample period depends on the forecast horizon.

3.2 Monetary Policy Uncertainty

To formalize the idea of uncertainty surrounding monetary policy and to summarize the observed asymmetry in the evolution of federal funds forecast errors, we now introduce the distribution-based measure of uncertainty described in the former subsection. For sake of brevity, we discuss the uncertainty measure obtained from the six-months-ahead forecast errors. The results for other forecast horizons is delegated to the appendix (see Figures 24–26).

Figure 5 plots the real-time uncertainty index obtained from federal funds forecast errors. We use five years of monthly data (from 1983:04 to 1988:06) to approximate the conditional distribution of forecast errors in the beginning of the sample period. We further update the distribution with monthly observations as they become available.

One of the key features of the uncertainty measure is that we can distinguish between upside and downside uncertainty. Blue (light-colored) bars in Figure 5 indicate periods of upside uncertainty and red (dark-colored) bars indicate periods of downside uncertainty. Since our measure is based on the time-varying forecast error distribution, the findings related to the behavior of the forecast errors directly translate into the characteristics of the uncertainty index.

Upside and downside uncertainty are strongly clustered. Tightening cycles are associated with downside uncertainty (i.e., interest rates are higher than expected) and easing cycles with upside uncertainty (i.e., interest rates are lower than expected). As before, one possible explanation is that the Fed generally cut or hiked rates more aggressively than anticipated. There is no historic evidence for uncertainty related to the Fed intervening less aggressively than anticipated. However, there is one exception: while uncertainty is generally low over the ZLB period, upside uncertainty started to increase in late 2014, immediately after the Fed ended purchases in October 2014. This particular episode of upside uncertainty at the end of our sample seems to be related to the uncertainty surrounding the lift-off of the FFR. Agents overestimated the policy rate consistently over that particular period, implying that they expected the Fed to increase rates from the ZLB earlier. However, we can observe downside uncertainty since mid-2016, thus returning to the historical pattern for the following rate hikes. Finally, downside uncertainty somewhat decreases over time while upside uncertainty remains rather stable, reflecting the asymmetry in the tail behavior of the forecast error distributions discussed earlier.

3.3 The Role of Macroeconomic Uncertainty

3.3.1 Purging of Macroeconomic Uncertainty

So far, our measure of monetary policy uncertainty is based on forecast errors of the FFR. Thus, we assume that monetary policy is more or less uncertain given how predictable the policy rate is. However, it is possible that the uncertainty associated with the interest rate forecasts is due to the uncertainty about the macroeconomy. For instance, it is reasonable to think that uncertainty about inflation and real economic activity is higher in recessions. This could be reflected in interest rate uncertainty, yet it is capturing macroeconomic uncertainty instead of monetary policy uncertainty. Hence, given our current measure of monetary policy uncertainty, it is unclear whether the unpredictability in the FFR is due to uncertainty about economic conditions. If uncertainty stems from uncertainty about underlying economic conditions, this cannot be related to uncertainty surrounding the conduct of monetary policy (such as communication).

To address this issue, we purge the monetary policy uncertainty index of uncertainty in macroeconomic conditions, that is, output growth and inflation uncertainty. In the BCFF, survey participants also provide their forecasts for the underlying macroeconomic conditions. Therefore, we use the same framework to construct GDP growth uncertainty and GDP deflator-based inflation uncertainty using the six-months-ahead GDP growth and inflation forecast errors, respectively. The results for other forecast horizons are delegated to the appendix (see Figures 27–29). Assume, for example, that there was an unexpected event influencing GDP growth: this will be reflected in an unusually high GDP growth forecast error and, thus, a high level of output growth uncertainty (relative to the historical distribution of forecast errors). Both GDP and the GDP deflator are revised multiple times throughout the quarter. In calculating the forecast errors associated with these variables we rely on the Advance releases of the data, i.e., the first publically released values of the GDP and GDP deflator that are available in the first month of the subsequent quarter.

Figures 6 and 7 show the uncertainty index obtained for six-months-ahead BCFF forecast errors of GDP growth and inflation, respectively. As expected, neither output growth nor inflation uncertainty distinctively relate to the monetary policy cycle. Output growth and inflation uncertainty are generally high during recessions. In contrast to our monetary policy uncertainty index, which, by construction, attains low values during the ZLB period, macroeconomic uncertainty is relatively volatile and can reach high values over that period.

The purged monetary policy index is obtained as a residual from regressing the monetary policy uncertainty index on the indexes of output growth and inflation uncertainty. It would be possible to construct a monetary policy uncertainty index after purging the interest rate forecast errors from the errors associated with output growth and inflation. This is the strategy we follow in the next section. Here, it is assumed that the higher moment dynamics between inflation, output, and interest rates are distinctly different from the first moment dynamics. Figure 8 plots the purged and the original monetary policy uncertainty indices.[13] The purged index exhibits similar dynamics and correlates with the original measure with a correlation coefficient of 0.73 (in the overlapping period). Episodes of high uncertainty, such as the early and late 2000s easing cycles that are concurrent with recessions, remain high when controlling for macroeconomic uncertainty.

3.3.2 Purging Forecast Errors

As noted previously, an alternative approach one can take is to purge the FFR forecast errors of the forecast errors associated with output growth and inflation before obtaining

[13]The purged index starts in 1990:09, which is later than the starting date of the original index. This is because of the availability of inflation forecasts in the BCFF.

the uncertainty measure. Thus, we regress the six-months-ahead interest rate forecast errors on output and inflation forecasts. We obtain the residuals and construct the uncertainty index discussed before based on these residuals.[14] The purged errors exhibit similar patterns to the original (unpurged) BCFF forecast errors discussed in Section 2.2 (Figure 9). First, the Taylor-rule residuals are tightly linked to the monetary policy cycle, i.e., they are on average positive during tightening episodes and negative during easing episodes (see Table 3, column labeled as "Residual"). Second, the asymmetric evolution in the tails of the distribution based on the purged errors remains. As is the case for the original forecast errors, Figure 10 shows that the right tail of the residual-based conditional distribution tightens over time, while the left tail does not exhibit this downward trend.

Figure 11 shows the associated residual-based uncertainty index. As we can see, though the uncertainty index is more noisy (it is based on a regression residual), the relationship with the federal funds target rate remains: monetary policy tightenings are associated with downside uncertainty, while easings with upside uncertainty. Downside uncertainty is typically lower in magnitude relative to upside uncertainty and seems to be decreasing over time, again reflecting the notion that tightenings have been increasingly better communicated to the market relative to easings.

3.4 Comparison with Alternative Uncertainty Indices

We compare our metric of monetary policy uncertainty at the six-months-ahead horizon with other alternatives. In particular, we consider the measures of policy uncertainty proposed by Baker et al. (2016) (BBD, hereafter) based on news announcements from Access World News and 10 major papers, the refined news-based measure by Husted et al. (2016) (HRS, hereafter), realized volatility of six-months-ahead federal funds futures, and disagreement in the BCFF at the six-month horizon. Figure 12 shows the alternative indices over time, and Table 4 shows the correlations with our measure in full sample and conditional on the

[14] In doing so we overwrite the decision making of the agents in forming interest rate expectations and assume they use a Taylor-type rule in forming their expectations. For instance, assume that the interest rate is set based on a textbook example of $i_t = \rho + \phi_\pi \pi_t + \phi_y y_t + \nu_t$, where ν_t is a conditionally mean zero disturbance. Then, the forecast error associated with the interest rate is $i_t - E_{t-1}(i_t) = \phi_\pi(\pi_t - E_{t-1}(\pi_t)) + \phi_y(y_t - E_{t-1}(y_t)) + \nu_t$. By regressing the forecast errors associated with the FFR on the forecast errors associated with output growth (y_t) and inflation (π_t), we obtain a "pure" measure monetary policy uncertainty $\hat{\nu_t}$, a component not affected by macroeconomic uncertainty. The same expression would hold even if we assumed interest rate smoothing in the Taylor rule. We note that neither approach used for purging takes into account the parameter estimation error in the construction of the uncertainty index.

monetary policy cycle.

The upper left panel of Figure 12 displays the BBD monetary policy uncertainty (MPU) measures. The MPUs based on Access World News and 10 major papers exhibit spikes during the Fed easing cycles in the early 1990s and 2000s as well as the one following the financial crisis of 2007. In contrast to our measure of uncertainty, during Fed tightening episodes, the BBD measures remain generally at low levels. Interestingly, our index captures the heightened uncertainty surrounding the lift-off of the FFR, while the BBD measure based on Access World News remains at historically low levels. The measure based on 10 major newspapers, however, reports high historically unprecedented levels of uncertainty. The refined news-based measure by HRS behaves very similarly to the BBD measure based on 10 major newspapers, with the only exception that uncertainty is very low during the post-crisis easing cycle (see upper right panel of Figure 12). Given the observed patterns of the news-based measures, it is not surprising that our measure positively correlates more during easing cycles than during tightening cycles with both BBD measures and the HRS measure. However, once we compare our measure that is purged of macroeconomic uncertainty, correlations with the news-based measures become smaller and even slightly negative.

Further, we compare our measure of monetary policy uncertainty with realized volatility obtained from daily six-months-ahead federal funds futures data (see lower left panel of Figure 12). Realized volatility spikes during the easing cycles in the early 1990s, 2000s, and the post-crisis period, as well as during the tightening cycle in the mid-1990s. Realized volatility remains historically low surrounding the lift-off of interest rates from the ZLB. As is the case for the news-based measures, our measure has a higher positive correlation with realized volatility during easing cycles. Conditional correlations practically vanish once we compare realized volatility with our purged measure of monetary policy uncertainty.

Finally, we consider a measure of disagreement (lower right panel of Figure 12) defined as the difference between top-10-average and bottom-10-average forecasts. Disagreement is high at the beginning of our sample and decreases continuously, strongly reflecting the dynamics of the policy rate. For example, when the level of FFR is high, disagreement is high, too. Conditional correlations between disagreement and our monetary policy index are negative and again shrink significantly once we consider the purged version of monetary policy uncertainty.

Intriguingly, as Table 4 shows, our measure of monetary policy uncertainty correlates with the news-based measure and realized volatility, especially during periods of easing. This is not surprising given our finding that levels of monetary policy uncertainty have stayed more or less stable over time in periods of monetary policy easing. However, the key observation that monetary policy uncertainty has behaved asymmetrically over time in the sense that it has decreased in periods of tightening is masked by these alternative measures. Further, given that the monetary policy uncertainty, once purged of macroeconomic uncertainty, does not seem to correlate as much with the alternative measures (especially during easing) suggests that the alternative measures might be capturing a sizeable part of macroeconomic uncertainty.

We rely on the historical forecast error distributions to capture monetary policy uncertainty. There are other potential alternatives in the literature. For instance, one could use the conditional predictive distributions from the surveys. Most of the surveys do not provide such information about the FFR. The ones that do, start later; see for reference the Survey of Primary Dealers, conducted by the New York Fed, which starts from 2011, making the survey mostly irrelevant for the analysis of conventional monetary policy.[15]

Another option would be to back out the option-implied-volatilities as suggested in Wright (2017). The drawback of that approach, again, is that the sample will be shorter and the obtained measure, since it is a volatility measure, will be symmetric. A close alternative would be to use the Merrill Lynch Option Volatility (MOVE) Index, which is not derived from the FFR options, but instead from over-the-counter options on treasuries maturing in two to 30 years.

Documenting and analyzing the skewness and the implied asymmetry is the main interest of the current paper. Recently, there has been interest in market measures such as SKEW, which could be one potential avenue for further investigation.[16] Given the fact that in order

[15] See `https://www.newyorkfed.org/medialibrary/media/markets/survey/2018/jun-survey-pd.pdf`. The US Survey of Economic Forecasters provides density forecasts for inflation and output growth, but not interest rates. Clements (2018) compares the conditional predictive densities of these variables with the unconditional ones obtained based on the historical distribution of forecast errors, and finds the unconditional distributions to be more accurate. This gives us confidence that the distribution we are using is informative and not necessarily inferior to the alternatives.

[16] See some discussion, for instance, at `https://www.blackrockblog.com/2017/09/08/low-volatility-telling-us/`.

to back out the implied skewness, we would need to make strong modeling assumptions, as is the case for implied volatility, we do not investigate this approach in this paper.

3.5 A Market-based Measure of Monetary Policy Uncertainty

In addition to survey forecasts, we also use market-based forecasts of the FFR to see whether the observed characteristics of the BCFF policy rate forecasts remain. The contract price of federal funds futures represents the market opinion of the average daily federal funds effective rate as calculated and reported by the Federal Reserve Bank of New York for a given calendar month. It is designed to capture the market's need for an instrument that reflects the Federal Reserve's monetary policy. Federal funds futures and options have long been regarded as an effective means of tracking market expectations of monetary actions of the FOMC. Futures for the FFR started trading in the late 1980s (December 1988) but only up to a six-months-ahead horizon. Meaningful trading volumes of up to twenty-four-months-ahead begin only in 2004 (up to thirty-six-months-ahead in 2011). We use six-months-ahead federal funds futures as an alternative measure for expectations of future monetary policy. One disadvantage of working with market-based expectations measures such as futures is that they contain a risk premium, which is increasing with contract horizon. We follow Kuttner (2001) and use the difference between the future price before and after FOMC announcements dates to obtain a risk-premia-free measure.[17]

As described earlier, we use the surprises, that is, the daily changes in the futures' price around FOMC announcements. Figure 13 plots the federal funds future surprise at the six-months-ahead horizon. Since the surprises are defined in a one-day window, their magnitude is naturally smaller than the magnitude of the survey-based forecast errors. Nevertheless, a similar pattern as before occurs; there are generally more negative surprises during easing episodes and more positive surprises during tightening. As expected, surprises are small during the ZLB period. Moreover, similar to the survey-based forecast errors, the lift-off period seems to exhibit mainly negative surprises, an exception to the behavior observed before the ZLB. Table 3 confirms this (see columns labeled as "Surprise"), as surprises are on average negative during easing cycles and positive during tightening. Further, the average

[17]The data on federal funds futures are obtained from Bloomberg, while the FOMC announcements dates are obtained from the Federal Reserve's website, see `https://www.federalreserve.gov/monetarypolicy/fomc_historical_year.htm`.

surprise appears to be smaller in tightening episodes than in easing episodes. Recall that the same pattern can be observed with the survey-based forecast errors. Further, Figure 14 shows the left- and right-tail risk for the conditional distribution based on surprises at the FOMC-meeting frequency. We observe asymmetric tail behavior over time (abstracting from the ZLB period). While the right tail somewhat tightens, the left tail actually expands.

Figure 15 plots the real-time uncertainty index obtained from federal funds futures surprises at the six-month horizon. Note that the surprises are at the FOMC announcement frequency. Therefore, we calculate the uncertainty index at FOMC announcement frequency. With futures starting in 1988:12, we use FOMC announcement observations occurring between 1988:12 and 1993:06 to approximate the conditional distribution of surprises in the beginning of the sample period. To plot the index at a monthly frequency, we assume that uncertainty is zero in months with no meeting. Using the market measure of FFR expectations, a similar pattern for the monetary policy uncertainty index arises, although less pronounced. In particular, we can observe blue (light) bars mainly during episodes of easing and red (dark) bars during episodes of tightening. Note, however, that the clustering is less clear than is the case for the uncertainty index based on the BCFF survey forecasts. While the easing cycles of the early and late 2000s are mainly associated with upside uncertainty and the tightening cycle of the mid-2000s can be mostly related to downside uncertainty, the clustering along the monetary policy cycle is less clear throughout the 1990s. As is the case with the survey-based uncertainty index, market-based uncertainty is low during the ZLB and starts to rise again in late 2014. Similarly, the period surrounding the lift-off of the FFR is mostly associated with upside uncertainty implying that the policy rate was lower than expected, while the more recent hikes were accompanied by downside uncertainty.

The relation between the monetary policy cycle and FFR expectations—that is, easing (tightening) can be associated with upside (downside) uncertainty–seems robust to the measure of expectations (either survey- or market-based). Note also that the uncertainty index based on the BCFF survey is an ex-post measure of uncertainty since it is based on forecast errors. However, the uncertainty index based on the market-based surprise does not relying on any ex-post realization since we consider the one-day-window forecast revision (surprise) occurring around FOMC announcements. In that sense the surprises are revisions to expectations. It is interesting that though these two measures approach the question from different angles, they have comparable results.

4 Macroeconomic Effects of Monetary Policy Uncertainty

As discussed in the former sections, our uncertainty index for the FFR exhibits substantially different dynamics across the monetary policy cycle. This raises the question of whether this has any implications for macroeconomic transmission of monetary policy uncertainty. In what follows we assess whether there is non-linearity in the macroeconomic propagation of monetary policy uncertainty. To do so, we estimate a vector autoregression containing key macroeconomic variables and the monetary policy uncertainty index (both the original and purged versions) conditional on the monetary policy cycle. For the sake of transparency and clarity, we simply split our sample according to easing and tightening subsamples. An observation at time t falls into the tightening (easing) sample whenever the change in the FFR is positive (negative) at time $t-1$.[18] We then study the dynamic responses to innovations of monetary policy uncertainty in each subsample.[19]

The VAR is in the following variables:

$$y_t = \left[log(S\&P500)_t,\ U_t^*,\ \Delta^2(log(Wages)_t),\ Hours_t,\ log(Employment)_t,\ log(IndProd)_t\right]'.$$

As standard in the literature, we identify the structural innovations of uncertainty using a Cholesky scheme for each subsample (see, e.g., Bloom, 2009, and Jurado et al., 2015). Note that though the uncertainty index was depicted and discussed as of the forecast origin date earlier, in the VAR it enters as of the realization date, which mitigates any endogeneity concerns.

Figure 16 shows the impulse responses to a one-unit monetary policy uncertainty shock using the original index (based on six-months-ahead expectations) during easing (blue line) and tightening periods (red dashed line). Dotted lines represent the 68% confidence intervals. Indeed, there seem to be differences in the impulse responses of macroeconomic

[18]We use changes in the effective federal funds (as opposed to the federal funds target) rate here in order to have sufficiently large subsample sizes. Note that this choice, if anything, makes it harder to identify asymmetric effects since the association with monetary easing or tightening regimes becomes noisier.

[19]If we had to analyze the effects of the upside and downside uncertainties separately, the VAR framework would not be appropriate as the corresponding uncertainty indices would be capturing either left- or right-tail developments of the forecast error distributions, which would make the symmetry assumption embedded in the linear VAR framework inappropriate. A similar argument would apply to tail risk measures.

variables and stock prices. Industrial production, employment, hours, and the S&P 500 respond more to an uncertainty shock in periods of easing than they do in periods of tightening.

In particular, a monetary policy uncertainty shock decreases industrial production significantly, reaching its maximum effect of about 1.3 percentage points (pp) (annualized) after a year during easing episodes. Employment also decreases significantly up to 0.6 pp (annualized) and stock prices fall by about 3.8 pp (annualized) following a monetary policy uncertainty shock in the easing regime. However, a same-sized shock has no significant effects on either macroeconomic variables or stock prices in the tightening subsample.

The contractionary effects of monetary policy uncertainty during easing could be simply an artifact of easing episodes overlapping partly with recessions and, thus, periods of high macroeconomic uncertainty. To shed light on whether this is the case, we replace the original monetary policy uncertainty index with its purged version in the VAR. As explained earlier, the purged version controls the "pure" macroeconomic uncertainty by controlling for the uncertainty associated with macroeconomic fundamentals.

Figure 17 presents the corresponding impulse responses. In the case of the purged monetary policy uncertainty shock, the responses of stock prices, employment, and industrial production remain insignificant in the tightening subsample. In the easing subsample, stock prices, hours, employment, and industrial production decrease significantly following a monetary policy uncertainty shock when controlling for macroeconomic uncertainty, although the negative responses are less pronounced relative to those of the original index. In particular, the peak effects on industrial production, employment, and stock prices of monetary policy uncertainty get dampened to -0.4 pp, -0.3 pp, and -1.2 pp, respectively.

To see whether these results depend on the forecast horizon used to construct monetary policy uncertainty, we also estimate the same (conditional) VARs for the uncertainty measures (both original and purged versions) based on the three-months-ahead, nine-months-ahead, and twelve-months-ahead forecast error distributions.

Figure 18 shows the impulse responses following a one-unit monetary policy uncertainty shock (original version) based on nine-months-ahead expectations. Asymmetries in transmission across subsamples remain, and we observe similar responses during easing periods. However, in the tightening sample, responses of macroeconomic variables and stock prices are now significantly negative. That is, a monetary policy uncertainty shock decreases employment by about 0.6 pp (annualized), industrial production by 0.7 pp (annualized), and stock prices by 3 pp (annualized) after about a year during times of tightening. Results remain when we use the purged index based on the nine-months-ahead forecast errors.

Figures 20 and 21 show the responses (now without bands) for the original as well as purged monetary policy uncertainty indices at all alternative horizons, and confirm the patterns observed for the indices based on the six-months- and nine-months-ahead expectations. To sum up, first, monetary policy uncertainty has contractionary and significant effects during easing regimes for all horizons. Effects get dampened when purged of uncertainty surrounding macroeconomic fundamentals, but remain significantly negative across all horizons. Also, effects of monetary policy uncertainty seem to be stronger when the index is constructed based on the longer horizon forecast error distributions.[20] Second, monetary policy uncertainty has insignificant economic effects during tightening episodes when short-horizon-based expectations (three- to six-months-ahead) are used. However, once we include uncertainty measures obtained from longer horizon forecasts (nine- to twelve-months-ahead), we observe that economic effects become significantly negative; although still lower when compared with those in easing. Purged versions of the uncertainty index generate similar results.

To summarize: First, during easing episodes some negative macroeconomic effects may be linked to the Fed's conduct of monetary policy (such as communication) given that macroeconomic uncertainty is not the only source of recessionary macroeconomic effects. This is also the case during tightening episodes at longer horizons. Second, as discussed in Section 2.3, tightening episodes seem to be associated with clearer communication. Thus, clearer communication in tightening, associated with better predictability of monetary policy decisions, could be linked to better anchored expectations, which in turn makes monetary policy uncertainty less relevant for macroeconomic dynamics at the short horizons. However, expectations are less anchored at the longer horizons given that we observe contractionary macroeconomic effects at those horizons during tightening, suggesting that monetary policy communication might pin down shorter-term expectations better.

[20] This observation partly vanishes once we use the purged version of the monetary policy uncertainty indices.

5 Further Considerations: Monetary Policy Uncertainty at the ZLB

By construction, monetary policy uncertainty is historically low at the ZLB period since we use up to twelve-months-ahead FFR forecasts.[21] To shed some light on monetary policy uncertainty related to unconventional policy measures such as quantitative easing (QE) and forward guidance at the ZLB, we construct uncertainty based on survey forecasts for the 10-year Treasury bond yield.

The literature has shown that these unconventional monetary policies affect interest rates and, in particular, influenced the 10-year Treasury yield (see Gagnon et al., 2011; Krishnamurthy and Vissing-Jorgensen, 2011; Neely, 2015; and Hamilton and Wu, 2012, among many others). Thus, we use the 10-year Treasury bond yield to provide a measure of unconventional monetary policy uncertainty at the ZLB. Away from the ZLB, longer maturities are usually beyond the direct control of the central banks and thus less indicative of monetary policy uncertainty.

Figure 22 shows the uncertainty index obtained from the 10-year Treasury bond yield forecast errors. For illustrative purposes, we present only the ZLB period. As is the case with the uncertainty index for the FFR, upside and downside uncertainty occur in clusters. Once the ZLB is binding, the uncertainty index for the 10-year Treasury yield peaks around QE-related announcements. We identify high levels of uncertainty when the Fed first announced sterilized purchases of $600 billion in MBS, around the QE1 and QE2 announcement, around the Operation Twist announcement, around the Bernanke testimony in May 2013, and at the end of Fed's large scale asset purchases. The uncertainty index takes on relatively low values at the QE3 announcement and the start of Fed tapering. Interestingly, a clear pattern of whether upside or downside uncertainty links to these key QE policy interventions does not arise. For example, while the QE1 and QE2 announcements are associated with downside uncertainty, Operation Twist is associated with upside uncertainty. We also identify a period of high downside uncertainty at the Bernanke testimony, where the former Fed chairman announced the possibility of tapering the Fed's asset purchases in the future. Uncertainty seems to be generally lower at forward-guidance–related announcements.

[21] FFR expectations with horizons up to one to two years remained relatively flat following unconventional monetary policy announcements at the ZLB.

6 Conclusion

This paper characterizes monetary policy uncertainty and its impact on the macroeconomy. We start from the premise that monetary policy is more uncertain whenever there is less predictability in the FFR, measured by the accuracy of the BCFF for the FFR. We also consider a measure based on the "surprises," i.e., revisions of the FFR future's price on the FOMC announcement dates.

We document asymmetries in both the forecast errors and the implied uncertainty index dynamics. Forecast errors are, in general, positive when the monetary policy tightens and negative when the monetary policy is expansionary. Both forecast errors and uncertainty have been decreasing over time in the tightening episodes, suggesting an increasingly better communication strategy on behalf of the Fed when implementing a contractionary monetary policy. These dynamics are fairly robust and remain even when the monetary policy uncertainty is "purged" of uncertainty surrounding macroeconomic conditions, such as output growth and inflation.

In addition to the asymmetric behavior over the easing and tightening cycles, monetary policy uncertainty also has non-linear propagation effects. It is, in general, recessionary, yet the effects are stronger in easing relative to tightening. While the non-linearities remain, effects become smaller when we consider monetary policy uncertainty purged of macroeconomic uncertainty. In addition, longer horizon uncertainty appears to have stronger effects relative to shorter horizon uncertainty.

The results, overall, suggest that in tightening, the Fed not only well anchors the FFR expectations, but also anchors the propagation of the monetary policy shocks reasonably well, decreasing the macroeconomic relevance of monetary policy uncertainty. Our analysis suggests that expectations can be better anchored in monetary easing cycles. There is also room to further improve the propagation of the monetary policy uncertainty since monetary policy uncertainty appears to be recessionary in easings, thus counteracting the expansionary effects of the monetary easing.

References

Adrian, T., Boyarchenko, N. and Giannone, D. (2018). Vulnerable growth, *American Economic Review, forthcoming.*

Andrade, P., Crump, R. K., Eusepi, S. and Moench, E. (2016). Fundamental disagreement, *Journal of Monetary Economics* **83**(C): 106–128.

Andrade, P., Ghysels, E. and Idier, J. (2012). Tails of inflation forecasts and tales of monetary policy, *Working Papers 407*, Banque de France.

Baker, S. R., Bloom, N. and Davis, S. J. (2016). Measuring economic policy uncertainty, *Quarterly Journal of Economics* **131**(4): 1593–1636.

Bernanke, B. S. (2004). Central bank talk and monetary policy, *Remarks at the Japan Society Corporate Luncheon.*

Blinder, A. S. (2002). Through the looking glass: Central bank transparency, *Working Papers 116*, Princeton University, Department of Economics, Center for Economic Policy Studies.

Blinder, A. S., Ehrmann, M., Fratzscher, M., De Haan, J. and Jansen, D.-J. (2008). Central bank communication and monetary policy: A survey of theory and evidence, *Journal of Economic Literature* **46**(4): 910–945.

Bloom, N. (2009). The impact of uncertainty shocks, *Econometrica* **77**(3): 623–685.

Caggiano, G., Castelnuovo, E. and Groshenny, N. (2014). Uncertainty shocks and unemployment dynamics in U.S. recessions, *Journal of Monetary Economics* **67**(C): 78–92.

Chun, A. L. (2011). Expectations, bond yields, and monetary policy, *Review of Financial Studies* **24**(1): 208–247.

Cieslak, A. (2018). Short-rate expectations and unexpected returns in treasury bonds, *Review of Financial Studies, forthcoming.*

Clements, M. P. (2018). Are macroeconomic density forecasts informative?, *International Journal of Forecasting* **34**(2): 181–198.

Creal, D. D. and Wu, J. C. (2017). Monetary policy uncertainty and economic fluctuations, *International Economic Review* **58**(4): 1317–1354.

Dovern, J., Fritsche, U. and Slacalek, J. (2012). Disagreement among forecasters in G7 countries, *The Review of Economics and Statistics* **94**(4): 1081–1096.

Feroli, M., Greenlaw, D., Hooper, P., Mishkin, F. S. and Sufie, A. (2017). Language after liftoff: Fed communication away from the zero lower bound, *Research in Economics* **71**(3): 452–490.

Fontaine, J.-S. (2016). What Fed funds futures tell us about monetary policy uncertainty, *Staff Working Paper 2016-61*, Bank of Canada.

Gagnon, J., Raskin, M., Remache, J. and Sack, B. (2011). The financial market effects of the Federal Reserve's large-scale asset purchases, *International Journal of Central Banking* **7**(1): 3–43.

Hamilton, J. D. and Wu, J. C. (2012). The effectiveness of alternative monetary policy tools in a aero lower bound environment, *Journal of Money, Credit and Banking* **44**: 3–46.

Husted, L. F., Rogers, J. H. and Sun, B. (2016). Measuring monetary policy uncertainty: The Federal Reserve, January 1985-January 2016, *IFDP Notes* **2016-04-11**.

Istrefi, K. and Mouabbi, S. (2017). Subjective interest rate uncertainty and the macroeconomy: A cross-country analysis, *Journal of international money and finance, forthcoming*.

Jo, S. and Sekkel, R. (2017). Macroeconomic uncertainty through the lens of professional forecasters, *Journal of Business & Economic Statistics* **0**(0): 1–11.

Jurado, K., Ludvigson, S. C. and Ng, S. (2015). Measuring uncertainty, *American Economic Review* **105**(3): 1177–1216.

Krishnamurthy, A. and Vissing-Jorgensen, A. (2011). The effects of quantitative easing on interest rates: Channels and implications for policy, *Brookings Papers on Economic Activity* (21587).

Kuttner, K. N. (2001). Monetary policy surprises and interest rates: Evidence from the Fed funds futures market, *Journal of Monetary Economics* **47**(3): 523–544.

Mumtaz, H. and Theodoridis, K. (2018). The changing transmission of uncertainty shocks in the U.S., *Journal of Business & Economic Statistics* **36**(2): 239–252.

Neely, C. J. (2015). Unconventional monetary policy had large international effects, *Journal of Banking & Finance* **52**(C): 101–111.

Newey, W. K. and West, K. D. (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix, *Econometrica* **55**(3): 703–708.

Poole, W. and Rasche, R. H. (2003). The impact of changes in FOMC disclosure practices on the transparency of monetary policy: Are markets and the FOMC better "synched"?, *Federal Reserve Bank of St. Louis Review* (Jan): 1–10.

Rossi, B. and Sekhposyan, T. (2015). Macroeconomic uncertainty indices based on nowcast and forecast error distributions, *American Economic Review* **105**(5): 650–655.

Scotti, C. (2016). Surprise and uncertainty indexes: Real-time aggregation of real-activity macro-surprises, *Journal of Monetary Economics* **82**(C): 1–19.

Sinha, A. (2015). FOMC forward guidance and investor beliefs, *American Economic Review* **105**(5): 656–61.

Swanson, E. T. (2006). Have increases in federal reserve transparency improved private sector interest rate forecasts?, *Journal of Money, Credit and Banking* **38**(3): 791–819.

Wright, J. (2017). Forward-looking estimates of interest rate distributions, *Annual Review of Financial Economics* **9**: 333–351.

Tables and Figures

Table 1: ***Sample Moments of BCFF Forecast Errors of the Federal Funds Rate Conditional on the Monetary Policy Cycle***

	Easing				Tightening			
	3-month	**6-month**	**9-month**	**12-month**	**3-month**	**6-month**	**9-month**	**12-month**
Nr.	62	62	62	62	69	67	67	65
Mean	-0.41	-0.64	-0.93	-1.22	0.13	0.15	0.17	0.20
Median	-0.26	-0.51	-0.93	-1.56	0.22	0.27	0.33	0.45
Std.	0.58	0.87	1.20	1.45	0.53	0.84	1.10	1.37
Skewness	-1.73	-0.31	-0.01	0.50	-1.60	-2.13	-1.40	-1.06

Notes: Descriptive statistics for the federal funds rate forecasts at the three-months-, six-months-, nine-months-, and twelve-months-ahead horizons. Observations at time t are associated with the easing (tightening) subsample whenever there was a negative (positive) change in the federal funds target rate in the previous period $t-1$.

Table 2: ***Unbiasedness and Rationality of BCFF Forecast Errors of the Federal Funds Rate Conditional on the Monetary Policy Cycle***

	Overall		Easing		Tightening	
	Wald-stats	**p-value**	**Wald-stats**	**p-value**	**Wald-stats**	**p-value**
			Unbiasedness			
3-month	2.26	0.13	19.57	0.00	2.78	0.10
6-month	4.58	0.03	16.47	0.00	1.11	0.29
9-month	7.91	0.00	17.16	0.00	0.61	0.43
12-month	13.48	0.00	17.34	0.00	0.60	0.44
			Rationality			
3-month	3.35	0.19	24.71	0.00	14.65	0.00
6-month	5.37	0.07	16.75	0.00	8.53	0.01
9-month	8.66	0.01	18.83	0.00	6.12	0.05
12-month	14.20	0.00	20.00	0.00	6.27	0.04

Notes: Unbiasedness and rationality tests (joint test of unbiasedness and efficiency) for the federal funds rate forecasts at the three-months-, six-months-, nine-months-, and twelve-months-ahead horizons. Observations at time t are associated with the easing (tightening) subsample whenever there was a negative (positive) change in the federal funds target rate in the previous period $t-1$. Wald test is implemented based on a Newey and West (1987) covariance estimator with a truncation parameter of $P^{1/4}$, where P is the effective sample size.

Table 3: ***Sample Moments of Taylor-rule Residuals and Surprises Conditional on the Monetary Policy Cycle.***

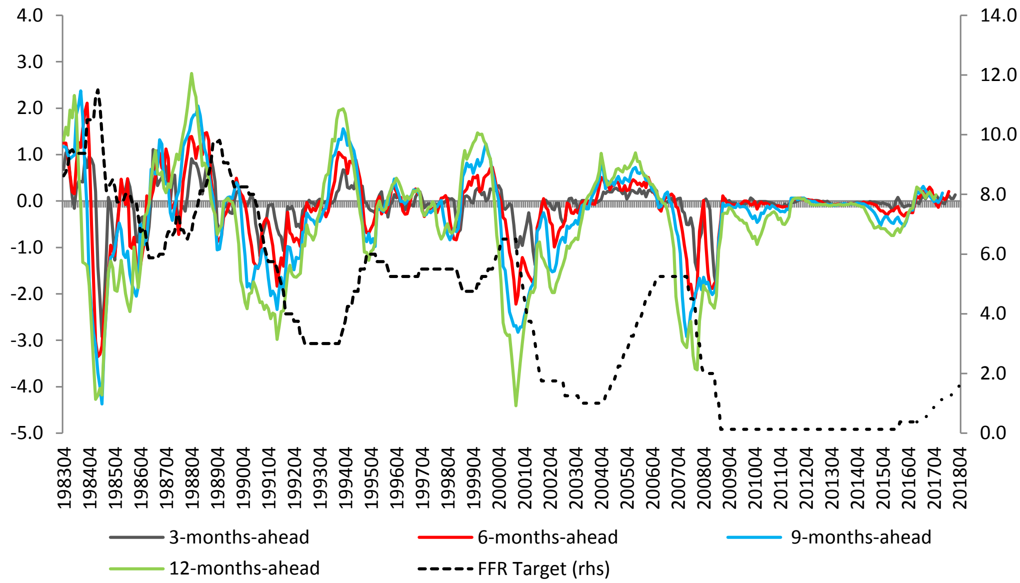
	Easing		Tightening	
	Residuals	**Surprise**	**Residuals**	**Surprise**
Nr.	54	41	55	41
Mean	-0.42	-0.05	0.33	0.02
Median	-0.24	-0.05	0.21	0.02
Std.	0.68	0.12	0.46	0.06
Skewness	-0.12	-0.45	0.42	0.71

Note: Taylor-rule residuals are the residuals obtained from a regression of federal funds forecast errors (six-months-ahead) on GDP forecast errors (six-months-ahead) and price forecast errors (six-months-ahead). Surprises are the daily changes in federal funds futures at the six-months-ahead horizon around FOMC announcements dates.

Table 4: ***Correlations with Alternative Indices***

	Realized Volatility	**BBD MPU 1**	**BBD MPU 2**	**HRS MPU**	**Disagreement**
			Original Index		
Full Sample	0.28	0.20	0.00	0.14	0.19
Easing	0.17	0.13	0.29	0.13	-0.30
Tightening	0.05	0.10	-0.08	-0.09	-0.20
			Purged Index		
Full Sample	0.18	0.10	0.01	0.09	0.20
Easing	0.03	-0.06	0.08	-0.05	-0.05
Tightening	-0.02	-0.06	0.00	0.12	-0.05

Figure 1: ***BCFF Forecast Errors for the Federal Funds Rate***



Note: This figure plots forecast errors based on the BCFF federal funds rate forecasts at the three-months-, six-months-, nine-months-, and twelve-months-ahead horizons (left axis) and federal funds target rate (right axis).

Figure 2: ***Forecast Error Distributions Over Time***

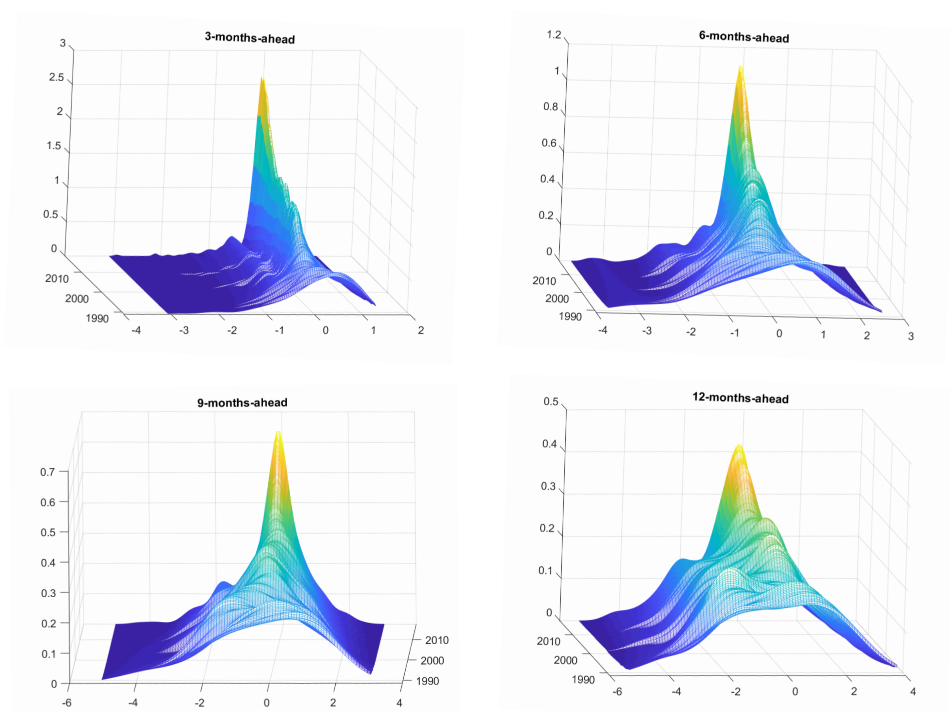
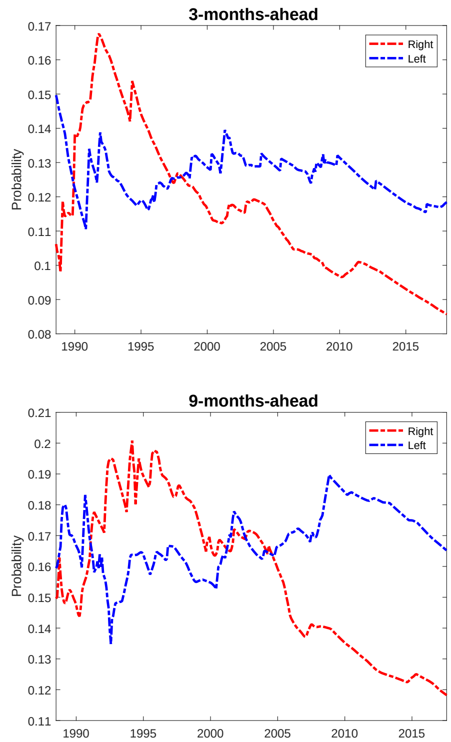


Figure 3: ***Tail Risks of Forecast Errors Over Time***



Note: This figure plots the probabilities associated with BCFF forecast errors one standard deviation below (blue line) and above the mean (red line).

Figure 4: ***Illustrative Example for the Uncertainty Index***

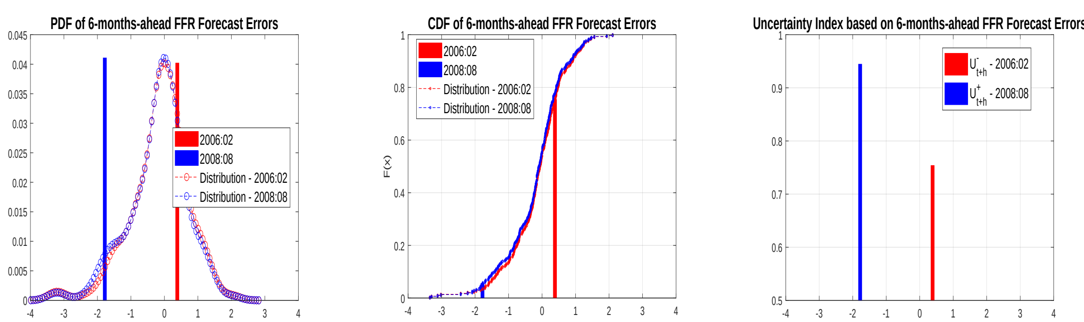
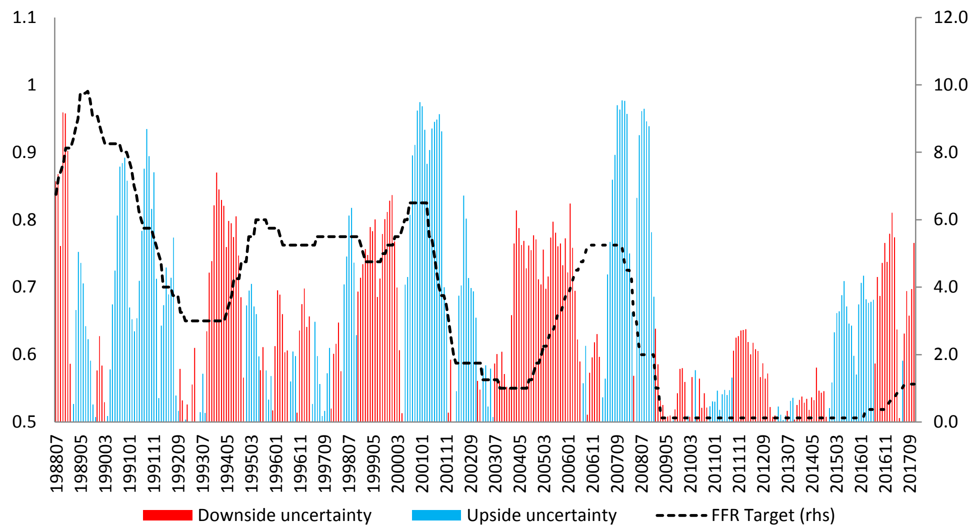
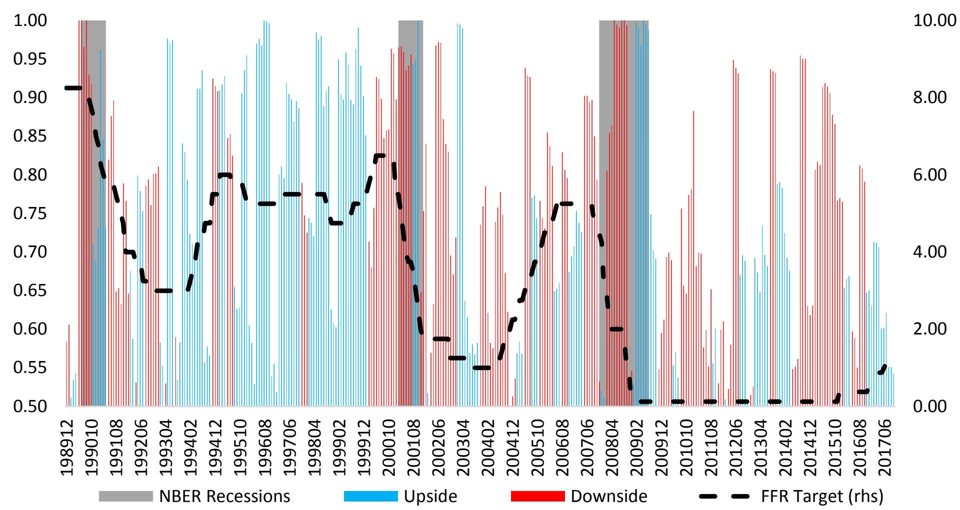


Figure 5: ***Monetary Policy Uncertainty Index***



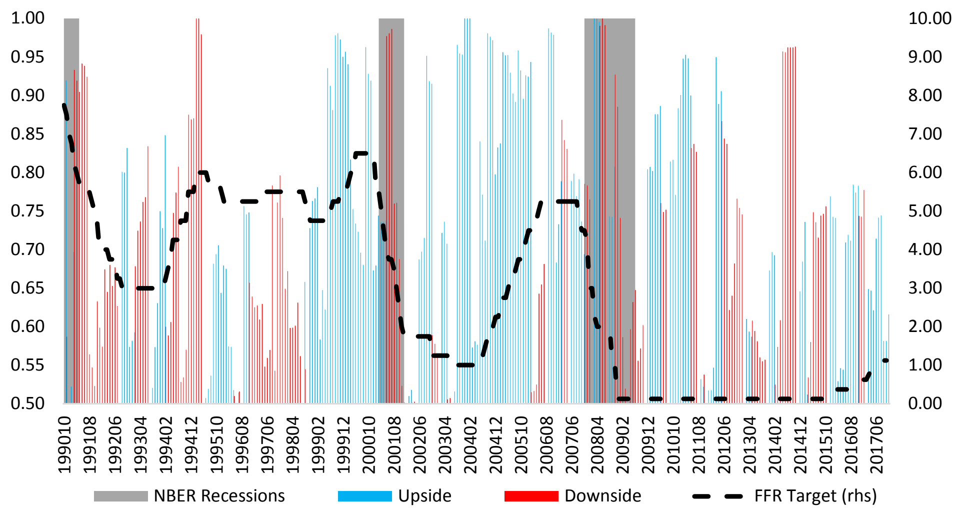
Note: This figure plots upside and downside uncertainty obtained from the six-months-ahead federal funds rate forecast errors from the BCFF survey.

Figure 6: ***Output Growth Uncertainty Index***



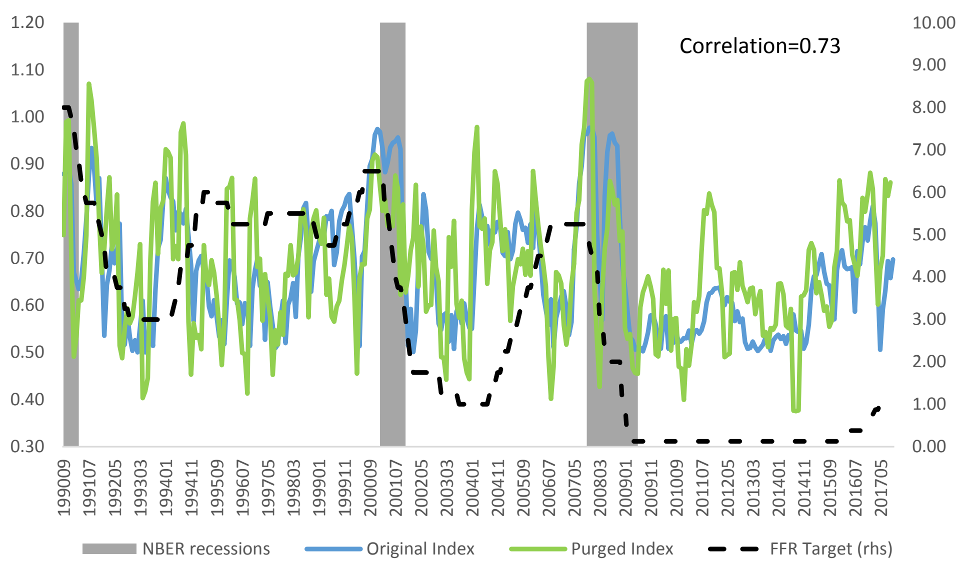
Note: This figure plots upside and downside uncertainty obtained from the six-months-ahead BCFF GDP growth forecast errors. Shaded bars represent NBER recession dates.

Figure 7: ***Inflation Uncertainty Index***



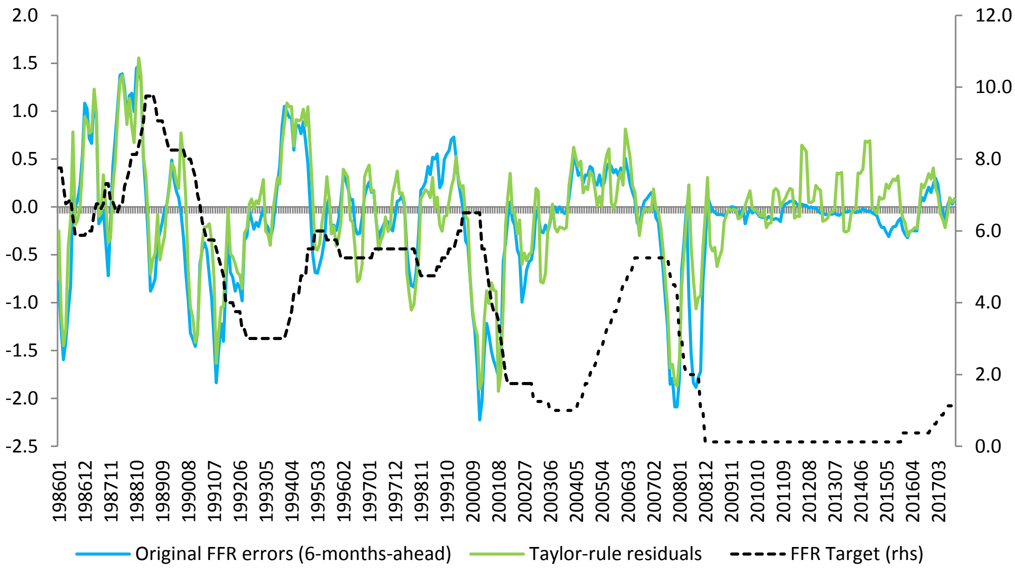
Note: This figure plots upside and downside uncertainty obtained from the six-months-ahead BCFF GDP deflator-based inflation forecast errors. Shaded bars represent NBER recession dates.

Figure 8: ***Monetary Policy Uncertainty Index Purged of Macroeconomic Uncertainty***



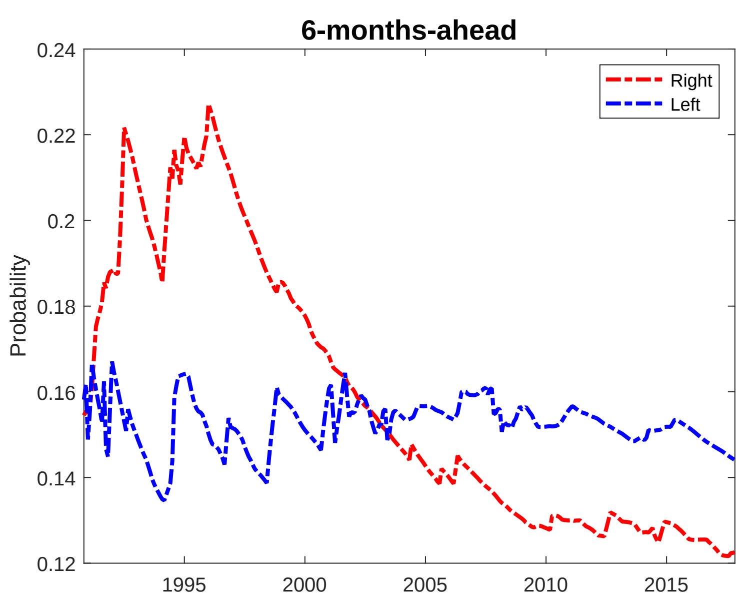
Note: This figure plots the purged uncertainty index: the normalized residuals of a regression of the federal funds rate uncertainty index obtained from the six-months-ahead BCFF forecast errors on the uncertainty indexes obtained from the six-months-ahead BCFF forecasts errors of output and prices, respectively.

Figure 9: ***Taylor-rule Residuals: Purged Federal Funds Rate Forecast Errors***



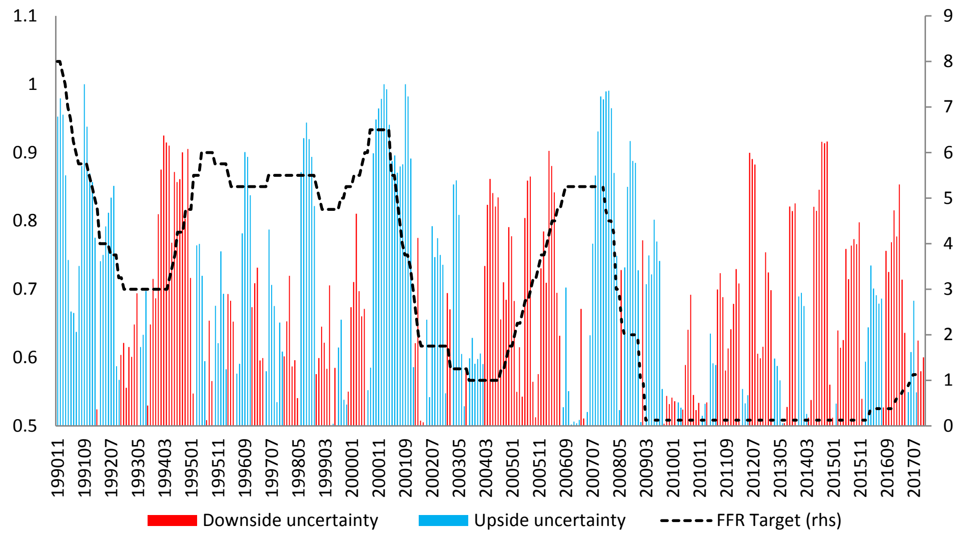
Note: This figure plots the Taylor-rule residuals obtained from a regression of federal funds rate forecast errors (six-months-ahead) on output growth and inflation (six-months-ahead) forecast errors.

Figure 10: ***Taylor-rule Residuals: Tail Risk Over Time***



Note: This figure plots the probabilities associated with the Taylor-rule residuals one standard deviation below (blue line) and above the mean (red line).

Figure 11: ***Monetary Policy Uncertainty Based on Taylor-rule Residuals***



Note: This figure plots the uncertainty index obtained from the Taylor-rule residuals.

Figure 12: ***Alternative Uncertainty Indices***

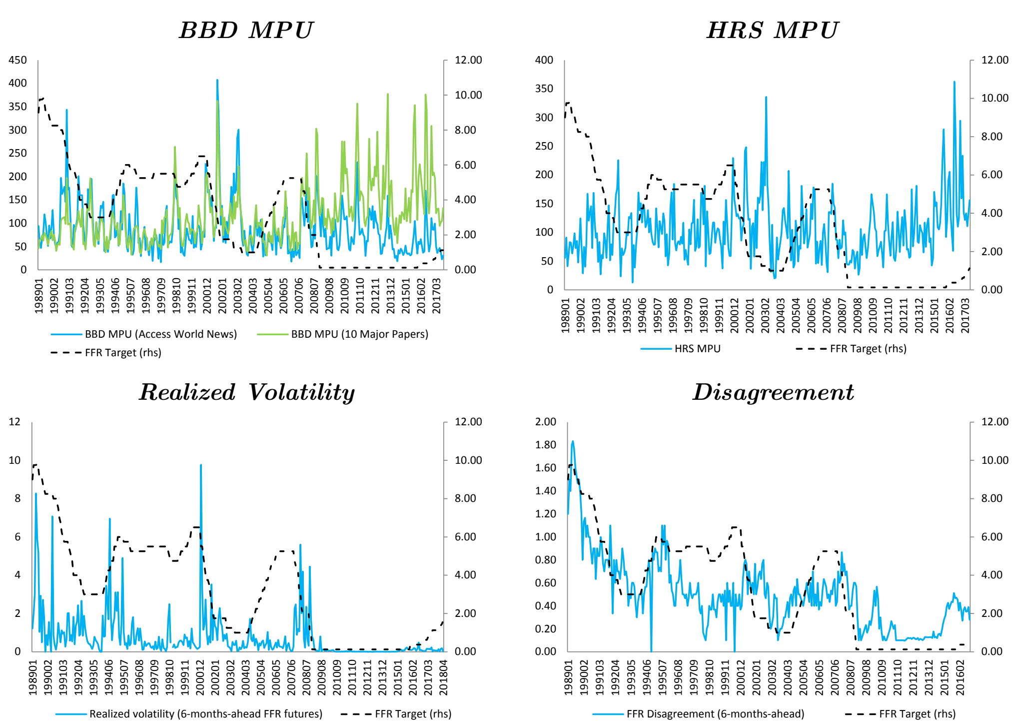
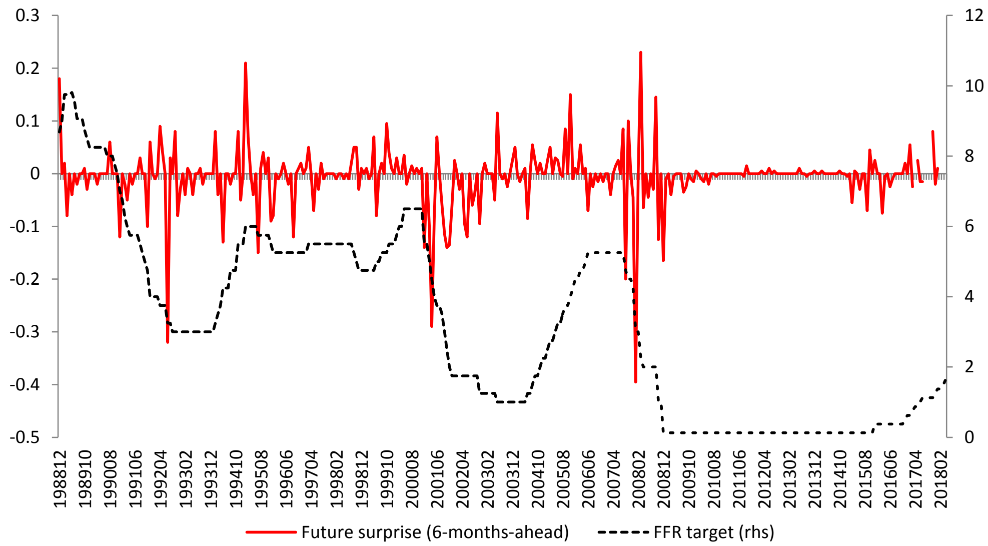
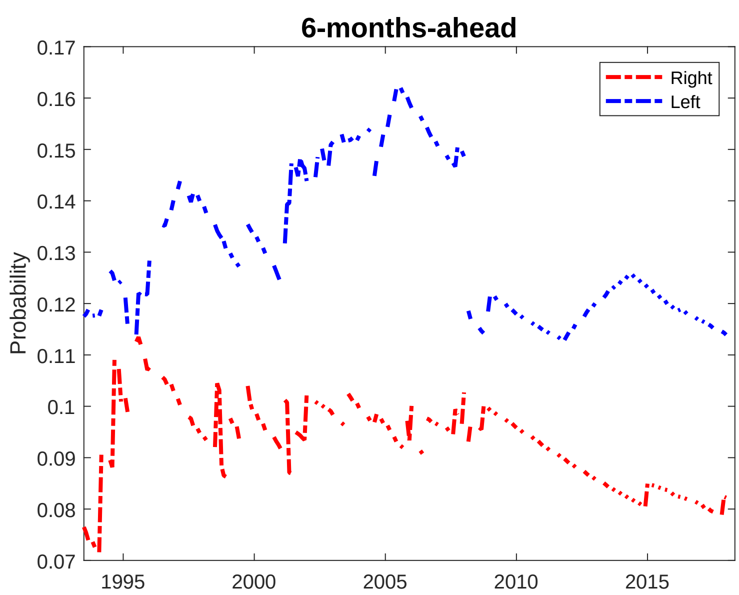


Figure 13: ***Federal Funds Future Surprises***



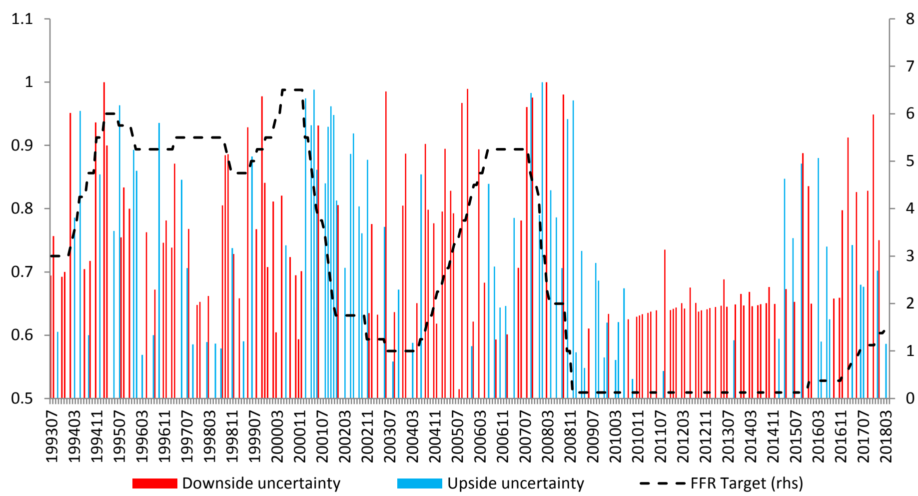
Note: This figure plots the FFR future surprises at the 6-month horizon (daily changes of six-month future prices around FOMC announcement dates).

Figure 14: ***Federal Funds Future Surprises: Tail Risk Over Time***



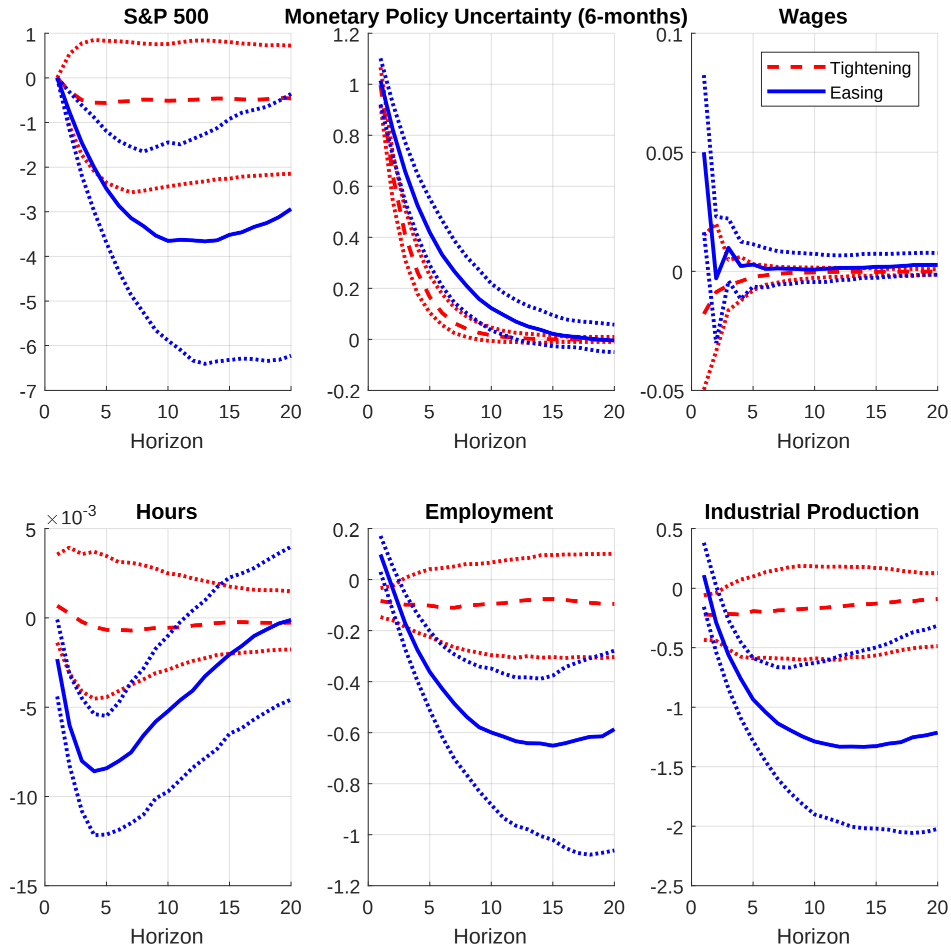
Note: This figure plots the probabilities associated with the Taylor-rule residuals one standard deviation below (blue line) and above the mean (red line).

Figure 15: ***Market-based Monetary Policy Uncertainty Index***



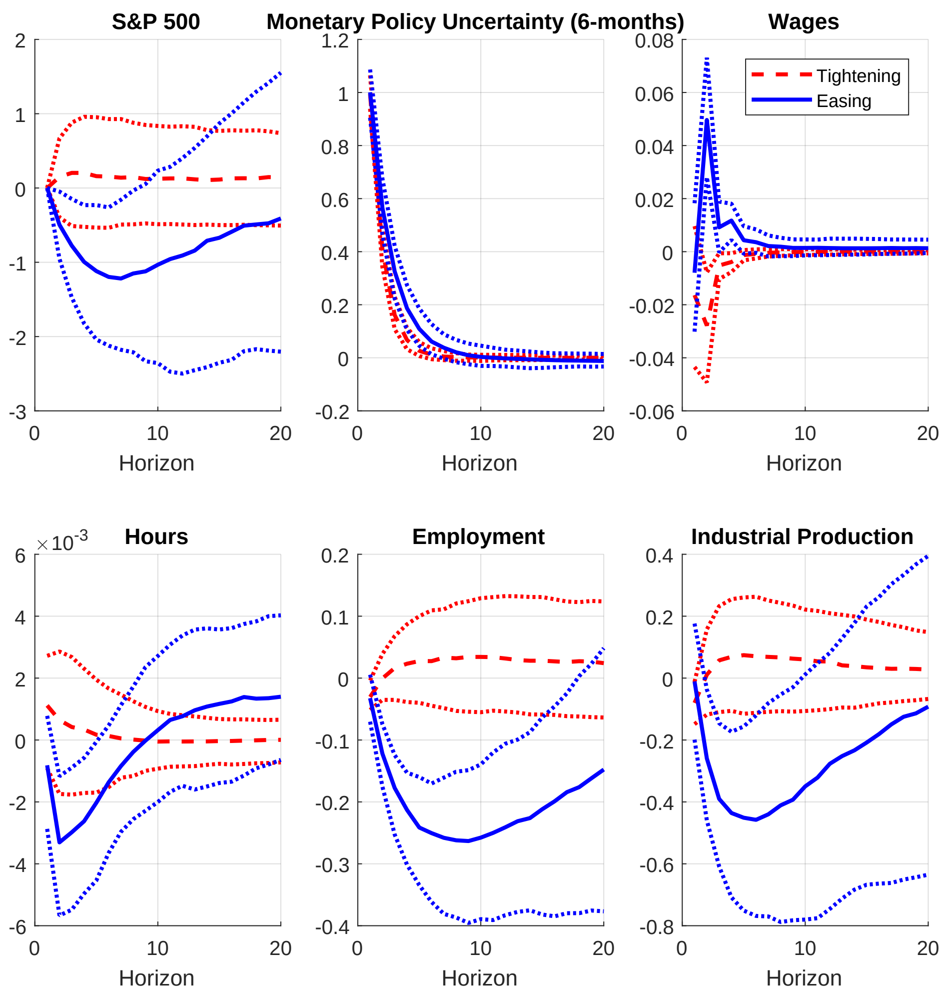
Note: This figure plots upside and downside uncertainty obtained from the six-months-ahead Federal funds future surprises (daily changes of six-month future prices around FOMC announcement dates).

Figure 16: ***Impulse Responses Conditional on the Monetary Policy Cycle: Original Index***



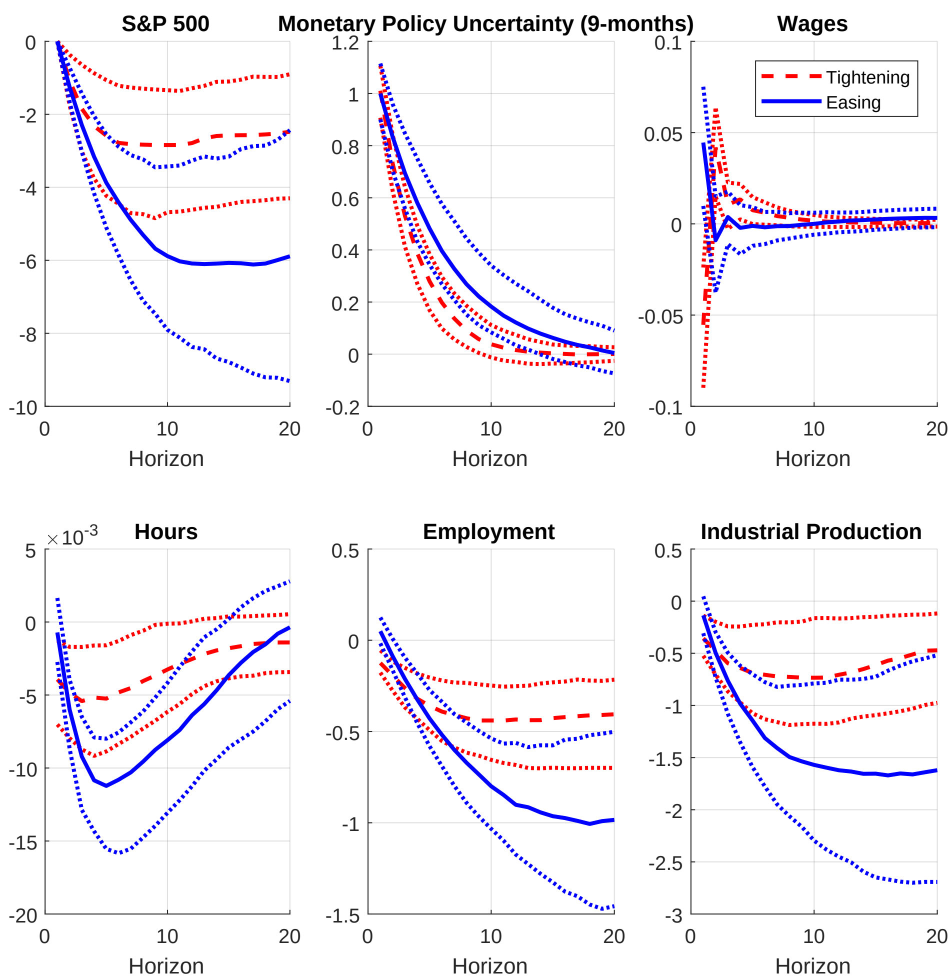
Note: This figure plots the impulse responses of the S&P 500, monetary policy uncertainty (based on six-months-ahead expectations), wages, hours, employment and industrial production to a one-unit monetary policy uncertainty shock. Red dashed (blue solid) lines are the point estimates obtained from the tightening (easing) subsample. Dotted lines represent the 68% confidence bands.

Figure 17: ***Impulse Responses Conditional on Monetary Policy Cycle: Purged Index***



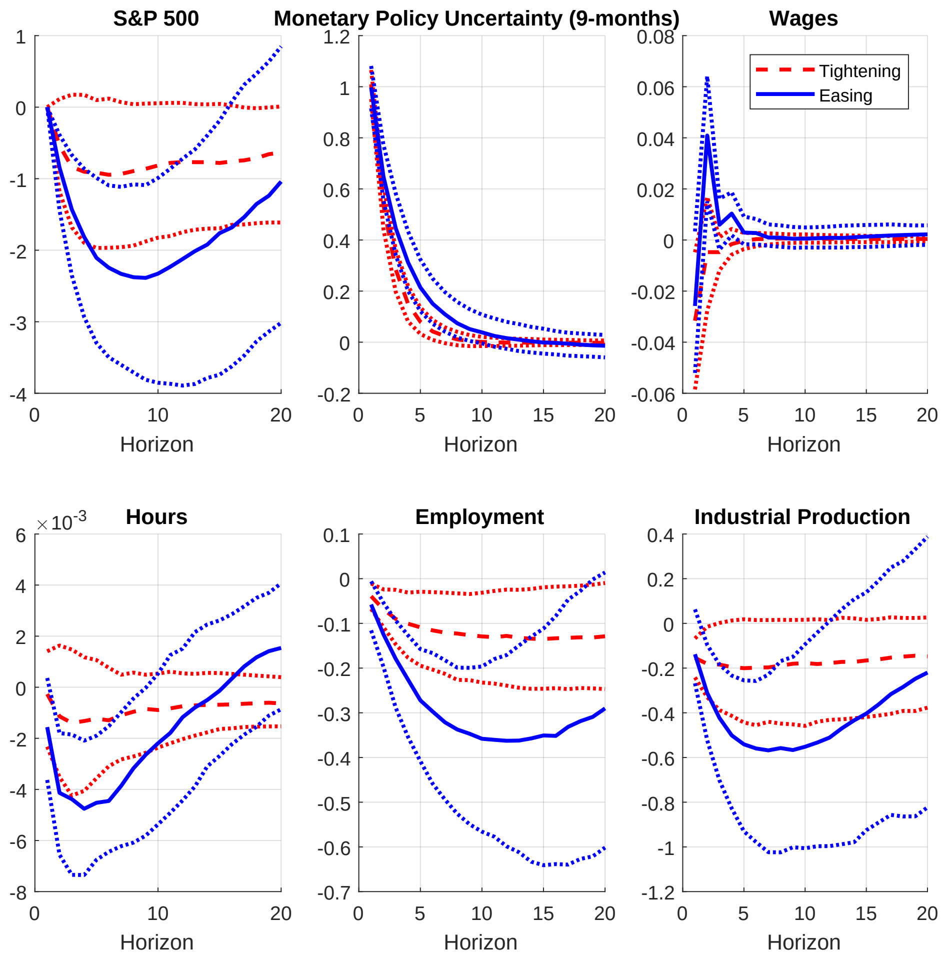
Note: This figure plots the impulse responses of the S&P 500, purged monetary policy uncertainty (based on six-months-ahead expectations), wages, hours, employment, and industrial production to a one-unit monetary policy uncertainty shock. Red dashed (blue solid) lines are the point estimates obtained from the tightening (easing) subsample. Dotted lines represent the 68% confidence bands.

Figure 18: ***Impulse Responses Conditional on the Monetary Policy Cycle: Original Index (nine-months-ahead)***



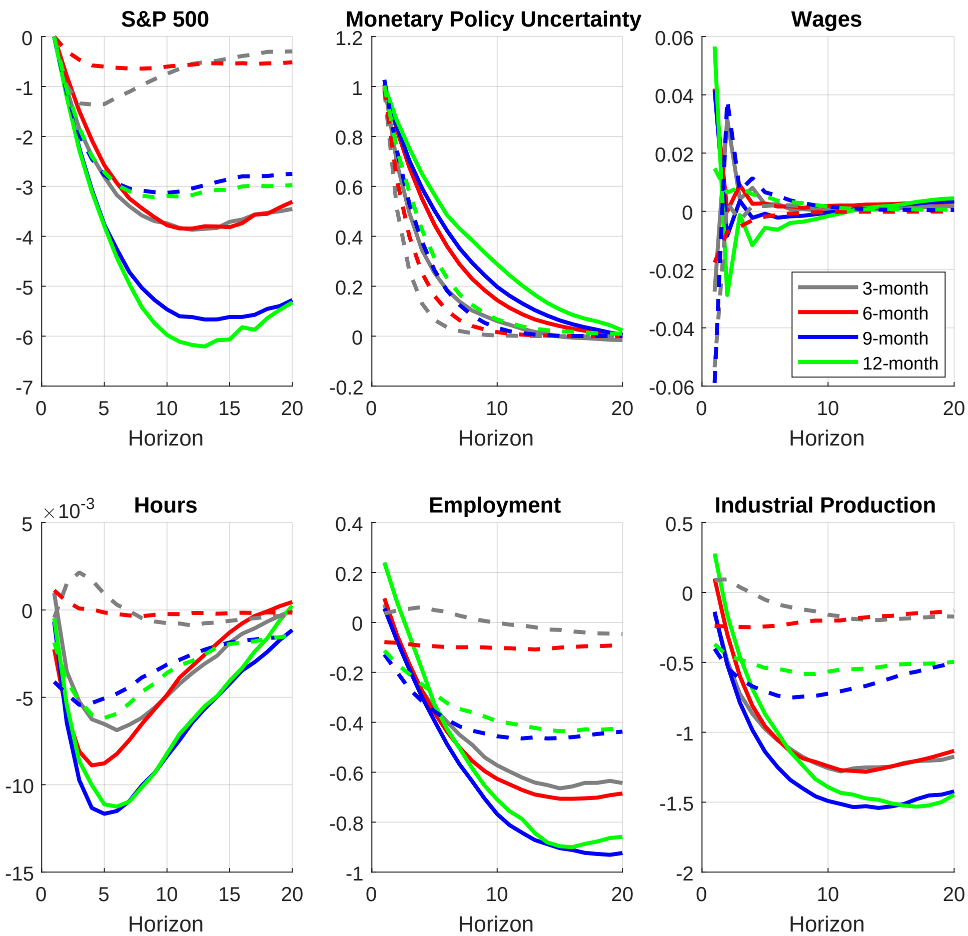
Note: This figure plots the impulse responses of the S&P 500, monetary policy uncertainty (based on nine-months-ahead expectations), wages, hours, employment, and industrial production to a one-unit monetary policy uncertainty shock. Red dashed (blue solid) lines are the point estimates obtained from the tightening (easing) subsample. Dotted lines represent the 68% confidence bands.

Figure 19: *Impulse Responses Conditional on Monetary Policy Cycle: Purged Index (nine-months-ahead)*



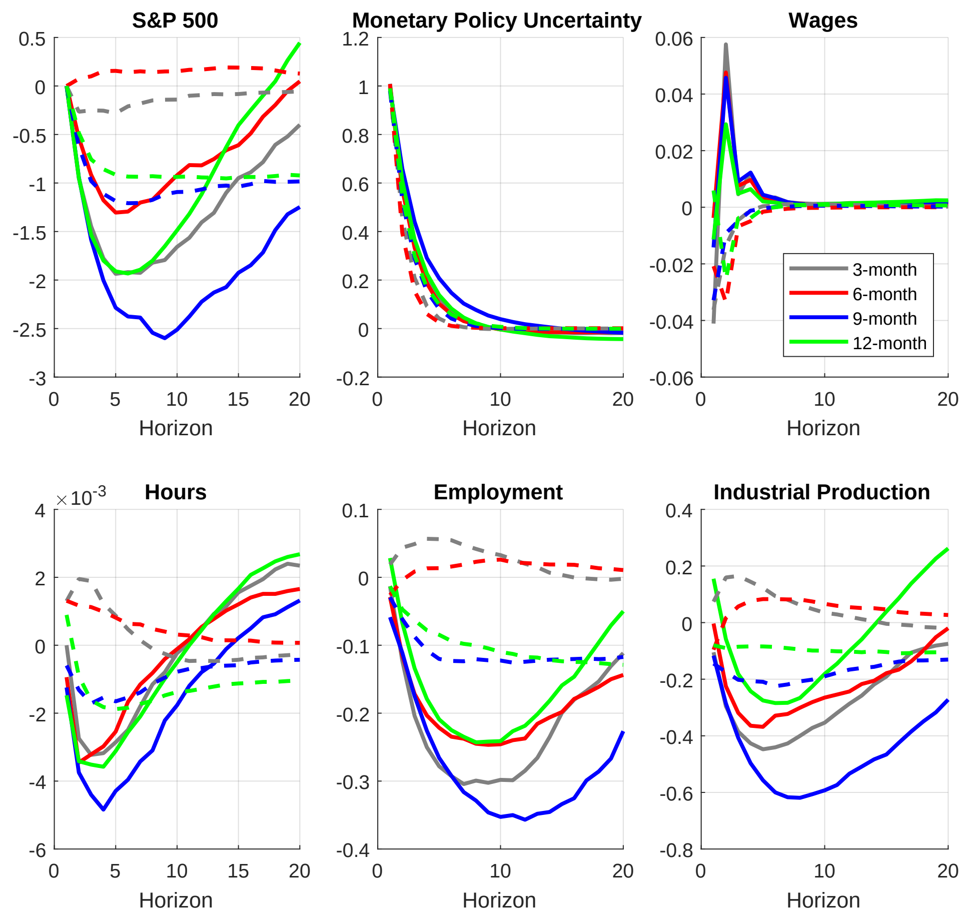
Note: This figure plots the impulse responses of the S&P 500, purged monetary policy uncertainty (based on six-months-ahead expectations), wages, hours, employment, and industrial production to a one-unit monetary policy uncertainty shock. Red dashed (blue solid) lines are the point estimates obtained from the tightening (easing) subsample. Dotted lines represent the 68% confidence bands.

Figure 20: ***Impulse Responses Conditional on Monetary Policy Cycle: Original Index at Alternative Horizons***



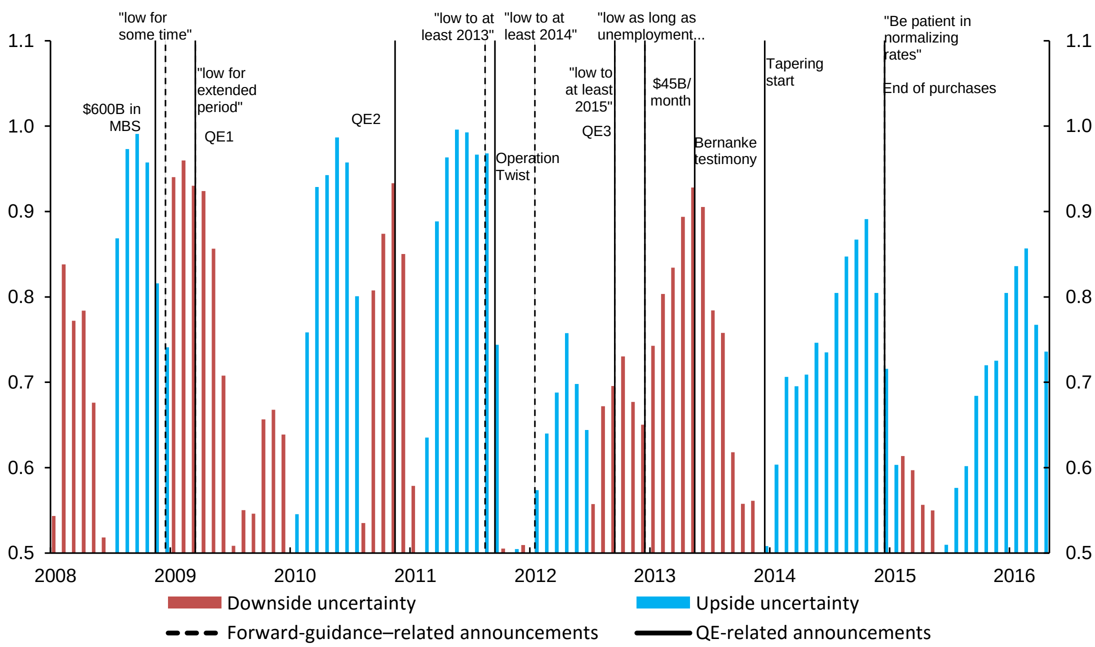
Note: This figure plots the impulse responses of the S&P 500, monetary policy uncertainty, wages, hours, employment, and industrial production to a one-unit monetary policy uncertainty shock for several forecast horizons (three-, six-, nine-, and twelve-months-ahead). Dashed (solid) lines are the point estimates obtained from the tightening (easing) subsample.

Figure 21: ***Impulse Responses Conditional on Monetary Policy Cycle: Purged Index at Alternative Horizons***



Note: Note: This figure plots the impulse responses of the S&P 500, purged monetary policy uncertainty, wages, hours, employment, and industrial production to a one-unit monetary policy uncertainty shock for several forecast horizons (three-, six-, nine-, and twelve-months-ahead). Dashed (solid) lines are the point estimates obtained from the tightening (easing) subsample.

Figure 22: ***Monetary Policy Uncertainty Index at the ZLB***

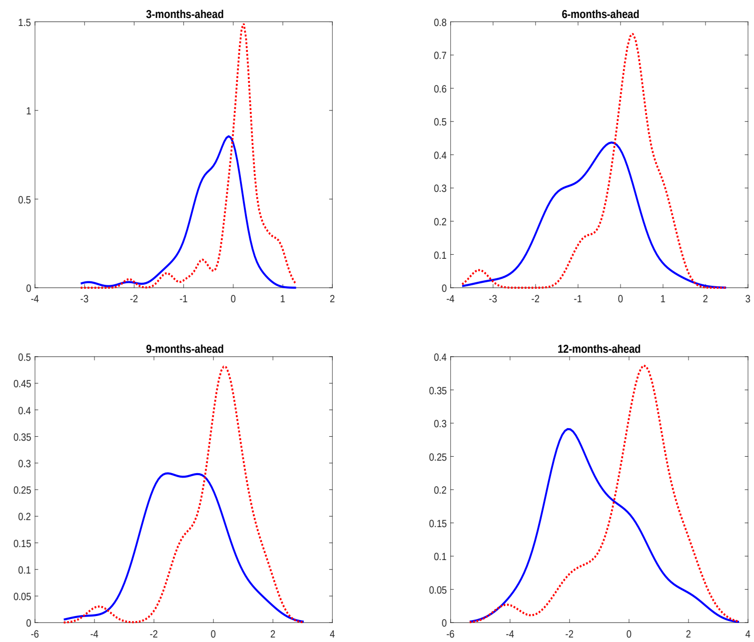


Note: This figure plots upside and downside uncertainty obtained from the six-months-ahead 10-year Treasury bond yield forecast errors from the BCFF survey over the ZLB period.

Appendix

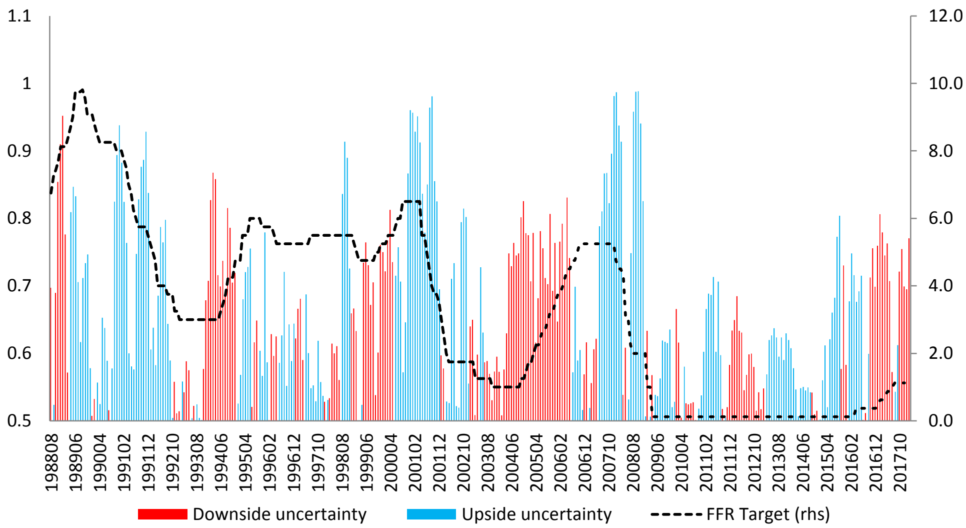
This section presents additional figures for completeness and to provide further evidence on robustness.

Figure 23: ***Conditional Empirical Distributions of BCFF Forecast Errors of the Federal Funds Rate***



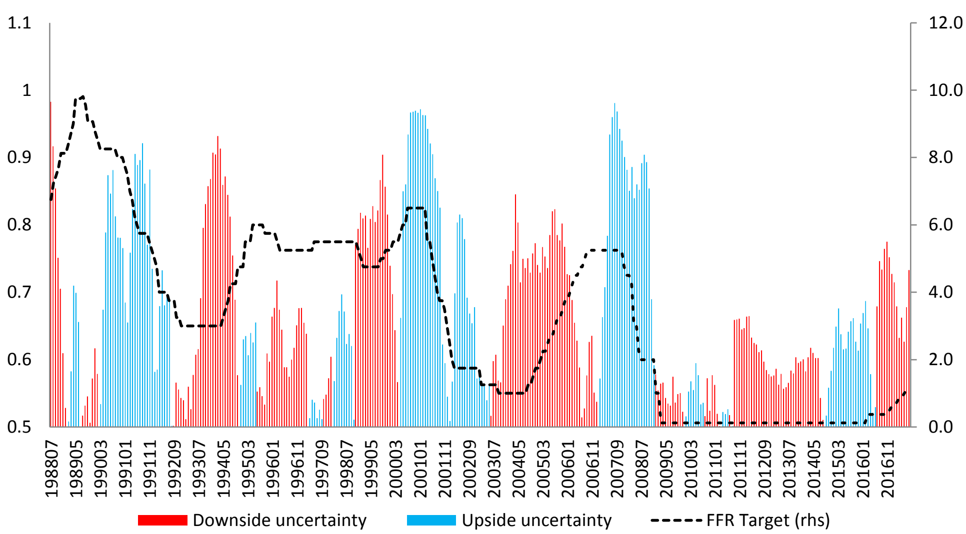
Notes: The blue (red) line shows the empirical distribution of federal funds rate forecast errors at the six-months-, nine-months-, and twelve-months-ahead horizons for easing (tightening) subsamples. Observations at time t are associated with the easing (tightening) subsample whenever there is a negative (positive) change in the federal funds target rate in the previous period $t-1$.

Figure 24: ***Monetary Policy Uncertainty Index (based on three-months-ahead expectations)***



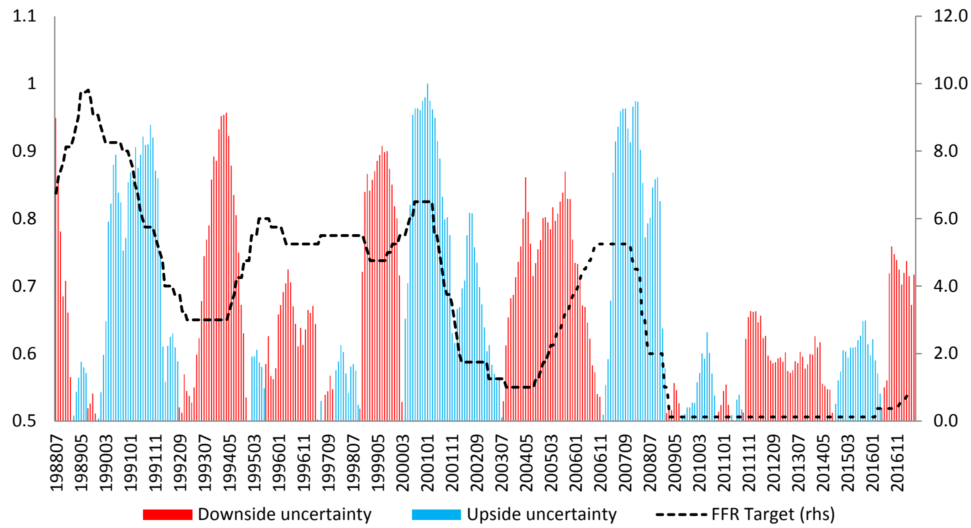
Note: This figure plots upside and downside uncertainty obtained from the three-months-ahead federal funds rate forecast errors from the BCFF survey.

Figure 25: ***Monetary Policy Uncertainty Index (based on nine-months-ahead expectations)***



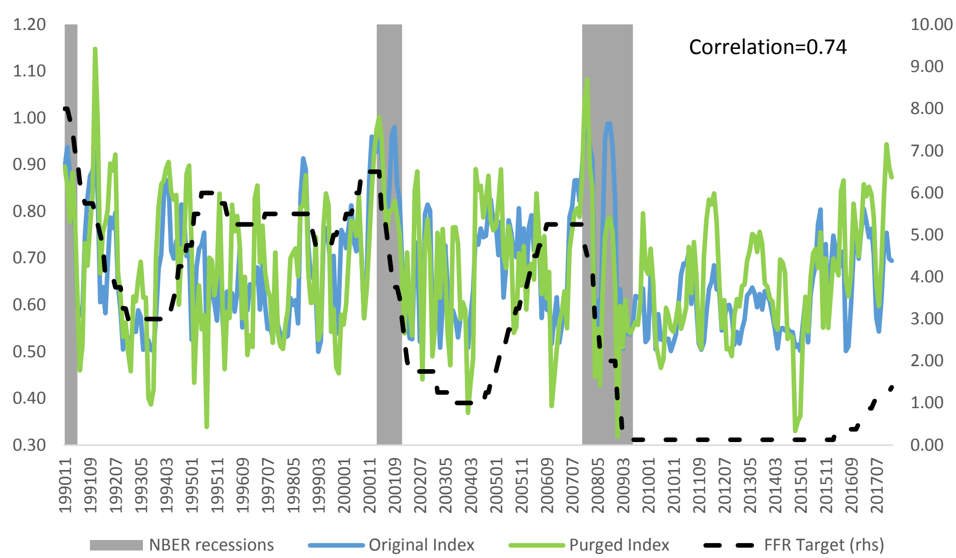
Note: This figure plots upside and downside uncertainty obtained from the nine-months-ahead federal funds rate forecast errors from the BCFF survey.

Figure 26: ***Monetary Policy Uncertainty Index (based on twelve-months-ahead expectations)***



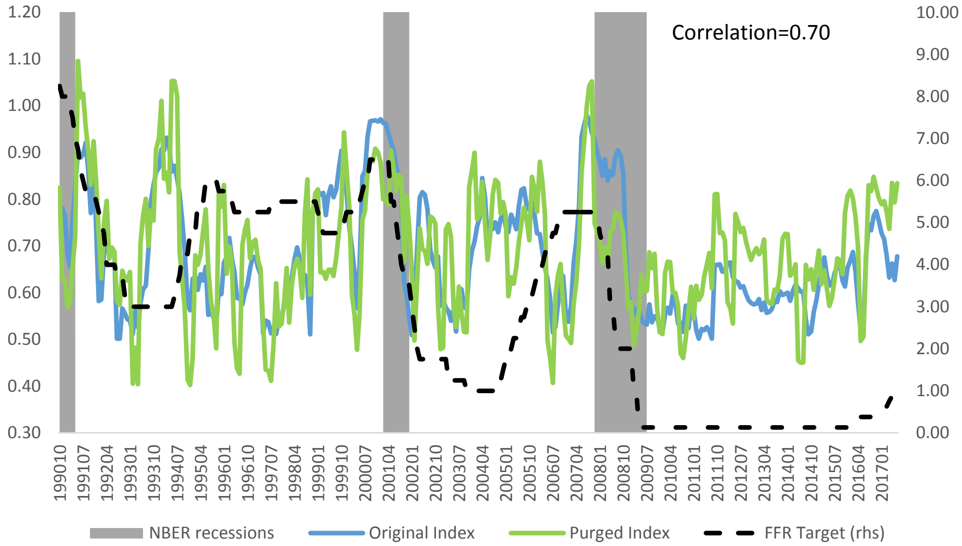
Note: This figure plots upside and downside uncertainty obtained from the twelve-months-ahead federal funds rate forecast errors from the BCFF survey.

Figure 27: ***Monetary Policy Uncertainty Index Purged of Macroeconomic Uncertainty (based on three-months-ahead expectations)***



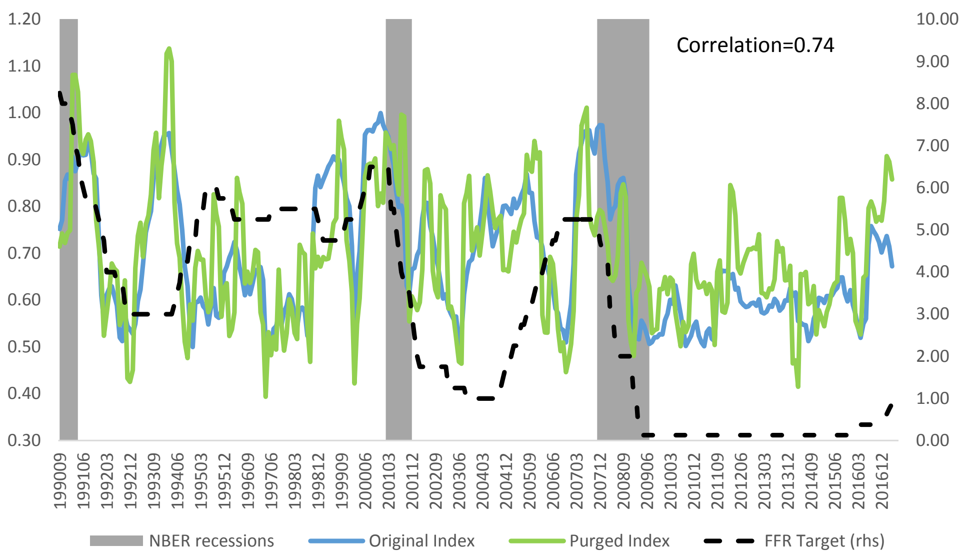
Note: This figure plots the purged uncertainty index: the normalized residuals of a regression of the federal funds rate uncertainty index obtained from the three-months-ahead BCFF forecast errors on the uncertainty indexes obtained from the three-months-ahead BCFF forecasts errors of output growth and inflation, respectively.

Figure 28: ***Monetary Policy Uncertainty Index Purged of Macroeconomic Uncertainty (based on nine-months-ahead expectations)***



Note: This figure plots the purged uncertainty index: the normalized residuals of a regression of the federal funds rate uncertainty index obtained from the nine-months-ahead BCFF forecast errors on the uncertainty indexes obtained from the nine-months-ahead BCFF forecasts errors of output growth and inflation, respectively.

Figure 29: ***Monetary Policy Uncertainty Index Purged of Macroeconomic Uncertainty (based on twelve-months-ahead expectations)***



Note: This figure plots the purged uncertainty index: the normalized residuals of a regression of the federal funds rate uncertainty index obtained from the twelve-months-ahead BCFF forecast errors on the uncertainty indexes obtained from the twelve-months-ahead BCFF forecasts errors of output growth and inflation, respectively.