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Monetary Policy Uncertainty and the Response of the Yield Curve to Policy Shocks

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Monetary Policy Uncertainty and the Response of the Yield Curve to Policy Shocks*

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Abstract

This paper studies the non-linear response of the term structure of interest rates to monetary policy shocks and presents a new stylized fact. We show that uncertainty about monetary policy changes the way the term structure responds to monetary policy. A policy tightening leads to a significantly smaller increase in long-term bond yields if policy uncertainty is high at the time of the shock. We also look at the decomposition of bond yields into expectations about future policy and the term premium. The weaker response of yields is driven by the fall in term premia, which fall even more if uncertainty about policy is high. These findings are robust to the measurement of monetary policy uncertainty, the definition of the monetary policy shock and to changing the model specification. Conditional on a monetary policy shock, higher uncertainty about monetary policy tends to make yields of longer maturities relatively more attractive. As a consequence, investors demand even lower term premia. This intuition is supported by *long-term* monetary policy disagreement, which leads to opposite effects with term premia increasing even more after a policy shock.

Keywords: Monetary policy uncertainty, term structure, term premium, unconventional monetary policy, local projections

JEL classification: E43, E58, G12

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1 Introduction

The term structure of interest rates, that is, the range of bond yields across the maturity spectrum, is closely tracked by central bankers and market participants. The reason for this is twofold. First, long-term interest rates should contain information about the public's expectations about future monetary policy. Central banks use the term structure to study the stance of monetary policy perceived by markets. Second, the term structure itself can be a policy target. Unconventional monetary policies such as forward guidance and asset purchases, which the Federal Reserve (Fed) implemented after the financial crisis, were designed to reduce long-term interest rates and, hence, to flatten the yield curve at the zero lower bound. The latter dimension implies that monetary policy can, to some extent, affect nominal interest rates for longer maturities. This paper studies the Fed's ability to steer bond yields if the public is uncertain about the future direction of monetary policy.

It is well established that monetary policy can move the term structure (Evans and Marshall, 1998; Cochrane and Piazzesi, 2002). In fact, the effect of monetary policy on longer-term yields is at the core of the monetary transmission mechanism. However, researchers derive this finding using linear regression models for large samples of time series without allowing for the connection between policy shocks and bond yields to vary over time. Here we study a specific source of non-linearity, the changing degree of uncertainty about future monetary policy. Even though monetary policy is now better communicated and more predictable than in the past, policy anticipation is less than perfect. This gives rise to a considerable degree of monetary policy uncertainty. Empirical evidence suggests that the degree of uncertainty about monetary policy can be large and volatile (see, among others, Husted et al., 2016). This motivates us to analyze whether monetary policy is less effective in driving bond yields if households and market participants have doubts about monetary policy in the future, which are incorporated in long-term yields.

In this paper, we provide new stylized facts on the response of the yield curve to monetary policy. We proceed as follows. First, we use data on fitted yields on U.S. governments bonds and estimates of expectations component, respectively, from Adrian et al. (2013a) and Kim and Wright (2005) and relate yields on bond of different maturities, the expectations component and the term premium to a monetary policy shock. The monetary policy shock is derived from asset-price responses on FOMC meeting days.

A series of local projections (Jordà, 2005) generates impulse response functions following a monetary policy shock. They show that bond yields increase after a policy tightening and term premia fall. Let us for a moment set aside the interpretation of

the latter finding.

Second, we use several measures of monetary policy uncertainty, which are news-based, market-based or survey-based. Among them are the narrative index provided by Husted et al. (2016), a measure based on forecasts derived by Istrefi and Muabbi (2017) and the variance of monetary policy surprises. In a separate exercise, we use measures of disagreement about future monetary policy, i.e. the dispersion of T-bill forecasts or forecasts of the inflation year 10 years ahead. These uncertainty measures are used to condition the impulse response of the term structure variables to a monetary policy shock on monetary policy uncertainty. Local projections are sufficiently flexible to accommodate the estimation of the non-linear term structure response to monetary policy shocks resulting from the interaction between the shock and the level of uncertainty. Our results suggest that the response of yields to a policy impulse is significantly reduced if uncertainty is high at the time the shock occurs. If uncertainty is two standard deviations above its sample mean, the response of 10-year yields can even become negative. To corroborate this findings, we also estimate asymmetric local projections in which we differentiate between tightening and easing shocks and state-dependent local projections, in which we differentiate between two regimes, a high-uncertainty and a low-uncertainty regime.

Third, in order to assess whether the muted policy effect on yields is coming from the response of the expectations component or the term premium, we estimate impulse responses of these two components of bond yields conditional on uncertainty. Interestingly, the response of expectations of future short-rates is insensitive to monetary policy uncertainty. However, term premia fall even stronger the higher is the degree of policy uncertainty at the time the shock hits. Hence, it is the term premium response that is behind the reduced grip of policy on bond yields. The results are robust to the measurement of monetary policy uncertainty and the nature of the monetary policy shock. The findings also survive when we control for other sources of policy uncertainty, control for recessions and condition on the exogenous component of monetary policy uncertainty only. Hence, this paper establishes a new stylized fact: the response of bond yields to policy shocks is muted if uncertainty is large. This is due to the response of term premia, which fall even stronger than under certainty about future policy.

The fall in term premia after a surprise tightening of monetary policy is well documented, see the evidence provided by Crump et al. (2017) as well as the theoretical results derived by Rudebusch and Swanson (2012). The term premium is the compensation that investors demand in order to be willing to hold longer-term securities instead of a revolving sequence of investments into short-term debt. If policy

tightens, the return on nominal securities increases. At the same time, the policy tightening leads to a fall in real economic activity and consumption. Hence, returns increase in a state of the world in which investors appreciate the additional interest rate income. As a result, investors require a smaller premium to hold bonds. This effect is larger for longer maturities. The presence of uncertainty about future monetary policy amplifies the fall in term premia. This is because the uncertainty about policy translates into uncertainty about nominal returns, which makes a longer maturity relatively more attractive compared to a shorter maturity. Hence, the term premium falls more strongly after a policy tightening if uncertainty is large. Put differently, our results suggest that for very *low* levels of monetary policy uncertainty, monetary policy becomes *more* effective in influencing the yield curve.

We lend additional support to this finding by also looking on disagreement about long-term inflation, measured as the inter-quartile range of 10-year ahead information forecasts from the Survey of Professional Forecasters. In contrast to the measures of monetary policy uncertainty discussed before, this proxies long-term disagreement. In the long-run, inflation is the dominating risk for investors into nominal securities. If we use this measure to interact monetary policy shocks, we find opposing results: term premia fall less if disagreement is high. This is because long-term disagreement, in contrast to short-term uncertainty or disagreement, makes longer maturities less attractive for investors following a policy shock. As a result, term premia increase rather than fall.

The results put forward in this paper offer several implications for the design and the evaluation of monetary policy. The response of the term premium is one important channel for the transmission of unconventional policies such as forward guidance. The effects of monetary policies designed to reduce long-term bond yields can become less effective if monetary policy uncertainty is large. In this case, term premia would increase and partly offset the stimulating policy impulse. For monetary policy uncertainty being very low, monetary policy becomes more effective and term premia fall even stronger. This calls for monetary policy to be as predictable as possible in order to avoid large swings in monetary policy uncertainty. Likewise, under uncertainty the yield on long-term bonds becomes a noisy indicator of the policy stance as the effect of policy is obscured by the offsetting influence of monetary policy uncertainty. Finally, our results also offer a perspective on interest rate "conundrums" (Alan Greenspan) seen in recent years. A policy tightening that goes hand in hand with flat or even falling bond yields could be the result of elevated levels of monetary policy uncertainty.

This paper rests on several strands of the empirical literature. First, since Baker et

al. (2016) proposed their Economic Policy Uncertainty (EPU) index, the literature on the effects of uncertainty shocks has exploded. This literature mostly focuses on the broadly defined EPU and does not study the interaction of monetary policy with uncertainty.

Aastveit et al. (2017) present a paper that is closely related to this paper. They show that high levels of general policy uncertainty reduce the influence of Fed policy on real economic variables such as consumption and investment. In a similar vein, Castelnuovo and Pellegrino (2017) present results from a nonlinear vector autoregression and an estimated DSGE model which support the notion that uncertainty dampens the effects of monetary policy. While they focus on the end of the monetary policy transmission process, we study the early stage of the transmission from the central bank to interest rates. Although these authors look at broadly defined economic policy uncertainty, our results are consistent with their findings.

Another closely related paper comes from Andrade et al. (2016). These authors study forward guidance under heterogeneous beliefs of market participants. They extend a New-Keynesian model of monetary policy by heterogeneous interpretations of forward guidance announcements of the Fed. Their results show that ambiguity of policy signals can reduce the effectiveness of policies such as forward guidance. We show more general results suggesting that monetary policy uncertainty in general, not just ambiguity about forward guidance, reduces policy effectiveness.

A second strand of the literature studies the impact of empirical measures of uncertainty, often incorporated in survey data, on the term structure. Buraschi and Jiltsov (2005), Arnold and Vrugt (2010), Dick et al. (2013), Buraschi et al. (2014) and D'Amico and Orphanides (2014) propose models that use survey information and find that uncertainty about monetary policy or the inflation target, is a main driver of bond market volatility and the size of the term premium, respectively. The authors use information from surveys of financial professional forecasters to proxy uncertainty. D'Amico and Orphanides (2014) show that the probability distribution of inflation forecasts from the Survey of Professional Forecasters (SPF) becomes an even more important driver of bond premia in periods of high inflation.

A third strand studies the effects of long-term inflation uncertainty on the term structure of interest rates. Cogley (2005) estimates a Bayesian VAR model that establishes a link between uncertainty about the inflation target and risk premia on long-term U.S. bonds. In a much cited contribution, Wright (2011) relates the fall in term premia in a cross-country data set to the fall in inflation uncertainty.

A fourth strand presents articulate term structure models which incorporate uncertainty. Ulrich (2013) explains term premia on U.S. bonds through Knightian un-

certainty about trend inflation. Creal and Wu (2014) build a term structure model where second moments, which reflect uncertainty, have effects on several macroeconomic variables including the yield curve. A general equilibrium model of the term structure is presented by Leippold and Matthys (2015). They show that an increase in policy uncertainty, either broadly defined using the EPU index or narrowly defined using the EPU-subindex on monetary policy, leads to lower bond yields but a high volatility of bond yields. Sinha (2016) presents a dynamic stochastic general equilibrium model for the yield curve. Uncertainty, which is calibrated with options data, reduces long-term bond yields.

In contrast to the literature, we do not look at the effect of uncertainty on the yield curve as such. Rather, we study the response of the yield curve to monetary policy shocks when future monetary policy is uncertain. It is the interaction of monetary policy shocks and uncertainty, that is, the nonlinear nature of the response of the yield curve that we are interested in.

The remainder of this paper is organized as follows. Section two introduces the data series used in this study. Among them are several alternative measures of monetary policy uncertainty and disagreement. Section three estimates the main model and discusses its findings, while section four sheds light on the robustness of our findings. Section five estimates a model that allows for an asymmetric effect of easing and tightening shocks. A state-dependent model is estimated in section six. Finally, section seven draws some policy conclusions. A web-appendix contains additional material.

2 Data

In this section we explain the data used in this paper. We start with data on bond yields and then discuss our benchmark measure of monetary policy uncertainty.

2.1 Yield curve data

To conceptualize the empirical approach of this paper, let us reconsider that the continuously compounded yield on an n -period discount bond, $y_t(n)$, can be decomposed as follows

$$y_t(n) = \frac{1}{n} \mathbb{E}_t [i_t + i_{t+1} + \dots + i_{t+n-1}] + tp_t(n) \quad (1)$$

$$= y_t^{\text{exp}}(n) + tp_t(n), \quad (2)$$

where i_t is the risk free nominal short-term interest rate and $tp_t(n)$ is the nominal term premium. Note that this decomposition describes an identity. In the absence of the term premium, the expectations hypothesis of the term structure of interest rates implies that the long-term yield equals the average expected short-term rate of the life of the bond. The term premium is the compensation investors demand for bearing interest rate risk. Hence, a time-varying term premium reflects the deviations of bond yields from what is implied by the expectations hypothesis. We refer to $y_t^{\text{exp}}(n)$ as the expectations component of bond yields.

In the following, we study how all three components of Equation (1) respond to monetary policy shocks and whether these responses are affected by monetary policy uncertainty. For that purpose, we use the results from the estimated linear term structure model of Adrian et al. (2013a). Throughout the paper, we focus on maturities of $n = 1, 2, 5, 10$ years.

These authors use the zero coupon yield data constructed by Gurkaynak et al. (2007) and provide estimated expectations components for all maturities. The term premium is then computed as the difference between yields and the estimated expectations component. The web appendix contains a graph of all elements of (1).

In the robustness section we will also use an alternative dataset on the yield curve based on the estimation of Kim and Wright (2005), which is also often used in the term structure literature.

2.2 Monetary policy uncertainty

In this paper, we use alternative measures of monetary policy uncertainty, MPU_t . We will also study measures of disagreement about future monetary policy.

Benchmark measure of monetary policy uncertainty. Our benchmark measure of monetary policy uncertainty is the newspaper-based indicator proposed by Husted et al. (2016). They construct a monetary policy uncertainty indicator which counts the uncertainty-related newspaper articles on the Fed in the *New York Times*, the *Wall Street Journal* and the *Washington Post*. The index reflects the uncertainty perceived by the public. We use the narrow MPU10 measure from Husted et al. (2016), which restricts the uncertainty-related terms in newspaper articles to appear in a proximity of at most 10 words to the words "Federal Reserve" or "monetary policy". We keep the broad index of Husted et al. (2016), i.e. the one without restrictions about the proximity of terms, for the robustness exercise below.

Since the raw data is very volatile, we construct a 12-month moving average, $\widehat{MPU10}_t$. The weighted average exhibits a smooth cycle in policy uncertainty. For the em-

pirical analysis below, we also demean this series and normalize it by its standard deviation

$$\widetilde{MPU10}_t = \frac{\widehat{MPU10}_t - \overline{MPU10}}{\sigma_{MPU10}},$$

where \overline{MPU} is the sample mean of the moving average index and σ_{MPU} is the standard deviation of the weighted index. This shows policy uncertainty in terms of standard deviations from its mean. Below, we will study scenarios of monetary policy shocks emanating from situations with policy uncertainty being one or two standard deviations above its mean. The same demeaning and normalization is applied to all other series such that the level and the fluctuations of uncertainty are comparable across measures. However, the other measures are not smoothed by taking moving averages, as they appear much less volatile.

Figure (4) shows that policy uncertainty fluctuates around a constant mean. It can be seen that policy uncertainty peaks before major policy changes. In 2002/2003, in a phase of unusually low interest rates, uncertainty is high due to concerns about the begin of the tightening cycle, which finally started in 2004. Likewise, policy uncertainty increases sharply before the lift-off of the federal funds rate in December 2015, after almost seven years with the policy rate at the zero lower bound.¹ In 2008/9, in contrast, monetary policy uncertainty is extremely low. Given the decline in both real activity and inflation and the increase in financial stress, the future course of monetary policy appears to have been relatively undisputed. It is worth mentioning that the post-2008 period of policy being constrained by the zero lower bound did not lead to a markedly higher degree of policy uncertainty.

Alternative measures of short-term monetary policy uncertainty. As mentioned before, we also use the MPU3 index of Husted et al. (2016), which is plotted in panel (b) of Figure (4). For this series, we also construct a 12-month moving average. It behaves very similarly to the MPU10 measure. The third measure is the subjective interest rate uncertainty index of Istrefi and Mouabbi (2017). They construct this series based on information on forecast disagreement in the Consensus Economics survey. To construct a measure of uncertainty and not only disagreement, they add information on conditional forecast error volatility along the lines of Lahiri and Sheng (2010). The specific measure we use is uncertainty based on the 3-month interest rate 12 months ahead, which is shown in panel (c) of Figure (4). The fourth measure of monetary policy uncertainty is probably the most straightforward. Since

¹In December 2015, when the Fed indeed tightened policy, which is not included in this sample, uncertainty falls to more normal levels.

the monetary policy shock series introduced below, the change of two year Treasury yields on FOMC meeting days, reflects the surprise component of the monetary policy stance, a natural measure of uncertainty is the squared surprise component. The series we use is the average squared shock over the previous six months, which is shown in panel (d) of Figure (4).

Figure (4) also contains information on NBER-dated recessions. During recessions, all measures of monetary policy tend to increase. This finding is consistent with the results of Fontaine (2016) and others. For our purposes, this pattern implies that we need to disentangle the effects of recessions on the yield curve and those of increases of monetary policy uncertainty. We address this issue in the robustness section of this paper.

2.3 Disagreement about monetary policy

We also use two measures of disagreement about monetary policy. Since disagreement is not necessarily representative for market uncertainty about future policy, we need to distinguish both dimensions carefully. The first measure is the inter-quartile range of forecasts from the Survey of Professional Forecasters (SPF). We use the 12 months ahead survey forecasts of 3-month T-bill rates. Forecasters covered by the Survey of Professional Forecasters are asked to give their expected 3-month T-bill several quarters ahead. We exploit this information and use the cross-section dispersion of T-bill expectations, measured as the inter-quartile range, that is, the difference between the 75th percentile and 25th percentile of the cross-sectional forecast distribution. Since the survey is conducted on a quarterly basis, we interpolate the forecast dispersion from a quarterly to a monthly frequency. The forecast dispersion is plotted in panel (e) of Figure (4). Disagreement about future interest rates peaks in the late 1980s, in the aftermath of the 2001 recession and in 2008/9 at the height of the financial crisis. Remarkably, during 2011/2012 when the Fed communicated to keep interest rates low for some time into the future, disagreement falls to a low, two standard deviations below its mean. According to the measure plotted here, these policies successfully reduced forecast dispersion.

The second measure is an indicator that reflects long-term disagreement, for example, about the inflation target pursued by the Fed in the long-run. The disagreement measure introduced before was reflecting short-term disagreement. For that purpose, we use the dispersion of the forecasts for the 10-year inflation forecasts included in the SPF. The underlying SPF forecasts are about the average inflation rate over the coming 10 years. Panel (f) in Figure (4) depicts the series of long-run inflation uncertainty in units of standard deviations from its sample mean. The series

reaches a low in 2005, suggesting that during the Great Moderation before the financial crisis, disagreement among forecasters about the long-run inflation rate was low. After the crisis, long-term disagreement fluctuated mildly around its sample mean. Interestingly, the correlation between the normalized inter-quartile ranges for the one year ahead 3-month T-bill rate and the 10-year ahead inflation rate is essentially zero. Hence, both indicators are orthogonal and reflect different horizons of monetary policy disagreement.

3 The empirical approach

This section introduces non-linear models to shed light on the transmission of policy to the term structure of interest rates.

3.1 Interacted local projections

We provide impulse responses to monetary policy shocks, ε_t , based on local projections (Jordà, 2005).² Local projections are preferable over vector autoregressions (VAR) due to their ability to handle non-linearities. Here, we extend the linear local projection with an interaction term that reflects the intertwined nature of monetary and monetary policy uncertainty. Each of the three elements from Equation (1), $y_t \in (y_t(n), y_t^{\text{exp}}(n), tp_t(n))$, dated $t + h$, is separately regressed on the monetary policy shock at t , ε_t , as well as lags of the vector \mathbf{x}_t , which includes y_t as well as other potential control variables

$$y_{t+h} = \alpha_h + \beta_h \varepsilon_t + \delta'_h \sum_{s=1}^q \mathbf{x}_{t-s} + u_{t+h}, \quad (3)$$

where u_t is the projection residual. This equation can be understood as one equation of a VAR system. Plotting the estimated β_h as a function of the horizon h gives the dynamic response of the dependent variable to a policy shock at t . The estimated β_h reflects the unconditional impact of a policy shock on h -periods ahead yields. We set $q = 2$, and the vector \mathbf{x}_t includes the dependent variable as well as our measure of monetary policy uncertainty, \widetilde{MPU}_t . If ε_t is a true shock, that is, an unexpected change in monetary policy, it should be uncorrelated with contemporaneous macroeconomic variables. Therefore, we do not include additional control variables. The source of the monetary policy shock is discussed below.

Since the dependent variable is dated h periods ahead, the error terms will exhibit serial correlation. We follow Jordà (2005) and apply a Newey-West correction to

²Aastveit et al. (2017) also obtain their findings from non-linear local projections.

our estimation errors. The maximum lag for the Newey-West correction is set to $h + 1$. The Newey-West corrected errors are used to construct confidence bands around our estimates.

One advantage of local projections is the flexibility to account for an interaction of policy effects. To shed light on whether the yield-response is stronger or weaker in times of high uncertainty about monetary policy, we extend this linear model to account for the interaction of a policy shock and the standardized measure of monetary policy, \widetilde{MPU}_t .

$$y_{t+h} = \alpha_h + \beta_h \varepsilon_t + \gamma_h \left(\varepsilon_t \times \widetilde{MPU}_t \right) + \delta'_h \sum_{s=1}^q \mathbf{x}_{t-s} + u_{t+h}. \quad (4)$$

The overall effectiveness of monetary policy consists of the unconditional effect, β_h , plus an effect that is conditional on policy uncertainty

$$\frac{\partial y_{t+h}}{\partial \varepsilon_t} = \beta_h + \gamma_h \times \widetilde{MPU}_t. \quad (5)$$

Below, we plot $\beta_h + \gamma_h \times \widetilde{MPU}_t$ as a function of h for different levels of \widetilde{MPU}_t . In particular, we look at impulse responses originating from levels of monetary policy uncertainty one or two standard deviations above its mean. We estimate the model for the maturities mentioned before, using monthly data over the sample period 1994:1 to 2015:11. The sample begins in 1994, when the Fed introduced post-meeting statements, and ends in the month before the "lift-off" of the Federal funds target rate in December 2015 after several years in which policy was constrained by the effective lower bound.

3.2 Monetary policy shock

It remains to specify the monetary policy shock, ε_t . Since linear projections, in contrast to VAR models, do not account for the mutual interaction between monetary policy and the business cycle, and hence identifying assumptions cannot be used to isolate shocks, an identified shock must be put into the model.

We use two alternative shock series, both of which are derived from the real-time financial markets response on FOMC meeting days. It is important to note that both shocks, which are used to estimate the nonlinear impact on yields, are not derived from a linear structural model. Our primary shock series is the daily change of two-year Treasury yields on FOMC meeting days. This series is also used in Hanson and Stein (2015). Under the assumption that on FOMC meeting days two-year Treasuries are driven only by news about monetary policy, this series reflects the

exogenous change to the monetary policy stance. This shock series is more suitable than changes in Federal Funds Futures, which are frequently used to measure the surprise change in interest rates, since Futures are severely affected by the zero lower bound on nominal interest rates. The shock series is shown in panel (a) of Figure (5).

The alternative shock series used below is taken from Swanson (2017). He applies the Gürkaynak et al. (2005) method and collects high frequency responses of several asset prices to FOMC announcements. From these responses, the author extracts three factors, which are then combined with identifying restrictions in order to correspond to the three main components of policy, that is, adjustment of the Federal Funds target rate, asset purchases and forward guidance.³ This shock series is presented in panel (b) of Figure (5). Since both shock series have a different variance, we normalize each shock by its standard deviation. The correlation between both shock series is 0.63.

3.3 Results

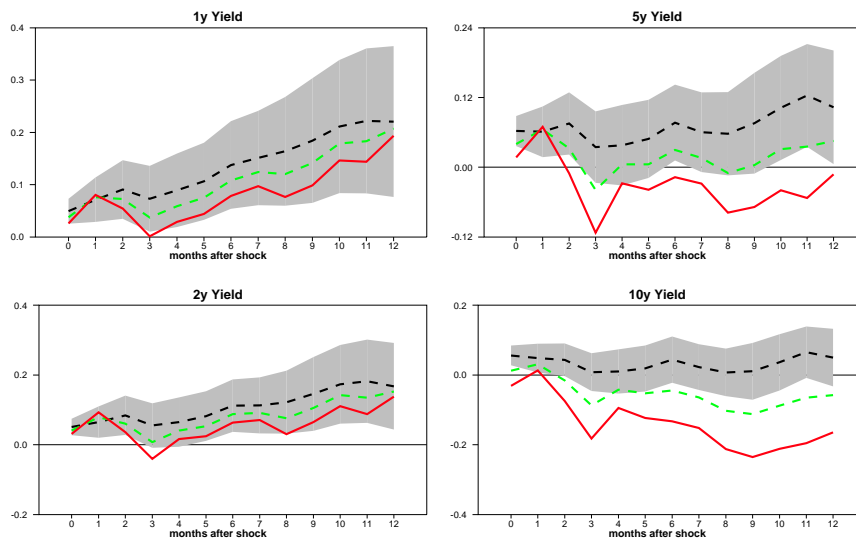
The resulting impulse response functions for bond yields are plotted in Figure (1). In this figure as well as in all subsequent ones, the black, dashed line shows the unconditional response of yields to an identified monetary policy tightening, one standard deviation in size, which corresponds to the estimated β_h coefficient. We find that on impact, yields at all four maturities significantly increase. As expected, the response is stronger at the short end of the yield curve, hence the shock leads to a tilting of the yield curve. Furthermore, the response is more persistent at the 1-year horizon than at the 10-year horizon. Note that this response is not conditional on the degree of monetary policy uncertainty.

To visualize how elevated levels of uncertainty affect the transmission to the yield curve, we now plot the full response given in Equation (5) for a level of monetary policy uncertainty that is one (green, dashed line) or two standard deviations (red, solid line), respectively, above its sample mean. For shorter maturities, that is, one and two year maturities, we find that the impulse responses under uncertainty lie within the confidence band around the unconditional estimate. This implies that monetary policy uncertainty, at the time the shock hits the term structure, plays no role for the adjustment of short-term yields. However, for longer term yields, in our case five and ten year maturities, a higher degree of uncertainty leads to a

³We use Swanson's (2017) "split sample" identification. Before 2009, monetary policy shocks are surprise changes of the Federal Funds rate target or surprise changes to forward guidance. From 2009 onwards, monetary policy shocks are surprise information about asset purchases and surprise forward guidance announcements.

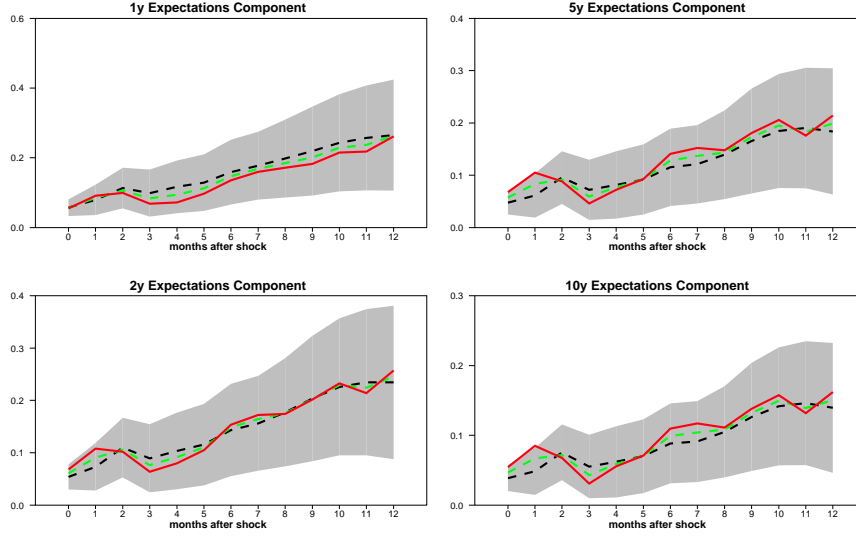
significantly smaller response of bond yields. For an uncertainty level that is two standard deviations above its mean, the response of the ten year yield even changes its sign. Overall, these results imply that monetary policy uncertainty severely impairs the Fed's ability to affect long term interest rates.

Figure 1: Response of yields to a monetary policy shock



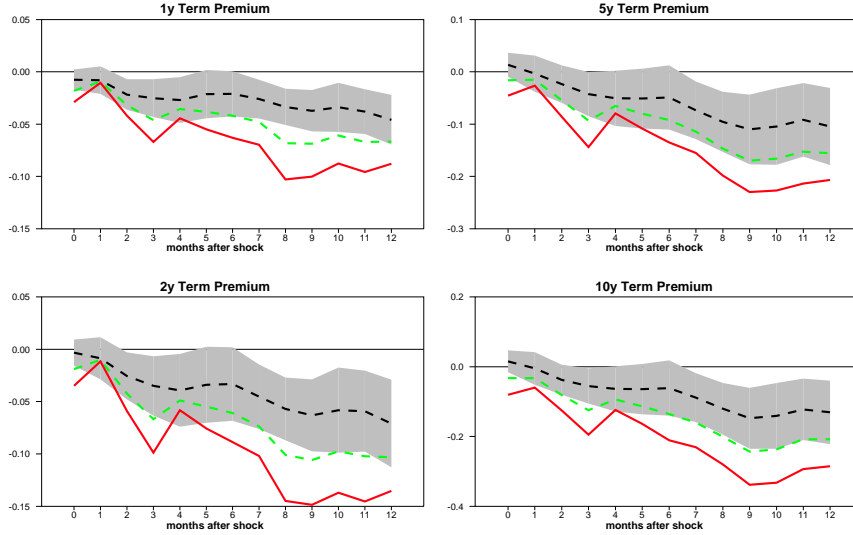
Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty measured by the MPU10 index being one or two standard deviations above its mean.

Figure 2: Response of expectations components to a monetary policy shock



Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty measured by the MPU10 index being one or two standard deviations above its mean.

Figure 3: Response of term premia to a monetary policy shock



Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty measured by the MPU10 index being one or two standard deviations above its mean.

Given the decomposition of bond yields in Equation (1), we now look at the two components of bond yields, the expectations component and the term premium, respectively. The results for the expectations components are shown in Figure (2).

The unconditional responses suggest that expectations about future short rates increase for all maturities. Under elevated levels of uncertainty, this response does not change significantly. This is because the impulse responses under monetary policy uncertainty are located within the confidence interval around the unconditional response. Hence, even higher levels of uncertainty do not hamper the Fed's ability to affect expectations about future policy. In light of the decomposition of yields, this finding implies that the response of the expectations component cannot explain the strong impact of uncertainty on fitted yields discussed in the previous paragraph. This leaves us with the term premium as the remaining element of (1) to explain the reduced effectiveness of policy under uncertainty.⁴ Figure (3) shows the responses of the estimated term premia to the policy shock. We find the response of term premia to unconditional policy shocks to be negative. Hence, a policy tightening leads to a reduction in term premia. The sign of this response is consistent with the results of Adrian et al. (2013b) and Crump et al. (2017). It is also consistent with the idea that monetary policy shocks depress consumption growth and lead to higher returns on risk-free assets. Hence, an increase in the bond's payoff when consumption growth is expected to be low, should make investors more willing to invest in longer-term bonds and lead to a lower risk premium.⁵

The question now is whether higher monetary policy uncertainty enforces or dampens this effect. Our central finding is that a policy tightening under uncertainty lead to an even larger drop in the term premium. As Figure (3) shows, shocks emanating from states with uncertainty being one or two standard deviations larger than the sample average lead to responses that are outside the confidence band around the unconditional estimates. Hence, it is the negative response of the term premium that holds the key to the smaller reaction of yields under uncertainty. The fall in the term premium after the shock is larger under uncertainty. This result is corroborated in several alternative specifications below.

What is the intuition behind this finding? As mentioned before, it is intuitive that the compensation demanded by investors in order to invest in the long end of the yield curve falls if policy tightens. This is the unconditional response. Under monetary policy uncertainty, investors are unsure about the short rate in the near future. Hence, the longer end of the yield curve becomes relatively more attractive than the short end. Investors would be reluctant to repeatedly invest into the short end. Consequently, the term premium falls even more than under certainty.

To conclude this section, let us stress that the model is non-linear but symmetric.

⁴As a matter of fact, "explain" does not mean a structural interpretation.

⁵The sign of this response is consistent with the findings of Rudebusch and Swanson (2012).

This means that the effects for a policy easing rather than tightening would be of identical size in absolute terms. A policy easing, such as implied by the unconventional measures the Fed implemented while the economy was at the zero lower bound, reduces long-term interest rates even more when uncertainty about policy is relatively low.

3.4 Short- and long-term disagreement about monetary policy

A measure of disagreement about future monetary policy is the difference of interest rate forecasts among forecasters at a given point in time. Here we use the inter-quartile range of the 3-months T-bill forecasts from the Survey of Professional Forecasters. The resulting estimates, again only for the 10-year maturity, are shown in Figure (13). We again find that contractionary policy shocks, originating in times of high disagreement, lower the term premium even more than shocks from normal times. For exceptionally low levels of disagreement, such as during 2011/12, we would find a positive response of the term premium to a tightening shock. This implies that a policy easing, which was implemented at that time, did have the expected effects and led to a lowering of term premia.

The interpretation of our findings rests on the assumption that the degree of uncertainty or disagreement is about the short to medium run only. Put differently, if our intuition is correct, the beliefs about monetary policy in the long-run, e.g. the anchoring of inflation expectations, should not be affected by current policy disagreement. To shed light on the impact of monetary policy shocks under long-term disagreement, we re-estimate the model for inter-quartile range of 10-year ahead inflation forecast from the Survey of Professional Forecasters as introduced before. Importantly, the disagreement about 10-year ahead inflation forecasts is supposed to capture long-run doubts about monetary policy.

Figure (12) contains the responses of the long end of the yield curve to the monetary policy shock conditional on long-run inflation disagreement. As mentioned before, the long-run risk for buyers of nominal bonds should be inflation as opposed to short-run policy uncertainty. We find support for our conjecture: conditional on disagreement, the response of yields has changed only marginally. Now the term premium response to monetary policy is muted if uncertainty is large - exactly the opposite of what we find under short-term interest rate uncertainty. Put differently, disagreement about the long-term inflation perspective makes longer maturities less attractive for bond investors, such that the term premium does not fall if policy tightens.

The following section strengthens this evidence by estimating models with other proxies for monetary policy uncertainty and different model specifications.

4 Robustness

This section presents evidence that corroborates and extends the results from the previous sections. To save space, we estimate each modification for the 10-year maturity and the Adrian et al. (2013a) dataset only.⁶

Swanson (2017) shocks. Figure (6) plots the response of the 10-year bond yield and its components to a Swanson (2017) shock, one standard deviation in size. Long-term nominal bond yields hardly respond to the policy shock. This is because the stronger decline of the 10-year term premium is compensated by the slightly stronger response of the expectations component.

Alternative measures of monetary policy uncertainty. The results for the MPU3 index of Husted et al. (2016) are very similar to the findings from the baseline model. To save space, these results are shown in the web-appendix. The results based on the 3M12M index of Istrefi and Mouabbi (2017) are shown in Figure (7). Following a monetary policy tightening, bond yields fall if uncertainty is large. This result is again driven by the response of the term premium. The response of the expectations component, however, is not affected by the degree of uncertainty. Figure (8) reports the results based on the moving average of past squared shocks as a measure of monetary policy uncertainty. Under uncertainty, the term premium responds stronger than under certainty. The effect, however, is slightly weaker than for other model specifications.

The role of NBER recession dates. It is well known that the effects of monetary policy on the real economy differ between phases of the business cycle (see Tenreyro and Thwaites, 2016). It could be argued that the loss in effectiveness of monetary policy with respect to bond yields reflects recessions, with monetary policy uncertainty simply being larger during recessions than during boom periods. To disentangle both factors, we run a regression in which the monetary policy shock interacts not only with the degree of uncertainty, but in a separate interaction term also with a dummy that is one during an NBER-dated recession and zero otherwise,

⁶Additional results, e.g. for the Kim and Wright (2005) data set, can be found in the web-appendix.

i.e. we control for policy effects condition on the stage of the business cycle. Figure (9) plots the impulse responses. We find that all results remain qualitatively unchanged. Hence, our baseline findings originate from fluctuations in monetary policy uncertainty and not from different states of the business cycle.

Purging MPU from other types of policy uncertainty Our measures of monetary policy uncertainty could potentially reflect other types of policy uncertainty. Besides counting newspaper articles on monetary policy as a crude way to measure monetary policy uncertainty, other sources of uncertainty may also manifest themselves in uncertainty about Fed policy. For example, political deadlock, i.e. genuine policy uncertainty, could lead to delays in the Senate confirmation of the candidate for the Fed chair.

We purge the measure of monetary policy uncertainty from general policy uncertainty. Specifically, we regress the raw MPU series on the Baker et al. (2016) index of general policy uncertainty. The residual, i.e. the part of MPU unexplained by policy uncertainty, is used for the interaction term in our model. The resulting responses are shown in Figure (10). We find the the results remain qualitatively unchanged.

The endogenous nature of monetary policy uncertainty. The empirical model used before interacts the monetary policy shock with a *given* level of monetary policy uncertainty. Thus, we assume monetary policy to be exogenous. This is a strong assumption that we might want to relax as a surprise change in the monetary policy stance, hence, a shock, potentially also reveals information and affects monetary policy uncertainty. Furthermore, recent monetary policies, such as forward guidance, have specifically been designed to affect the public’s expectations and, as a result, to change monetary policy uncertainty.⁷

We construct a measure of monetary policy uncertainty that is purely exogenous, that is, orthogonal to the monetary policy shock. Creating such a measure requires us to extract the endogenous reactions of uncertainty to other macroeconomic variables. Here, we estimate an auxiliary VAR model that includes five variables: the log of industrial production, the log of the Consumer Price Index, the Wu and Xia (2016) shadow federal funds rate, monetary policy uncertainty and the Financial

⁷In the web-appendix we compare monetary policy uncertainty measured by all five indicators, three months before a forward guidance announcements to three months after the announcements. We draw on Del Negro et al. (2015) and Swanson (2017) and pick August 2011 and January 2012 as months in which important forward guidance information was issued by the Fed in its post-meeting statements. We see that uncertainty is lower in the months after the announcement than before.

Stress Index calculated by the Federal Reserve Bank of Chicago.

We then identify an uncertainty shock, a change in monetary policy uncertainty that is orthogonal to the other four variables in the system. This is accomplished by imposing that within a given period, monetary policy uncertainty responds to output, prices and monetary policy but not financial stress. Hence, the uncertainty variable is ordered forth and a simple Cholesky identification is imposed. This allows us to extract the shock component of uncertainty, which is orthogonal to the information contained in the VAR model. This shock component is then used as an interacting variables in our local projections. The resulting impulse responses are shown in Figure (11). The results do not change qualitatively.

Decomposing the response of the term premium. The nominal term premium on an n -period bond corresponds to the sum of the real term premium and the inflation risk premium. In our previous findings we show that the response of the nominal term premium under uncertainty drives most of the responses of bond yields. We now aim to understand which component of the nominal term premium is responsible for this. For that purpose, we take a series of estimated 10-year inflation risk premia for the U.S. from the recent work of Hördahl and Tristani (2014). Subtracting the inflation risk premium from the 10-year nominal term premium estimated by Adrian et al. (2013a) gives us a proxy for the real risk premium. In the next step, we estimate the baseline local projection separately for the nominal, the real and the inflation risk premium. Figure (12) depicts the resulting impulse response functions. We find that movements of term premium are mostly driven by real term premium. The real term premium falls after a policy tightening, and the effect becomes stronger if monetary policy uncertainty is high. The inflation risk premium, in contrast, does not respond at all to the monetary policy shock.

This result is consistent with the literature. Hanson and Stein (2015) show that the real term premium, even that for 10-year maturities, responds to monetary policy shocks. In the affine term structure model, Abraham et al. (2016) document that monetary policy is able to drive real term premia. They also argue that announcements of the Federal reserve about its asset purchase programs are mostly transmitted through reducing real term premia as opposed to inflation risk. Finally, Kliem and Meyer-Gohde (2017) show that the real term premium is a more important driving force for nominal term premia than inflation risk.

5 The asymmetric transmission of policy shocks

Using a non-linear but symmetric model so far, positive and negative monetary policy shocks lead to identical responses in absolute terms. It could be argued that the role of monetary policy uncertainty differs between tightening and easing cycles, respectively. Recently, Dahlhaus and Sekhposyan (2017) show that the effect of uncertainty on long-term interest rates is stronger in easing relative to tightening periods as long-term inflation expectations are more firmly anchored in tightening periods.

To assess whether the response of yields to monetary policy is affected by possible asymmetries, we distinguish expansionary and contractionary policy shocks along the lines of Tenreyro and Thwaites (2016). We modify the local projections introduced before and let the coefficients α_h and γ_h be different according to the sign of the shock, such that the modified model becomes

$$y_{t+h} = \alpha_h + \beta_h^+ \max[\varepsilon_t, 0] + \gamma_h^+ \left(\max[\varepsilon_t, 0] \times \widetilde{MPU}_t \right) + \beta_h^- \min[\varepsilon_t, 0] + \gamma_h^- \left(\min[\varepsilon_t, 0] \times \widetilde{MPU}_t \right) + \delta_h' \sum_{s=1}^q \mathbf{x}_{t-s} + u_{t+h}. \quad (6)$$

The coefficient β_h^+ (β_h^-) reflects the impact of a tightening (easing) shock. Additionally, the coefficient γ_h depends on the sign of the shock. The responses are asymmetric if $\beta_h^+ \neq \beta_h^-$ or $\gamma_h^+ \neq \gamma_h^-$. Below, in to simplify the interpretation, we plot $-\beta_h^-$ as well as $-\gamma_h^-$ for alternative levels of uncertainty.

The results are shown in Figure (15). The left column of the figure reports the impulse responses after an expansionary shock, while the right column shows the effects of a tightening shock. The findings are ambiguous. The unconditional response of yields after an easing shock is not significant. A tightening shock, on the other hand, leads to an increase in yields. This is consistent with the findings of Tenreyro and Thwaites (2016). The effect of monetary policy uncertainty, however, is symmetric across both types of shocks.⁸ We find similar patterns in the responses of term premia. The implication of this analysis is that our main findings are not driven by asymmetric responses to easing and tightening shock conditional on above-average levels of monetary policy.

⁸In Dahlhaus and Sekhposyan (2017), the effect of monetary policy uncertainty shocks is higher if conditioned on policy easing periods.

6 The state-dependent transmission of policy shocks

Another way of looking at non-linear monetary policy transmission to the yield curve is to separate two regimes that are characterized by different degrees of monetary policy uncertainty. Suppose there are two observable regimes, I and II. We construct a dummy variable, I_t , which is one if the economy is in regime I and zero if the economy is in regime II. For $I_t = 1 \forall t$ the model collapses to the linear benchmark presented before. State I stands for a regime with high monetary policy uncertainty and state II is the corresponding state with a low degree of uncertainty

$$I_t = \begin{cases} 1 & \text{if } \widetilde{MPU}_t > \tau \\ 0 & \text{if } \widetilde{MPU}_t \leq \tau, \end{cases}$$

where τ is the threshold that separates both states. We set $\tau = 0.0$, that is, the economy is in the high-uncertainty state 1 if monetary policy uncertainty exceeds its long-run average. If monetary policy uncertainty is lower than the sample mean, the system is in state 0. The model can now be generalized to

$$\begin{aligned} y_{t+h} = & I_{t-1} \left[\alpha_h^I + \beta_h^I \varepsilon_t + (\delta_h^I)' \sum_{s=1}^q \mathbf{x}_{t-s} \right] \\ & + (1 - I_{t-1}) \left[\alpha_h^{II} + \beta_h^{II} \varepsilon_t + (\delta_h^{II})' \sum_{s=1}^q \mathbf{x}_{t-s} \right] + u_{t+h}. \end{aligned} \quad (7)$$

In this model, the constant, the impact of policy shocks and the influence of the control variables are allowed to differ across regimes. The estimated β_h^I reflects the impact of monetary policy in the high-uncertainty state, and β_h^{II} is the dynamic multiplier of policy shock in the low-uncertainty state.

It is important to recognize that we do not need to assume that the system stays in one regime during the entire adjustment to shocks. It is sufficient that the economy is in a given state at the time the shock occurs. In contrast to VAR models, we do not derive impulse responses from iterating the coefficient matrices. This is one of the major advantages of local projections when it comes to estimating state-dependent impulse response functions.

The results are shown in Figure (16).⁹ Each figure contains the responses in the low uncertainty-state and the high uncertainty-state, together with the respective confidence bands. The results are fully in line with the findings obtained from the

⁹The web appendix shows that the distribution of tightening and easing shocks, respectively, is not very different across the two states.

interacted model discussed before. For the 10-year yields, policy shocks lead to an increase in yields independently of the level of uncertainty. When uncertainty is large, however, the impact turns negative. The figure shows that this pattern of yields is not reflected in the responses of the expectations components. Across all maturities, both responses overlap, suggesting no significant difference between the regimes. It is again the response of the term premia that is reflected in the behavior of yields. Term premia fall as a response to monetary policy, and fall even stronger if the policy shock occurs in a high uncertainty-regime. Hence, the results from the state-dependent model are completely consistent with those from the interacted model.

7 Conclusions

In this paper we studied the response of bond yields to monetary policy shocks. In particular, we conditioned the response to policy shocks on the degree of monetary policy uncertainty. We find that monetary policy uncertainty affects the way the yield curve responds to monetary policy. If uncertainty is large, a policy shock leads to a smaller increase in long-term yields compared to a situation with a low degree of uncertainty. This is because term premia fall even stronger as a reaction to a policy shock if future monetary policy is uncertain.

We argue that this is in line with the notion of the term premium as a compensation for interest rate risk. A tightening leads to a contraction in economic activity at a time when the return on nominal bonds increases. Standard asset pricing models suggest that in this case, investors should demand a lower premium for holding longer term maturities. Uncertainty about monetary policy makes shorter maturities less attractive compared to longer maturities, since policy uncertainty reflects uncertainty about the future short rate. As a result, investors demand even lower term premia when buying longer-term securities.

Our results have several implications for monetary policy. First, the Fed and other central banks increasingly rely on the management of expectations ("forward guidance") to steer monetary conditions if the policy rate is constrained by the effective lower bound. The aim of this policy is to lower long-term bond yields. Our results suggest that a monetary policy easing, e.g through promising to keep policy rates low, is fully effective in lowering yields only if monetary policy uncertainty is at or below its sample average. If policy uncertainty is large, which has been the case during some episodes at the effective lower bound, policy is less effective in reducing yields. Thus, our results call for monetary policy to be as predictable as possible in

order to be fully effective.

Second, the information content of the yield curve about the stance of monetary policy should be taken with a grant of salt. Often shifts in the yield curve are interpreted as reflecting changes in the expected stance of monetary policy. Not only is it difficult to account for the role of the unobserved term premium, but also is the link between changes in policy and the movement of long-term yields obscured by the presence of non-linearities. Our results point to a non-linear relationship between policy impulses and the yield curve that complicates the extraction of information from the yield curve.

Third, our results can add a new perspective on explaining Alan Greenspan's "conundrum". Between 2004:6 and 2005:2 the Fed tightened monetary policy by raising the target for the federal funds rate by 150 basis points. Surprisingly, during this tightening cycle the long end of the yield curve remained essentially flat.¹⁰ According to the expectations hypothesis of the term structure, we would have expected an increase in long rates. Alan Greenspan, the Fed chair at this time, famously coined this inconsistency a "conundrum".

If, at the time of the tightening cycle, uncertainty about monetary policy was high, our results suggest that 10-year bond yields can indeed remain flat or even decline after a shock. We find that uncertainty was indeed elevated during the 2004:6 to 2005:2 sample. Uncertainty was roughly one standard deviation higher than the sample mean. The previous finds suggest that an insignificant response of bond yields, or even a negative response due to a fall in term premia, is well within the range of possible outcomes.

One main question remains: does the non-linearity in the response of the yield curve transmit to the response of the real economy to monetary policy? Some preliminary results (not shown here) suggest that yields on corporate bonds and the dollar exchange rate also exhibit a smaller response to Fed policy if uncertainty is large. Likewise, Aastveit et al. (2017) show that consumption and investment respond less if general economic policy uncertainty, not uncertainty specifically about monetary policy, is high. This suggests that monetary policy uncertainty could also lead to a less effective transmission of monetary policy to the real economy. We leave this question for future research.

¹⁰See Backus and Wright (2007) and Hanson et al. (2017) for another interpretation on this period.

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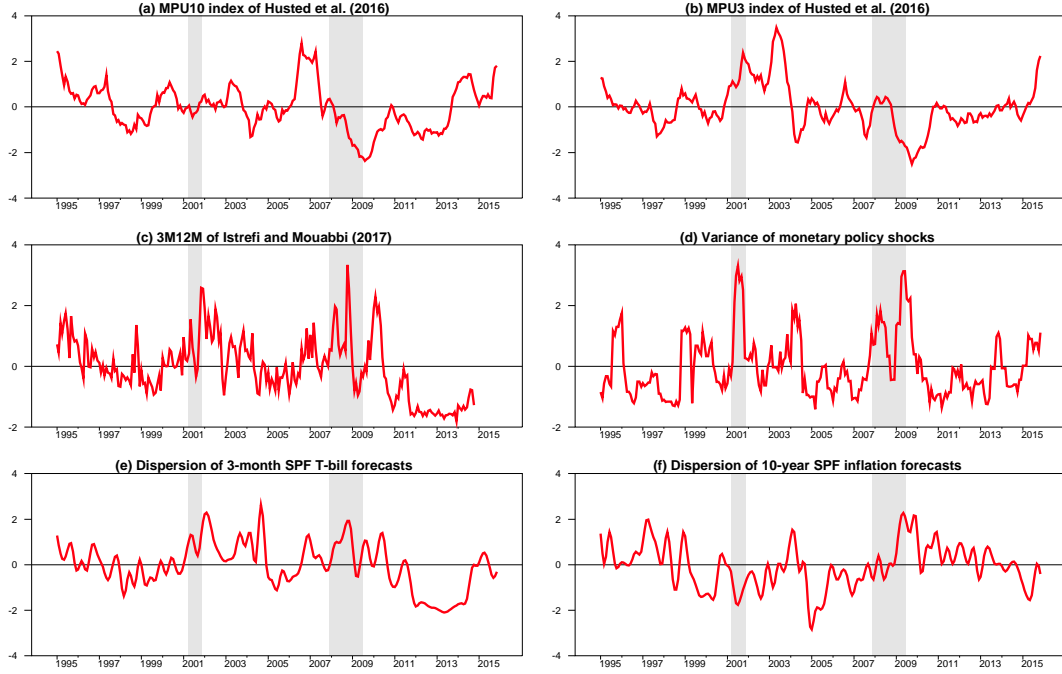
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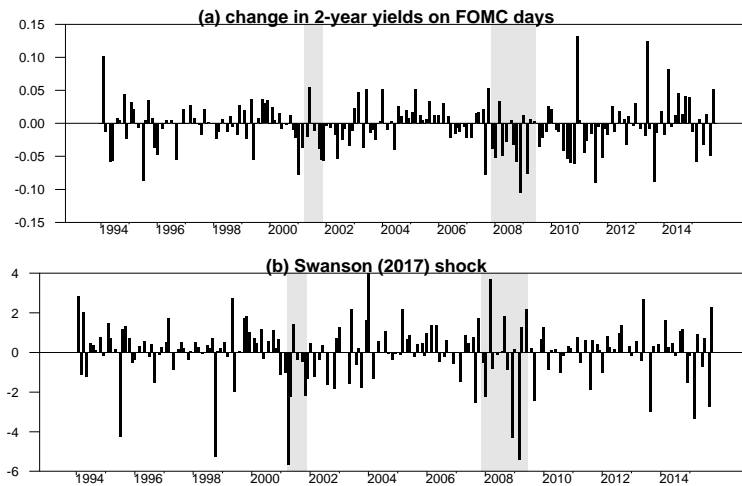
Appendix: Figures

Figure 4: Measures of monetary policy uncertainty and disagreement



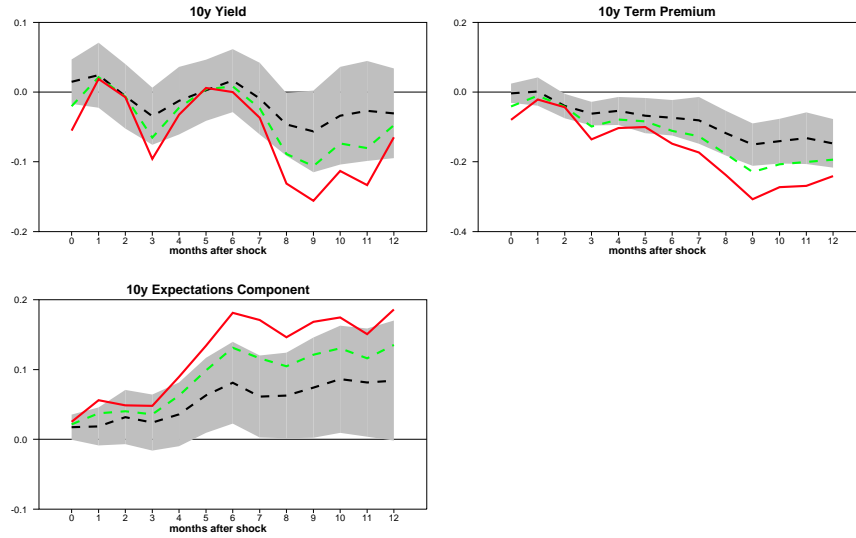
Notes: Measures of monetary policy uncertainty and disagreement in standard deviations from the sample mean. Details can be found in the main text.

Figure 5: Monetary policy shocks



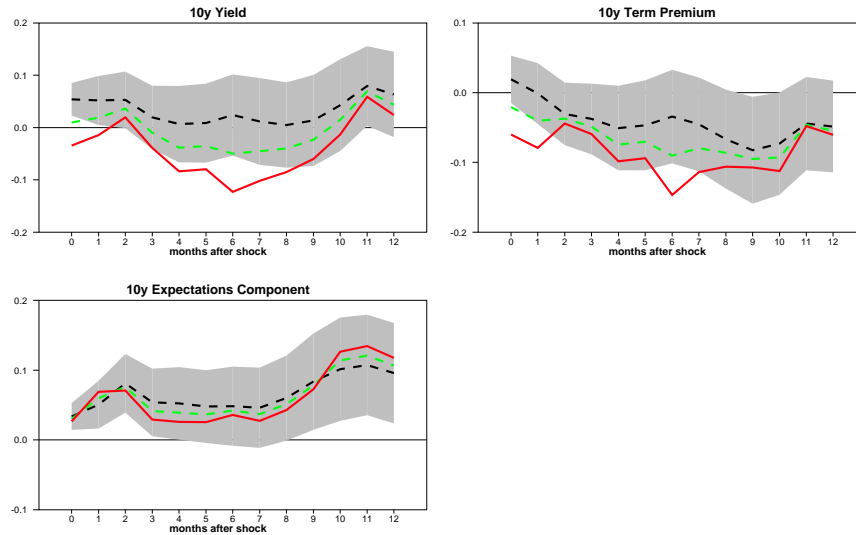
Notes: Panel (a) reports the change of yield on two-year Treasuries on FOMC meeting days measures in percentage points. Panel (b) shows the policy shock derived by Swanson (2017) based on the Gürkaynak et al. (2005) method measures in standard deviations.

Figure 6: Responses to a monetary policy shock: Swanson (2017) shock



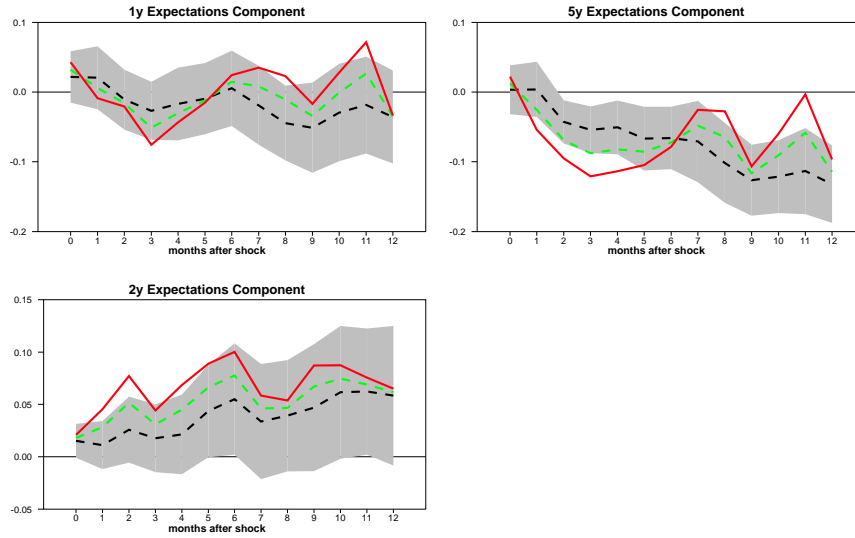
Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty, measured by the MPU10 index, being one (two) standard deviations above (below) its mean.

Figure 7: Responses to a monetary policy shock: 3M12M of Istrefi and Mouabbi (2017)



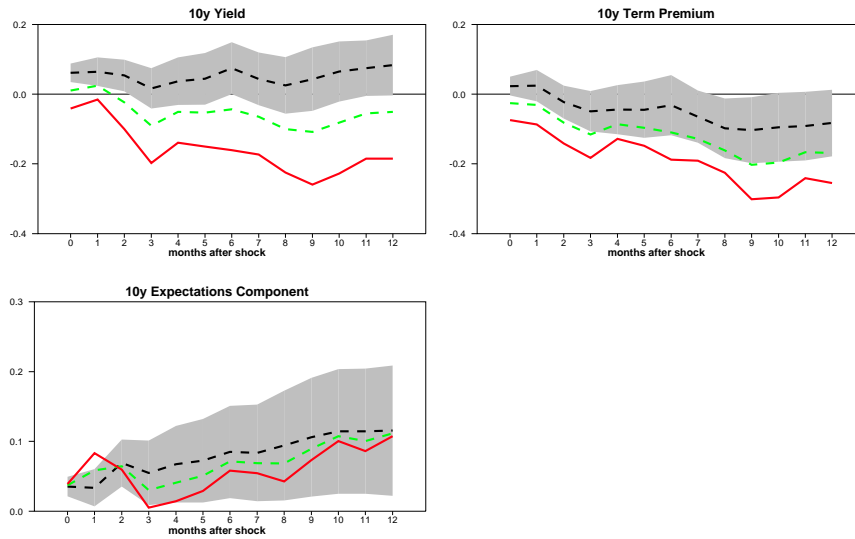
Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty, measured by the 3M12M index of Istrefi and Mouabbi (2017), being one or two standard deviations above its mean.

Figure 8: Responses to a monetary policy shock: variance of monetary policy shocks



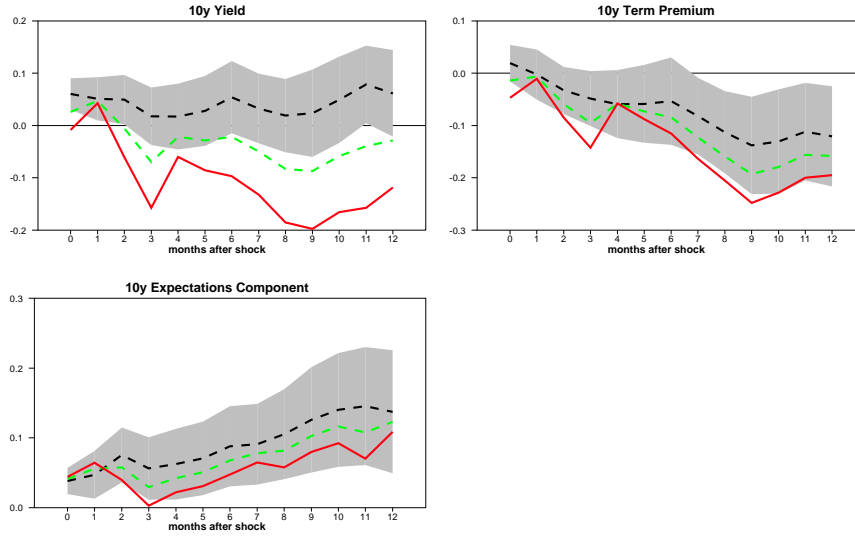
Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty, measured by the variance of the policy shock, being one (two) standard deviations above (below) its mean.

Figure 9: Responses to a monetary policy shock: NBER recessions



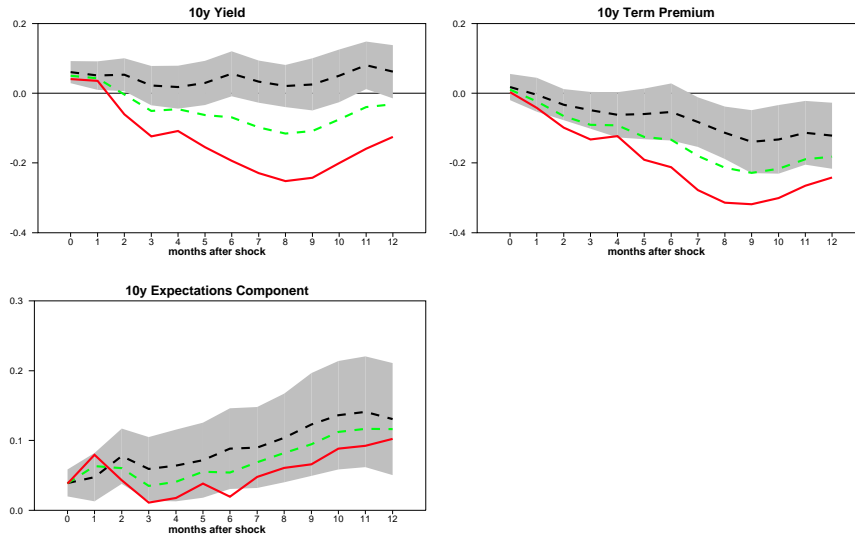
Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty, measured by the MPU10 index, being one or two standard deviations above its mean. We control for recessions by allowing for a second interaction term.

Figure 10: Responses to a monetary policy shock: controlling for other types of policy uncertainty



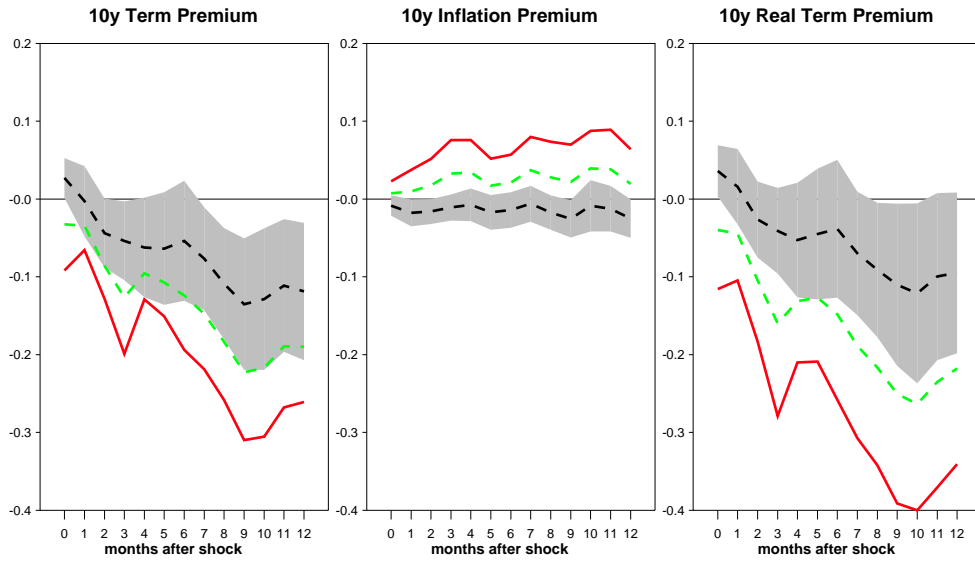
Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty, measured by the MPU10 index purged from other sources of policy uncertainty, being one or two standard deviations above its mean.

Figure 11: Responses to a monetary policy shock: exogenous component of monetary policy uncertainty



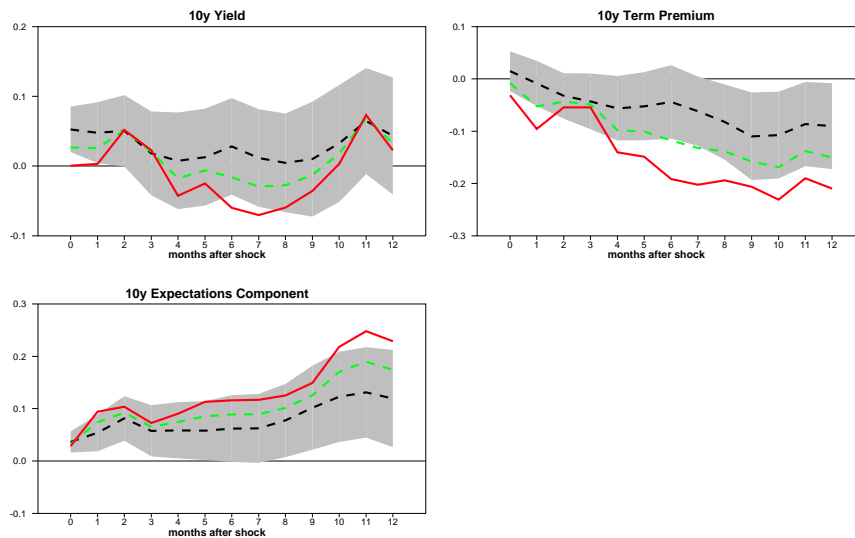
Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for the exogenous part of uncertainty, measured by the exogenous part of the MPU10 index identified through a VAR model, being one or two standard deviations above its mean.

Figure 12: Responses to a monetary policy shock: nominal term premium, inflation premium and real premium



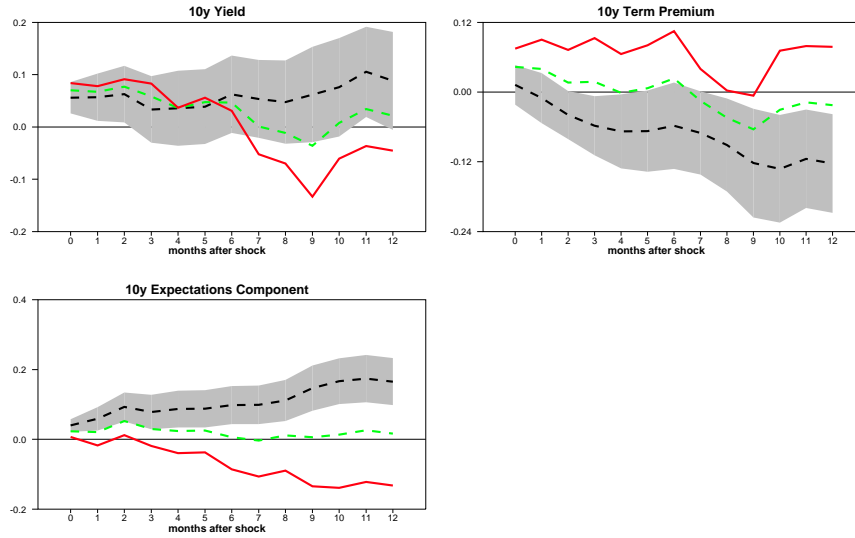
Notes: The black, dotted line is the unconditional response of real and nominal term premia as well as inflation risk to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty, measured by the MPU10 index, being one or two standard deviations above its mean.

Figure 13: Responses to a monetary policy shock: Disagreement of 3-month T-bill forecasts



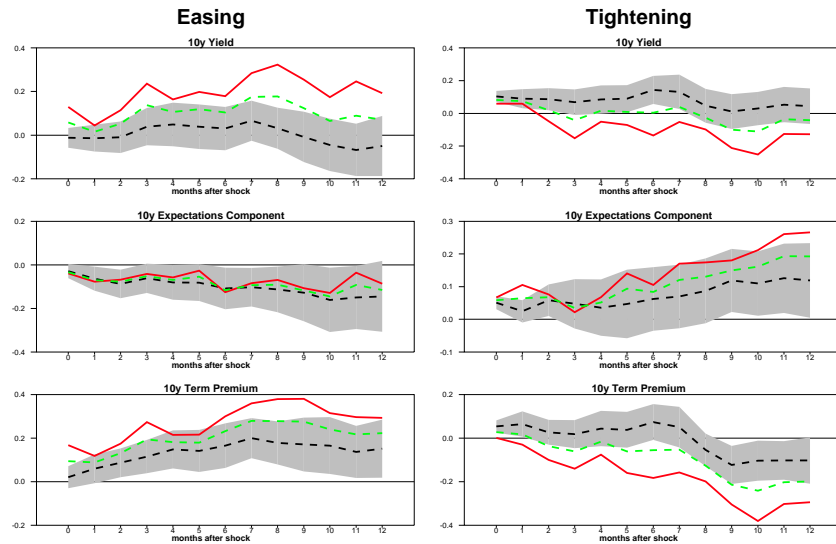
Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for the dispersion of Tbill forecasts being one (two) standard deviations above (below) its mean.

Figure 14: Responses to a monetary policy shock: Disagreement of 10-year inflation



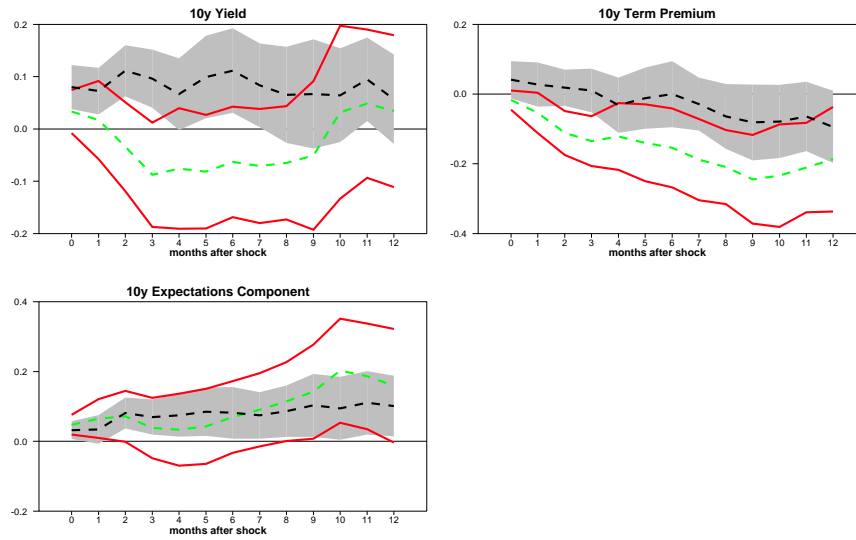
Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for the dispersion of inflation forecasts being one or two standard deviations above its mean.

Figure 15: Responses to a monetary policy shock: asymmetric responses



Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty, measured by the MPU10, index being one or two standard deviations above its mean.

Figure 16: State-dependent responses to a monetary policy shock



Notes: The black, dotted line is the response to a monetary policy shock in the low-uncertainty state with a 90% confidence band. The green, dotted (red, solid) line (confidence band) reflects the response in the high-uncertainty state.

Monetary Policy Uncertainty and the Response of the Yield Curve to Policy Shocks

Online Appendix

May 28, 2018

This appendix contains additional material which is not meant for publication in the journal. The additional material covers additional information on estimation results, additional robustness checks and the yield curve data.

1 Additional information on results

To illustrate the potentially endogenous nature of monetary policy uncertainty, we compare monetary policy uncertainty, measured by all five indicators, three months before a forward guidance announcements to three months after the announcements. We draw on Del Negro et al. (2015) and Swanson (2017) and pick August 2011 and January 2012 as months in which important forward guidance information was issued by the Fed in its post-meeting statements. In Figure (4), we find that uncertainty is lower in the months after the announcement than before.

Figures (5) and (6) show the unconditional distribution of monetary policy shocks and the distribution of shocks condition on the demeaned measure of monetary policy uncertainty being positive or negative, respectively. The purpose of these figures is to rule out alternative explanations of the state-dependence of monetary policy shocks. Since the distribution of tightening and easing shocks is relatively symmetric for monetary policy uncertainty being above and below the mean, respectively, our results are not driven by either positive and negative shocks being more important.

2 Additional robustness checks

Figure(1) shows the results based on the MPU3 measure of monetary policy uncertainty constructed by Husted et al. (2016). The effect of uncertainty on the response of the term premium is weaker, but still visible.

While the Adrian et al. (2013a) data is widely used in academic research, other estimates of the yield curve are available. In particular, the Kim and Wright (2005) dataset is a popular alternative. In order to check whether our results still hold, we change the yield curve estimates in our model. Figure (2) reports the results

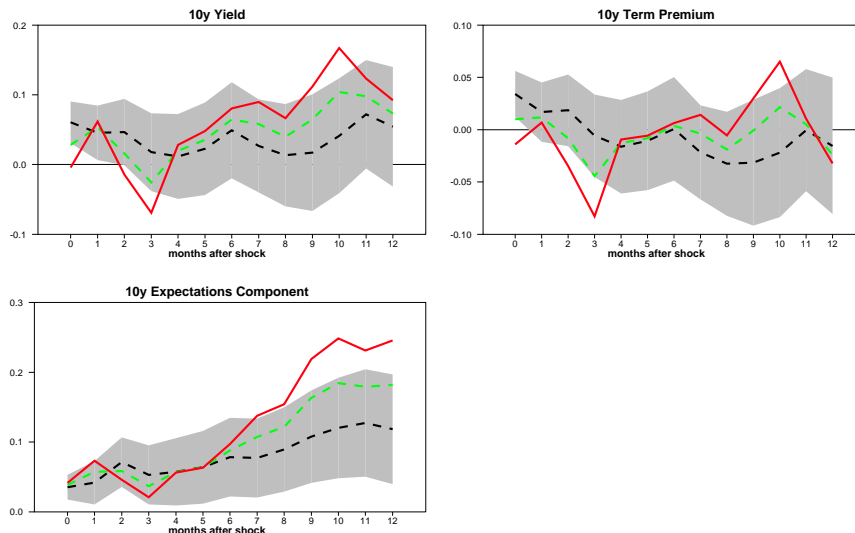
based on the 10-year yield and term premia estimated by Kim and Wright (2005) and the corresponding expectations component. The results remain very similar to our baseline findings.

To assess whether our results hold for a shorter sample that covers the recent financial crisis and zero lower bound (ZLB) on nominal interest rates, we estimate the baseline model for the sample period 2006 - 2015. Figure (3) presents the results. It can be seen that all major findings remain unchanged.

3 Data series

Figures (7) and (8) depict the yield curve data used in this paper.¹¹

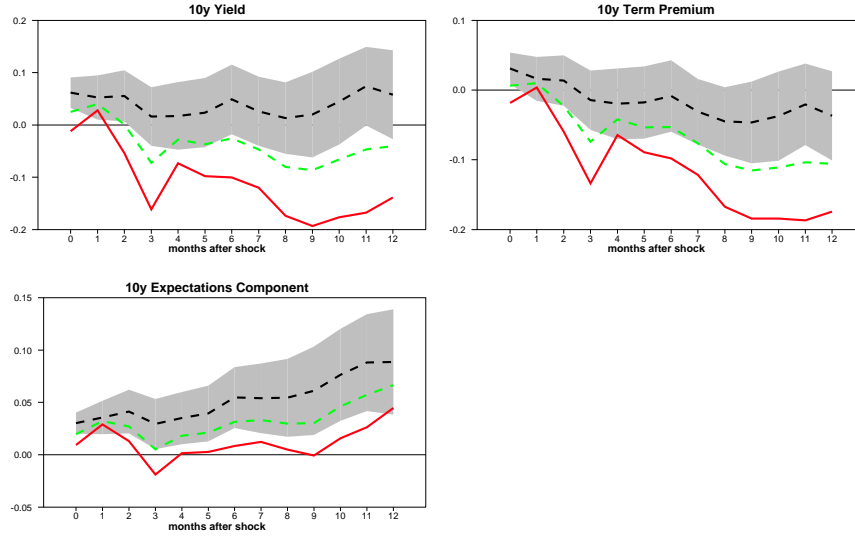
Figure 1: Responses to a monetary policy shock: MPU3



Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty, measured by the MPU3 index, being one or two standard deviations above its mean.

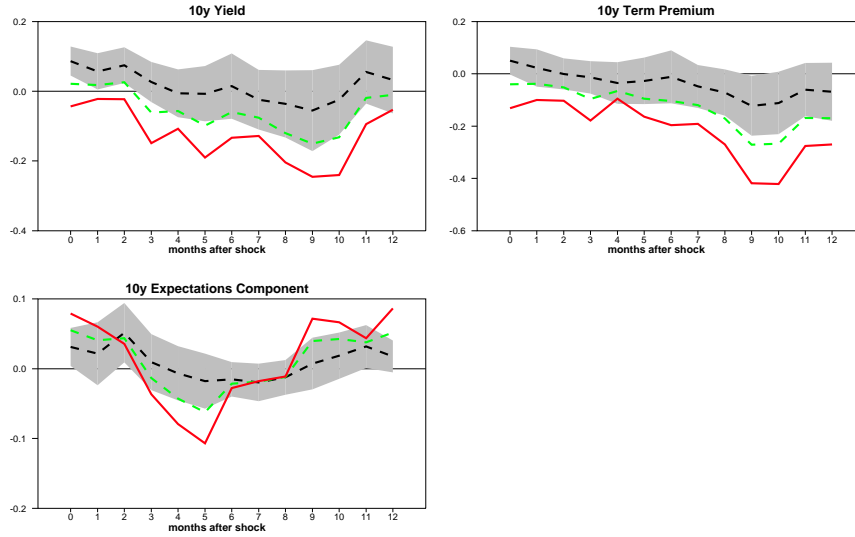
¹¹A comparison between both datasets is provided by Li et al. (2017).

Figure 2: Responses to a monetary policy shock: Kim and Wright (2005) data



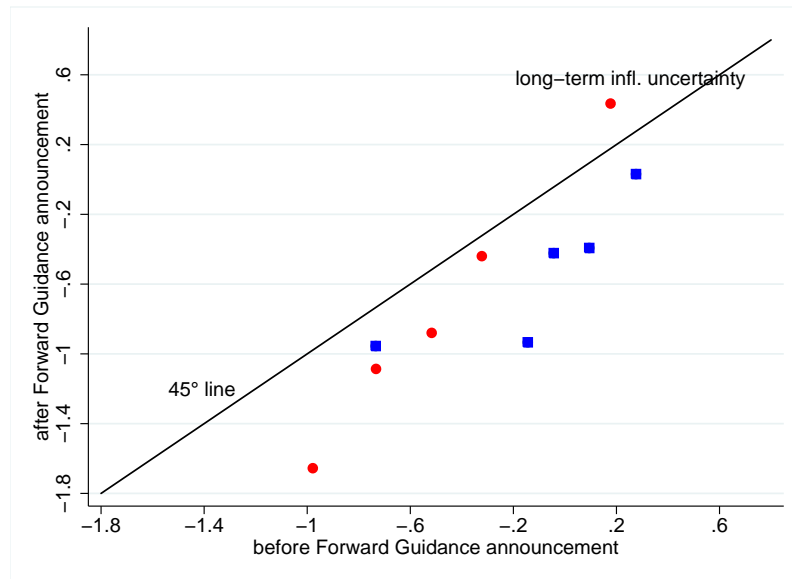
Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty, measured by the MPU10 index, being one or two standard deviations above its mean.

Figure 3: Responses to a monetary policy shock: subsample with ZLB



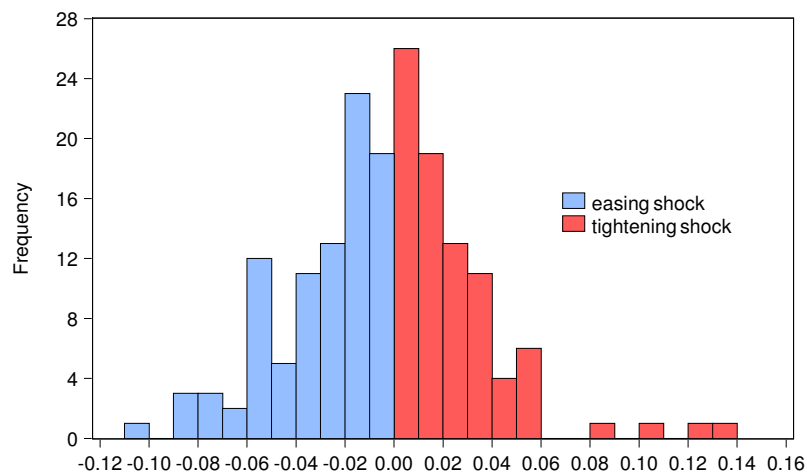
Notes: The black, dotted line is the unconditional response of bond yields to a monetary policy shock with a 90% confidence band. The green, dotted (red, solid) line reflects the response for uncertainty, measured by the MPU10 index, being one or two standard deviations above its mean.

Figure 4: Monetary policy uncertainty before/after forward guidance announcements



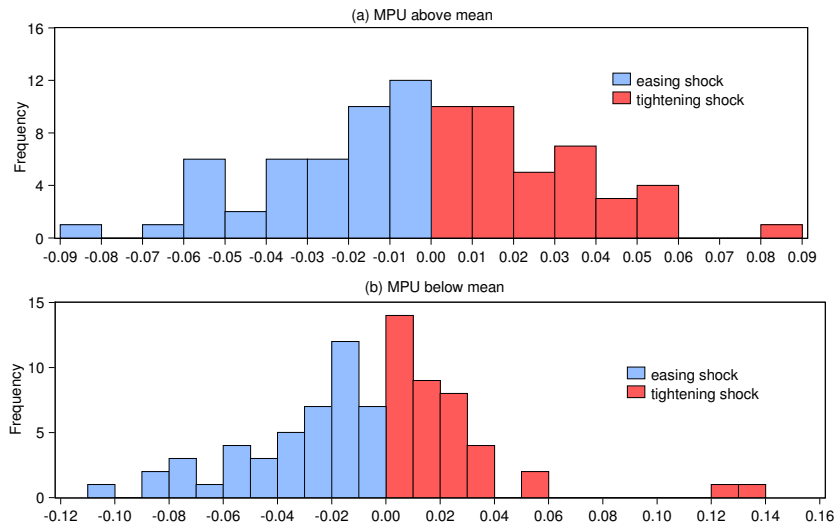
Notes: Monetary policy uncertainty in the three months after a forward guidance announcements compared to the three months before, for each uncertainty or disagreement measure (in standard deviations). The red (circles) reflect the August 2011 announcement, the blue (squares) the January 2012 announcement.

Figure 5: Distribution of monetary policy shocks



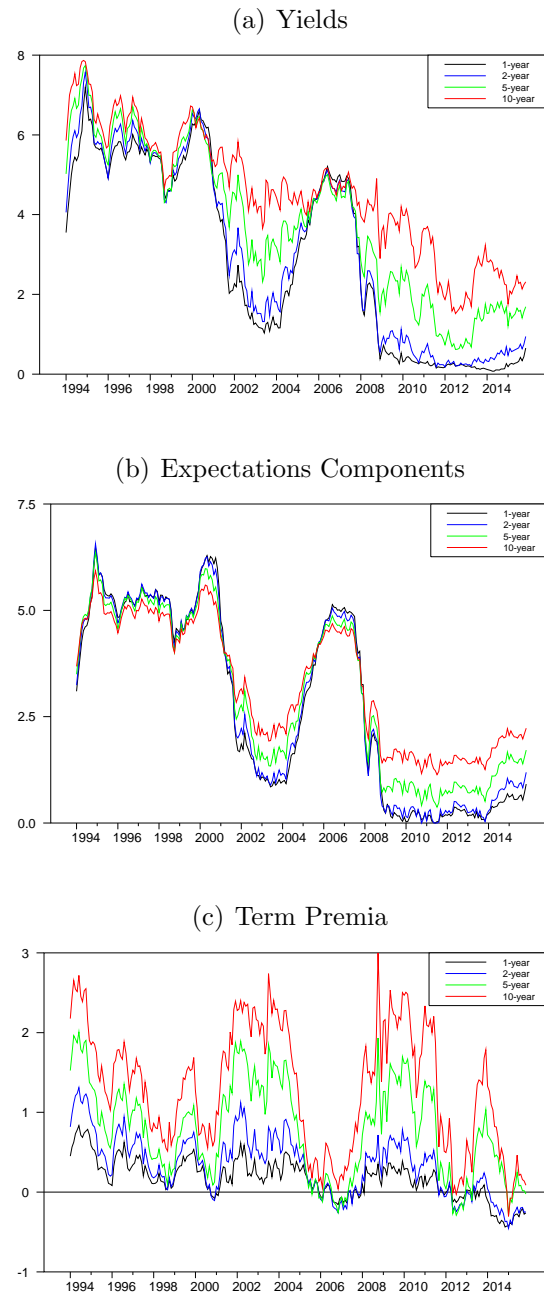
Notes: Distribution of change of two-year Treasury yields on FOMC meeting days.

Figure 6: Distribution of monetary policy shocks conditional on monetary policy uncertainty



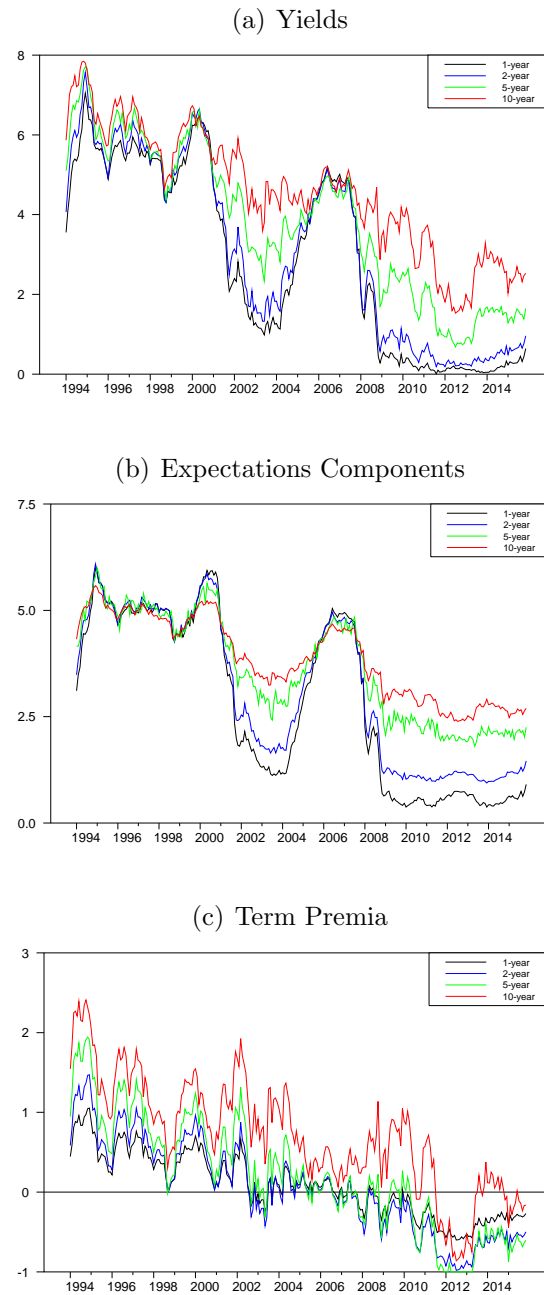
Notes: Distribution of change of two-year Treasury yields on FOMC meeting days conditional on monetary policy uncertainty, measured by the MPU10 index, being above or below its long run average.

Figure 7: Term structure data



Notes: Fitted yields, estimated term premia and implicit expectations components from Adrian et al. (2013a)

Figure 8: Term structure data



Notes: Fitted yields, estimated term premia and implicit expectations components from Kim and Wright (2005)

References

Li, C., A. Meldrum and M. Rodriguez (2017): “Robustness of long-maturity term premium estimates”, *FEDS Notes*, April 03 2017, Federal Reserve Board.