Disentangling the Information and Forward Guidance Effects of Monetary Policy Announcements*

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Abstract

Central bank announcements may comprise different information components. I use high-frequency financial market data and a theoretically founded identification scheme to disentangle FOMC announcements into a standard monetary policy shock, forward guidance regarding future interest rates and an information shock containing news about the economic outlook. My analysis shows that these different dimensions of monetary policy announcements have quite distinct effects on the term structure. Expansionary forward guidance leads to a persistent decrease in the term premium. The majority of the term premium response on announcement days is, however, caused by news about nominal risks to the economic outlook. Thus, for the transmission of forward guidance and information shocks to the real economy, the effects on market participants' expectations captured by the term premium turn out to be important. In a local projection analysis, I use the shock series as instruments to provide evidence for the effects of the different components of FOMC announcements. My results show a significant impact of the conventional monetary policy shock and the forward guidance shock on the real economy, without any evidence for a price or quantity puzzle. Further, information shocks have a considerable effect on actual and expected output growth demonstrating the importance of accounting for this additional component of monetary policy announcements.

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1 Introduction

Central bank communication as a monetary policy tool has become increasingly important in recent years, particularly since the possibilities to steer the economy via interest rate policy have been limited by the effective lower bound (Blinder, 2018; Cœuré, 2017; Weidmann, 2018). While the majority of the literature focuses on news about the future interest rate setting in monetary policy announcements (see Ramey, 2016, for a recent review), central banks also signal information about their perspective about the economic outlook to the public (Romer and Romer, 2000; Melosi, 2017). However, this implies an endogeneity problem for empirical research as market rate movements could reflect either an exogenous stimulus by the central bank or an updating of expectations by the market participants due to the new information.

Since Kuttner (2001) and Gürkaynak et al. (2005), there is a growing literature that uses changes in the nominal term structure in a short time window surrounding monetary policy meetings to quantify the surprise component of the respective announcement. These movements, however, do not represent a direct measure of exogenous monetary policy shocks. Campbell et al. (2012) and Nakamura and Steinsson (2018) argue that market participants also update their expectations about economic fundamentals in response to central bank announcements. Further, Cieslak and Schrimpf (2019) and Hansen et al. (2019) show that monetary policy affects long-term interest rates by providing signals about uncertainty and risks to the economic state. While both perspectives have in common that central bank communication moves the entire yield curve, they differ with respect to the mechanism through which long-term interest rates are affected. In general, interest rates on long-term bonds can be decomposed into two components: the average expected short-term interest rate for the duration of the bond and the term premium. News about economic fundamentals and the likely monetary policy response to that alter the expect path of the short-term interest rate. In contrast, higher uncertainty about the economic prospects leads investors to require a higher compensation for holding long-term bonds leading to an increase in the term premium.

In my paper, I provide a new identification strategy to disentangle the yield curve response on central bank announcement days into a monetary policy and a non-monetary policy related news component. Employing long-term inflation compensation forward rates as a market-based instrument for new information regarding the economic prospects that reflects both changes in the expected fundamentals and uncertainty about these expectations, I am able to construct a clean measure of monetary policy news. The remaining component represents all information gained by market participants that go beyond changes in the expected monetary policy path. Further, by using movements in the entire yield curve on announcement days, I can differentiate between a conventional monetary policy shock, i.e. a surprise change in the monetary policy rate, and a forward guidance shock. Collectively, I use these news components to provide new evidence for the effects of central bank communication on financial markets and the real economy.

Based on a standard New Keynesian model, I theoretically justify that long-term inflation compensation forward rates can be used to differentiate between surprises about the interest rate path and the information effect of central bank communication. In such models the expected path of inflation is determined by market participants' expectations about the current and future stance of monetary policy and by their assessment of economic fundamentals. However, as credible forward guidance is limited to a certain horizon, and given that the time for price adjustments is finite, monetary policy shocks should not affect very long-term inflation expectations.[1] Information about future economic prospects could, however, affect the distribution of beliefs among the market participants and thus long-term inflation compensation forward rates (Andrade et al., 2019).

To this end, I employ the high-frequency identification approach of Gürkaynak et al. (2005) and its extension by Swanson (2017). I extract three principal components from a broad range of asset prices for the sample period from July 1991 to September 2017 and rotate them in a way so that they have a clear structural interpretation. Based on the intuition provided above, I assume that high-frequency variations in five-year, five-year forward breakeven inflation rates implied by the TIPS market are solely driven by information related to economic prospects.[2] The residual asset price responses are partitioned into a component representing unexpected changes in the current monetary policy rate, i.e. the federal funds rate, and an orthogonal component which represents surprise changes in the future path of monetary policy. I call the latter forward guidance.[3]

My second contribution is that I provide new evidence for the effects of central bank communication on financial markets and the real economy using my identified measures of distinct monetary policy shocks and the additional information effect. First, I investigate how my identified shock instruments affect the term structure of interest rates by means of an event study. Importantly, I show that my information effect factor captures the news component of FOMC

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[1] Importantly, by focusing on long-term *forward rates*, the possibility that monetary policy is affecting even long-term interest rates is not excluded, as Hanson and Stein (2015) and Nakamura and Steinsson (2018) have shown recently. Rather, the restriction limits the horizon on which monetary policy may be able to alter expectations about the future.

[2] Market-based inflation compensation rates reflect both inflation expectations and an inflation risk premium. As shown by Abrahams et al. (2016), movements in long-term inflation compensation forwards are mainly driven by variations in the inflation risk premium. Further, the five-year, five-year forward breakeven inflation rate is a common measure for the degree of anchoring of inflation expectation in the literature. See, among others, Nautz et al. (2017).

[3] Note that the approach used in this paper does not identify specific unconventional monetary policy measures, e.g. explicit calendar-based forward guidance or large-scale asset purchase programs (LSAPs), and how they impact the economy. As discussed in Woodford (2012) and Bauer and Rudebusch (2014), LSAPs may affect the economy through similar transmission channels as forward guidance, i.e. the signaling channel of asset purchases. Consequently, the effects of different unconventional monetary policy measures may empirically interfere. For studies that explicitly identify specific monetary policy measures, see among others, Altavilla et al. (2019), Ciccarelli et al. (2017), and Swanson (2017). However, the approach outlined in this paper could be adopted following those papers to separately account for a LSAP shock.

statements that is concerned with nominal risks to the economic outlook.[4] Higher expected inflation represents bad news for future consumption and, thus, raises the term premium demanded by investors (Piazzesi and Schneider, 2007). Further, Rudebusch and Swanson (2012) and Crump et al. (2016) show that various demand and supply shocks move the nominal term premium as they lead to a persistent increase in inflation exactly when consumption is low. In a second step, I use local projection techniques to investigate the dynamic effects of my shocks on the real economy. Assuming that the three identified factors are at least correlated with the structural shocks of interest, I can recover the structural impulse response functions of macroeconomic variables by means of instrumental variables local projection (LP-IV). By explicitly accounting for the information effect, I provide new evidence for the efficacy of monetary policy.

In general, my findings highlight that the response of the term premium is key to understand how central bank announcements affect market participants' expectation and, thus, the real economy. I find that different monetary policy actions have quite distinct effects on the term premium: while a surprise cut in the short-term interest rate increases the nominal term premium moderately, expansionary forward guidance leads to a persistent decrease in the term premium. In line with Woodford (2012) and Filardo and Hoffmann (2014), this implies that forward guidance reduces uncertainty regarding the future path of the policy rate and, thus, reduces the risk compensation required by investors. As a consequence, expansionary forward guidance has a stronger impact on long-term rates than a target shock. Further, the information effect does not alter the expected average path of future short-term rates, but impacts the term premium strongly. By signaling higher long-term inflation risks, investors require a higher compensation for holding long-term bonds. Thus, the information effect represents additional news released during FOMC announcements that is orthogonal to the expected path of monetary policy.

With respect to the transmission of the different shocks to the real economy, my structural analysis similarly highlights the role of the term premium. An information shock that signals higher inflation risks does not only lead to an increase in the term premium, but also to a statistically and economically significant decrease in both actual output and output expectations. After controlling for the confounding news about the economic prospects, my monetary policy shocks have theoretically intuitive results. Expansionary forward guidance leads to a hump-shaped increase in output with a peak about one year after the announcement, while a conventional cut in the short-term interest rate has a persistent effect on the price level. Consequently, not accounting for the additional news component of central bank announcements reflected in movements of the term premium can distort the estimated impulse response functions of monetary policy shocks. This can explain the puzzling results regarding the effects of high-frequency identified

[4] While the information factor could theoretically also be driven by changes in the perceived inflation target of the FOMC, Abrahams et al. (2016) show that the inflation expectation component of TIPS inflation compensation measures is rather constant over the sample period.

forward guidance shocks reported in the literature (e.g. Lakdawala, 2019).

Related Literature: The paper is related to several strands of the literature. First and foremost, it contributes to the growing empirical literature on the Federal Reserve information effect (Romer and Romer, 2000; Barakchian and Crowe, 2013; Miranda-Agrippino, 2016; Melosi, 2017). Most closely related to this paper are Andrade and Ferroni (2016) and Jarociński and Karadi (2019). Jarociński and Karadi (2019) assume that information about the future policy path and about the economic fundamentals have contrary effects on stock prices. Similar to this paper, Andrade and Ferroni (2016) use high-frequency inflation expectation data to differentiate between forward guidance and an information effect. However, they use five-year inflation expectations for the Euro Area derived from inflation-linked swaps. Several aspects differentiate my paper from these papers. First, I perceive my identification strategy as complementary to the one of Jarociński and Karadi (2019). While their information effect reflects private information of the central bank about demand shocks, my information effect represents mostly nominal risks as inferred by bond holders. Further, my shock series appears to reflect mostly news about supply shocks: it increases long-term inflation expectations while lowering expected output. With respect to monetary policy, I explicitly distinguish between a standard monetary policy shock and forward guidance regarding the future short-term rate. Second, Andrade and Ferroni (2016) identify (Odyssean) forward guidance by assuming that one-year-ahead interest rates and five-year-ahead inflation expectations move in opposite direction. Market-based measures of inflation compensations reflect expected inflation rates and inflation risk premia. In fact, as shown in this paper, the effect of monetary policy announcements on risk premia is non-trivial. Movements in long-term inflation compensations can be the result of news about supply as well as demand shocks revealed by the central bank and, thus, can have opposing effects. Third, both papers use only one or two factors extracted from the term structure of interest rates. Consequently, they dismiss curvature information of the yield curve movements.

A number of recent papers show that an import transmission channel of monetary policy works through altering bond risk premia (Hanson and Stein, 2015; Abrahams et al., 2016; Crump et al., 2016; Kliem and Meyer-Gohde, 2017). Importantly, Cieslak and Schrimpf (2019) show that central bank communication events can be the source of risk preference shocks. While studying the co-movement between bond yields and stock returns, they identify non-monetary news revealed by central banks that affect market participants' assessment of economic fundamentals and their risk valuations. This paper contributes to this literature by providing evidence for the considerable and quite distinct effects of different monetary policy actions on the term structure.

Given the methodology employed, the paper also contributes to the literature that uses external instruments to analyze the dynamic effects of monetary policy. Gertler and Karadi (2015) highlight the importance of credit spreads and the term premium for the transmission mechanism of monetary policy using an SVAR identified with high-frequency data. In a more recent approach, Lakdawala (2019) decomposes conventional monetary policy into two components:

variations in the policy rate and in forward guidance. Applying the approach of Gürkaynak et al. (2005), he identifies two shocks by means of two instruments. In contrast to the results presented in this paper, he finds rather counterintuitive responses of output measures to forward guidance shocks, which he attributes to the presence of a potential information effect of central bank announcements. I contribute to this literature by explicitly showing the dynamic effects of these non-monetary policy related information.

2 Theoretical Effects of Monetary Policy

The goal of this Section is to provide a theoretical rationale for the identification strategy pursued in this paper. Starting from a non-stochastic steady state, the NKM can be expressed by the following Equations that represent the log-linearized intertemporal first order conditions around this steady state.[5]

$$\tilde{y}_t = \mathbb{E}_t[\tilde{y}_{t+1}] - \sigma(i_t - \mathbb{E}_t[\pi_{t+1}] - r_t^n) \tag{1}$$

$$\pi_t = \beta\mathbb{E}_t[\pi_{t+1}] + \kappa\tilde{y}_t \tag{2}$$

$$r_t = i_t - \mathbb{E}_t[\pi_{t+1}] = r_t^n + \varepsilon_{t,t-j}^{mp}, \tag{3}$$

$\tilde{y}_t$ denotes the output gap, e.g. describing the difference between the actual output in t, y_t, and the hypothetical flexible-price output level, y_t^n. Similarly, r_t^n denotes the equilibrium real interest rate when prices would be flexible - also referred to as the natural rate of interest. Both y_t^n and r_t^n are assumed to be functions of exogenous shocks to technology and preferences, respectively. The nominal interest rate i_t is the gross return on a risk-free nominal bond with a one-period maturity. π_t denotes inflation. Finally, $\varepsilon_{t,t-j}^{mp}$ denotes a monetary policy shock in period t as already announced in period $t-j$. All variables are denoted in percentage deviations from the steady state.

Equation (1) is the dynamic IS curve and (2) is the New Keynesian Phillips curve. Equation (3) is a simple rule where it is supposed that the central bank is able to manage the nominal interest rate so that the real interest rate tracks the natural rate of interest perfectly. The monetary policy rule deviates from the textbook representation as it is assumed that the central bank not only sets the current interest rate but also actively manages expectations about the future path of their policy by announcing future deviations from their particular policy rule.[6]

In the following, suppose an expansionary monetary policy announcement shock in terms of a negative deviation from the optimal policy rule in period $t+N$ that is announced in period t. Formally, we have $\varepsilon_{t+N,t}^{mp} < 0$. This implies that the current and expected future real interest rate gap is zero except for period N where $E_t r_{t+N} < E_t r_{t+N}^n$. Solving forward Equation (1),

[5] For a textbook presentation of the NKM see Galí (2008).

[6] The derivation builds on Andrade and Ferroni (2016).

this leads to a positive output gap, i.e. $\tilde{y}_t = -\sigma\varepsilon^{mp}_{t+N,t}$. Additionally, the expected output gap is positive for the subsequent periods until $t + N$. With respect to inflation, Equation (2) can be solved to

$$\begin{aligned} \mathbb{E}_t[\pi_{t+j}] &= -\kappa\sigma\frac{1-\beta^{N+1-j}}{1-\beta}\varepsilon^{mp}_{t+N,t} \qquad &\text{for } j \le N \\ &= 0 &\text{for } j > N \end{aligned} \tag{4}$$

using the expected path for the output gap. Up to period $t + N$, current and expected inflation are decreasing. After that period, monetary policy is expected to return to its optimal policy rule, adjusting r_t such that it equals the natural rate of interest r^n_t. The effect on the expected path for inflation can be translated into the effect on the path for the nominal interest rate using Equation (3).

$$\begin{aligned} \mathbb{E}_t[i_{t+j}] &= \mathbb{E}_t[r^n_{t+j}] - \kappa\sigma\frac{1-\beta^{N-j}}{1-\beta}\varepsilon^{mp}_{t+N,t} \qquad \text{for } j < N \\ \mathbb{E}_t[i_{t+N}] &= \mathbb{E}_t[r^n_{t+N}] + \varepsilon^{mp}_{t+N,t} \end{aligned} \tag{5}$$

r^n_t is assumed to be a function of the exogenous shocks to fundamentals like technology and preferences. As a consequence, the expectations of the future natural rate of interest can be modeled as a projection of the current state on the fundamentals, Ω_t,

$$\mathbb{E}_t[r^n_{t+j}] = \phi_j\Omega_t. \tag{6}$$

Combining (5) and (6), one can express the expected nominal interest rate in period $t + j$ as

$$\mathbb{E}_t[i_{t+j}] = \phi_j\Omega_t - \psi_j\varepsilon^{mp}_{t+N,t}, \tag{7}$$

where $\psi_j = \kappa\sigma\frac{1-\beta^{N-j}}{1-\beta} > 0$ for $0 < j < N$ and $\psi_N = -1$ as $\mathbb{E}_t[\pi_{t+N+1}] = 0$. Accordingly, the term structure of interest rates can be constructed as

$$\mathbb{E}_t[i_{t+N} - i_{t+j}] = (\phi_N - \phi_j)\Omega_t + (1 + \psi_j)\varepsilon^{mp}_{t+N,t}. \tag{8}$$

Assuming that in a short time-window surrounding monetary policy meetings the announcement by the central bank is the single event that affects the term structure, I follow Andrade and Ferroni (2016) and model monetary policy surprises as $\Delta_\epsilon(\mathbb{E}_t[i_{t+N} - i_{t+j}])$. As a monetary policy shock is a discrete event, equation (8) turns into

$$\Delta_\epsilon(\mathbb{E}_t[i_{t+N} - i_{t+j}]) = \Delta_\epsilon((\phi_N - \phi_j)\mathbb{E}_t[\hat{\Omega}_t]) + (1 + \psi_j)\varepsilon^{mp}_{t+N,t}, \tag{9}$$

where $\Delta_\epsilon(\mathbb{E}_t[\hat{\Omega}_t])$ denotes the potential revision of the expected evolution of the economic fundamentals due to the information revealed in the monetary policy meeting. The conventional high-frequency identification approach assumes that $\Delta_\epsilon((\phi_N - \phi_j)\mathbb{E}_t[\hat{\Omega}_t]) = 0$.[7] Thus, an ob-

[7] See Kuttner (2001), Gürkaynak et al. (2005), and Gertler and Karadi (2015) among many others.

served variation in the term structure around a monetary policy meeting could be interpreted as a measure for the monetary policy shock, either in terms of an exogenous variation in the current policy rate (if $N = 0$) or as a forward guidance shock (if $N > 0$).[8] However, monetary policy announcements do not only contain information about the monetary policy stance. For instance, the FOMC statements contain information about the assessment of the current economic conditions and discuss risks to the economic prospects. Moreover, the public may also infer information about the economic prospects from the actions of the central bank. If market participants interpret a given announcement as an endogenous response of the monetary policy authorities to economic conditions, they will update their expectations accordingly (Campbell et al., 2012; Nakamura and Steinsson, 2018). Consequently, the assumption that observed variations in nominal interest rates can be directly mapped onto the surprise component of monetary policy shocks seems rather restrictive.

In the following, I propose an instrument to disentangle the information released during monetary policy meetings into a component related to the current and expected path of monetary policy and a component reflecting changes in the expectations about the economic prospects. The economic intuition for the identification builds on the notion that central banks are limited in the horizon for which they can credibly communicate a path of their policy rate into the future. Consequently, the monetary policy related news component should effect market participants' expectations also only up to a certain horizon.

The assumption that there is an upper limit for how far in the future policy makers can affect market participants' expectations about the policy path can be justified by several strands in the literature. First, the analysis in Woodford (2012) shows that central banks rarely commit to a certain target rate for an extended period. Instead, central banks provide a projection for their policy rate conditional on their current information set. In terms of Equation (9), market participants perceive the new policy path as an exogenous deviation from the central bank policy rule, $\varepsilon^{mp}_{t+N,t}$, or as an endogenous response to the economic prospects that they have accessed differently so far, $\Delta_\epsilon((\phi_N - \phi_j)\mathbb{E}_t[\hat{\Omega}_t])$. However, announcing an exogenous deviation from the policy rate several months or years into the future bears the risk of losing reputation as a central bank. Forecasting errors increase with the horizon and, more importantly, the time-inconsistency problem related to such a commitment would become even more severe. Second, historically, the forward guidance of the FOMC was limited to a horizon of up to three years (Ehrmann et al., 2019; Lewis, 2019). For example, while using time-contingent forward guidance in 2011 and 2012, the FOMC explicitly referred to a period of "exceptionally low levels for the federal funds rate at least" for the next two or three years, respectively. The same is also true for the period where the FOMC linked its forward guidance to certain economic conditions. As it can be seen in the primary dealer survey conducted by the Federal Reserve Bank of New York,

[8] In reference to Gürkaynak et al. (2005) these shocks are commonly named *target shock* and *path shock*.

the median respondent mapped this forward guidance to a horizon of about two years out.[9] Lastly, the literature on limited commitment (Debortoli and Lakdawala, 2016) and on imperfect communication (Campbell et al., 2019) provides a micro-foundation for why it may not be optimal or not even possible to credible commit to a policy path several years into the future. In estimated DSGE models like in Del Negro et al. (2015) and Campbell et al. (2016) forward guidance is also modeled as a pre-announcement of future policy shocks with a fixed horizon.

In terms of the rationale discussed so far, suppose that the period $t + N + 1$ is beyond the horizon where monetary policy can effectively and credible communicate its policy path. The variation at the long end of the yield curve could not be driven by any announced policy actions, i.e. $\varepsilon^{mp}_{t+\tau,t} = 0, \forall \tau > N$. Consequently, this implies that any observed changes in the nominal term structure beyond N have to be driven by variations in the expected economic prospects.

$$\Delta_\epsilon(\mathbb{E}_t[i_{t+T} - i_{t+N+1}]) = \Delta_\epsilon((\phi_T - \phi_{N+1})\mathbb{E}_t[\hat{\Omega}_t]) \tag{10}$$

$$\Delta_\epsilon(\mathbb{E}_t[r_{t+T} - r_{t+N+1}]) + \Delta_\epsilon(\mathbb{E}_t[\pi_{t+T} - \pi_{t+N+1}]) = \Delta_\epsilon((\phi_T - \phi_{N+1})\mathbb{E}_t[\hat{\Omega}_t]). \tag{11}$$

Note that the last step made use of the Fisher equation. Due to the first-order log-linearization of the model equations, the baseline NKM framework derived so far implicitly alleges the expectations hypothesis of interest rates to hold. However, there is a huge literature that casts doubt on the strong implications of the expectations hypothesis (see Pflueger and Viceira, 2011, for a recent discussion). If one does not presume the expectations hypothesis of interest rates to hold, monetary policy may also affect bond risk premia. Thus, Equation (11) would become

$$\begin{aligned}\Delta_\epsilon(\mathbb{E}_t[i_{t+T} - i_{t+N+1}]) = \Delta_\epsilon(\mathbb{E}_t[r_{t+T,T} - r_{t+N+1,N+1}]) + \Delta_\epsilon(\zeta^{tp}_{t,T} - \zeta^{tp}_{t,N+1}) \dots \\ + \Delta_\epsilon(\mathbb{E}_t[\pi_{t+T,T} - \pi_{t+N+1,N+1}]) + \Delta_\epsilon(\zeta^{irp}_{t,T} - \zeta^{irp}_{t,N+1}),\end{aligned} \tag{12}$$

where $\mathbb{E}_t[r_{t+m,m}]$ and $\mathbb{E}_t[\pi_{t+m,m}]$ represent the average expected one period real interest rate and the inflation rate over the maturity m, respectively. The risk premium carried by the nominal bond can be split up in a real term premium required by investors for holding a long-term bond instead of recurring one-period bonds, $\zeta^{tp}_{t,m}$, and an inflation risk premium, $\zeta^{irp}_{t,m}$. The inflation risk premium compensates the bond holder for bearing the uncertainty regarding the exact future path of the inflation rate.[10]

As shown by Rudebusch and Swanson (2012), the upward sloping nominal bond market yield curve can be best explained by substantial long-run nominal risks instead of real risks.

[9] The Federal Reserve Bank of New York surveys primary dealers in the Treasury market, with results since January 2011 being available at https://www.newyorkfed.org/markets/primarydealer_survey_questions.html (accessed September 26, 2019).

[10] The introduction of real and inflation risk premia here is rather ad hoc and is used to rationalize the identification strategy. See Rudebusch and Swanson (2012) and Kliem and Meyer-Gohde (2017), among others, for fully micro-founded DSGE models yielding conclusions in line with this presentation.

Thus, Equation (12) collapses to

$$\Delta_\epsilon(\mathbb{E}_t[\pi_{t+T} - \pi_{t+N+1}]) + \Delta_\epsilon(\zeta^{irp}_{t,T} - \zeta^{irp}_{t,N+1}) = \Delta_\epsilon((\phi_T - \phi_{N+1})\mathbb{E}_t[\hat{\Omega}_t]). \tag{13}$$

Equation (13) implies that variations in long-run inflation expectation rates in a narrow window around monetary policy meetings result from market participants' update of their information set and revisions in their expectations about the economic prospects drawn from this information. Assuming that $\Delta_\epsilon(\phi_T - \phi_{N+1})$ is correlated with $\Delta_\epsilon(\phi_N - \phi_j)$ would yield that the left hand side of (13) can be used as an instrument for disentangling the effect of monetary policy announcement shocks and non-monetary information shocks as it is implied by Equation (9). For the empirical exercise in the subsequent Sections, it is important to note that market-based measures actually reflect inflation compensation - the sum of inflation expectations, risk and liquidity premia. So, neglecting the issue of liquidity premia, inflation compensations derived from financial market rates reflect the left-hand side of Equation (13).

Using changes in long-run inflation forwards as an instrument has the intuitive interpretation that monetary policy shocks and forward guidance would not alter the publicly perceived inflation target of the central bank. While policy makers may not unconditionally commit to a path for their policy rate several years into the future, inflation-targeting central banks are first and foremost interested in anchoring inflation expectations. Consequently, as long as the public perception was prior to the announcement that the monetary policy authorities were committed to price stability, surprise changes in the future policy path should not alter this perception.[11]

By providing information beyond the future policy path, central banks may also affect risk perceptions of market participants (Cieslak and Schrimpf, 2019). Using an affine term structure model to decompose the nominal and real yield curve, Abrahams et al. (2016) show that movements in long-run forward breakeven inflation rates derived from the TIPS market are mainly caused by variations in the inflation risk premium while long-run inflation expectations are fairly stable. Studying the drivers of the inflation risk premia, those seem to reflect forecasters' disagreement about future inflation. While aggregated long-run inflation expectations appear to be quite anchored, the information released during monetary policy announcements may affect the distribution of believes among market participants and, thus, cause movements in the term premium (Andrade et al., 2019). Alternatively, Hansen et al. (2019) argue for an uncertainty channel of central bank communication. In their model, central banks do not only signal new information about economic fundamentals, but also news concerning risks and uncertainty about the economic prospects. Similar to the rationale provided in this Section, those non-monetary news affect long-term interest rates predominately through changes in the term premium.

[11] A change in the long-run inflation target of the central bank may also yield a change in the long-run expectations. While this should result in a level shift of the expected inflation over different maturities, it should not affect the slope of the responses of the long-run expectations (see Nakamura and Steinsson, 2018).

3 Decomposition of the Dimensions of Monetary Policy Announcements

3.1 Main Data and Information Content of Asset Prices

In order to proxy for expected changes in the policy rate over different horizons, I mainly use the surprise component in federal funds futures and Eurodollar futures. While looking at changes in these asset prices on announcement days, one can correct for the ex-ante anticipated component of monetary policy. With respect to the seminal work of Gürkaynak et al. (2005), I extend their analysis in two ways. First, starting with the FOMC meeting in July 1991, I update the sample period until September 2017. Second, given that the federal funds rate was essentially at the zero lower bound between January 2009 and October 2015, there is little variation in short-term interest rate expectations. Following Wright (2012), I also consider the changes in Treasury yields. These time series may capture information about the surprise component of unconventional monetary policy measures, e.g. large-scale asset purchase programs (LSAPs), which work presumably on a much longer horizon than conventional monetary policy.

Specifically, the data set of asset price responses include the current-month and three-month-ahead federal funds futures contracts, the two-, three-, and four-quarter-ahead Eurodollar futures contracts, and the two-, five-, and ten-year Treasury yields.[12] Due to data availability issues, I have to rely on daily data. The dates of scheduled FOMC meetings are taken from the website of the Federal Reserve Board.[13]

I use the five-year, five-year forward breakeven inflation rate as the instrument to disentangle information about the future policy rate path and news about the economic prospects. This particular forward rate is commonly used in the empirical literature as well as in practice to assess the anchoring of inflation expectations (see Nautz et al., 2017, for an overview). The daily time series is taken from the data set constructed in Gürkaynak et al. (2010b) which is available on the Federal Reserve's website. The data set covers the period between January 1999 and September 2017.[14]

[12] The changes in the federal funds futures contracts are scaled by the number of days remaining until the end of the month (see Gürkaynak et al., 2005, for details). Accordingly, these series provide information about the change in the expected federal funds rate after the current and next meeting. The Eurodollar series indicate changes in the expected path of monetary policy over the horizon between four months and one year ahead. Finally, the Treasury yields provide similar information up to ten years into the future.

[13] For the overlapping periods, I matched the dates with the ones printed in the Appendix of Gürkaynak et al. (2005) and provided in the replication files of Nakamura and Steinsson (2018).

[14] The forward breakeven inflation rate is the inflation rate that equates nominal and real Treasury spot rates at a given maturity in dollar terms. These financial market rates do not only reflect expected inflation, but also the inflation risk premium and the liquidity premium present in the TIPS market. In order to account for the considerable high liquidity premias in the first years and during the Global Financial Crisis reported by Abrahams et al. (2016), among others, I exclude these periods from my regressions.

3.2 Factor Model and Identification of Distinct Shock Measures

To identify measures of distinct monetary policy announcement shocks, the responses of short-term interest rate futures and Treasury yields on FOMC meeting days are jointly modeled by a factor model. Collecting the responses of all considered asset prices on FOMC meeting days into a $T \times n$ matrix X, where $T = 222$ represents all the scheduled meetings and $n = 8$ is due to the eight asset series. Following Gürkaynak et al. (2005), X can be represented with a simple factor model

$$X = F\Lambda + \xi, \tag{14}$$

where F is a $T \times k$ matrix consisting of $k \leq n$ unobserved factors, Λ is a $k \times n$ matrix of factor loadings, and ξ is a $T \times n$ matrix of white noise disturbances. As shown in Swanson (2017), at least three latent factors, $k = 3$, underlie the response of the considered asset prices to monetary policy announcements when the sample includes the pre- and post-crisis period.[15] The latent factors can be estimated through principal component analysis. For this, I standardize X such that all columns have a zero mean and a unit standard deviation. The first three principal components explain roughly 94% of the variation in the data matrix X.

Akin to reduced-form VAR innovations, there is no reason why these factors should have any meaningful structural interpretation. Using a sufficient rotation matrix U, one can represent X by a factor model where the rotated factors $\tilde{F}$ have an economic interpretation as outlined in Section 2. Thus, Equation (14) can be rewritten as

$$X = F\Lambda + \xi = \tilde{F}\tilde{\Lambda} + \xi, \tag{15}$$

where $\tilde{F} = FU$ and $\tilde{\Lambda} = U'\Lambda$ for any $k \times k$ orthogonal matrix U. As $k = 3$, three restrictions about the behavior of the factors are sufficient to uniquely identify U. First, the factor representing the information effect is the single factor that is correlated with changes in the five-year, five-year forward breakeven inflation rate on announcement days. Second, with respect to the two monetary policy shocks, only the target shock loads into the current-month federal funds futures rate.

In spirit, the problem of finding a suitable rotation matrix equals the identification of an impact matrix in a SVAR analysis. The latent factors obtained from the principal component analysis can be considered as a weighted average of the underlying structural shock series. In the following, I will adopt the technique developed by Stock and Watson (2012) and Mertens and Ravn (2013) for identifying proxy SVARs to disentangle the two monetary policy shocks and the information effect shock.

Let $\tilde{F}_3 = FU_3$ be the information effect factor, while U_3 denotes the third column of the

[15] Swanson (2017) use the same set of financial market instruments but over a slightly shorter sample period. However, he utilize intra-daily data. In Appendix A, I provide reduced-form evidence that supports the assumption of $k = 3$.

rotation matrix U. The first identification assumption can be expressed as

$$
\begin{aligned}
E(m_t \tilde{F}'_{1,t}) &= 0 \\
E(m_t \tilde{F}'_{2,t}) &= 0 \\
E(m_t \tilde{F}'_{3,t}) &= \phi,
\end{aligned}
\tag{16}
$$

where m_t denotes a single external instrument variable. Using five-year, five-year forward breakeven inflation rates as a proxy variable, one can use the matrix-based closed-form solution presented in Mertens and Ravn (2013).[16]

As discussed by Gürkaynak et al. (2010b), among others, the TIPS market suffered historically from a considerable illiquidity in the first years after its establishment in 1997. Moreover, Abrahams et al. (2016) show that the liquidity premium in the real yields spiked up again in mid-2008 due to the financial market turmoils at that time. Consequently, I use only data for the subsample beginning with the FOMC meeting on January 31, 2001 and leave out the crisis period between June 2008 and June 2009. This implies that U_3 can actually only be explicitly identified for the post 2000 period. Thus, all the subsequent results are conditional on the assumption that the structural decomposition of the yield curve responses derived for this period holds for the entire sample period.

Having separated the effect of non-monetary policy information on the yield curve, one still has to decompose the two-dimensional monetary policy shocks. In the literature, the common approach is to assume that one dimension reflects the unexpected change in the current federal funds target while the other represents all surprise movements orthogonal to the first dimension. The first dimension, in the following referred to as *target shock*, should exclusively cause changes in the current-month federal funds futures rate as this contract matures before the next scheduled meeting. So, the target shock captures the surprise component of the interest rate decision by the Federal Reserve and may be interpreted as conventional monetary policy. The second dimension is identified by assuming that it is orthogonal to the first one and does not load into the current-month federal funds rate. It represents all information released during the FOMC announcement with respect to the future path of monetary policy as it is not affecting the current federal funds rate. Consequently, I will refer to this monetary policy dimension as *forward guidance*.[17]

While the restrictions solve uniquely for U and $\tilde{F}$ up to the sign of the individual factors, I suppose that the target factor has a negative effect on the current-month futures contract and the forward guidance factor has a negative effect on the four-quarter-ahead Eurodollar futures. Thus, both dimensions of policy announcements are cast in terms of expansionary monetary

[16] See Appendix B for details on the identification procedure.

[17] The outlined decomposition goes back to Gürkaynak et al. (2005) and is applied in Campbell et al. (2012) and Swanson (2017), among many others. Note that in parts of the literature the second dimension is called *path shock*. Details about the implementation of these restriction can be found in Appendix B.

policy. The information effect is normalized to have a positive correlation with movements in the forward breakeven inflation rate and long-run Treasury rates. Assuming that the information effect factor reflects nominal risks, the nominal bond holder will either expect a higher average short rate or demand a higher term premium. As unconditional higher inflation expectation may reflect anticipated positive demand shocks or negative supply shocks, it is a priori not clear whether a positive realization of the shock represents good news to the economic prospects.[18] In the following, I will present empirical evidence that underpins this duality in the information content of this shock series. Importantly, as the identification strategy does not depend on the fundamental cause that led to the variations in inflation compensation, the interpretation of the two monetary policy shock series is not affected by it.

3.3 Estimated Dimensions of Monetary Policy Announcements

In Table 1 the loadings of $\tilde{\Lambda}$ of the three factors are reported. The factors have by construction a mean of zero and a unit standard deviation. Accordingly, the coefficients can be interpreted as percentage changes of the respective variable due to a one standard deviation innovation of the respective factor.[19]

Table 1: Estimated Factor Loadings (Sample Period: 1991-2017)

	Target Factor	Forward Guidance Factor	Information Effect Factor
FF1	-1.00	0.00	0.00
FF2	-0.61	-0.57	-0.39
EDF2	-0.64	-0.72	-0.15
EDF3	-0.53	-0.80	-0.12
EDF4	-0.44	-0.87	-0.04
2y-TR	-0.46	-0.83	0.09
5y-TR	-0.29	-0.86	0.39
10y-TR	-0.16	-0.81	0.52

Note: FF1 and FF2 denote the current-month and three-month-ahead federal funds futures contracts, EDF2 to EDF4 denote the two-, three-, and four-quarter-ahead Eurodollar futures contracts, and the two-, five-, and ten-year Treasury yields are denoted as 2y-TR to 10y-TR.

[18] In principal, changes in breakeven inflation rates can be driven by movements in inflation expectations or risk premia. As it is shown by Gürkaynak et al. (2010a) and Bauer (2015), inflation compensation derived from TIPS data exhibit strong sensitivity to macroeconomic news and behave rather procyclical. In contrast, the risk premia are countercyclical, at least on business cycle frequency. Which effect dominates on a case-by-case basis is also not clear.

[19] All coefficients are significant at conventional levels as can be verified by regressing the asset price changes over the estimated shock series. Results upon request.

The first column of Table 1 shows the impact of the target factor. This factor is the dominating one with respect to its effect on the very short end of the yield curve. A one-standard deviation innovation leads to a roughly one percent decrease in the current-month federal funds futures rate. Changes in the implied rates of the current-month futures contracts track close movements in the effective federal funds rate. Consequently, the target factor can be considered as the surprise changes of the current federal funds rate. Further, the effect on the other interest rates decreases with increasing maturity. Given that monetary policy decisions are persistent in the sense that they are embedded in a medium run strategy, e.g. a monetary tightening cycle during an economic boom, an unexpected change in this component should affect interest rates with longer maturity as well.

The forward guidance factor has by construction no effect on the current-month federal funds futures rate. With respect to the other asset prices, the impact is hump-shaped with its peak effect on the four-quarter-ahead Eurodollar futures rate. This implies that innovations to this factor represent the surprise component of monetary policy announcements that particularly affects the expectations about the short-run interest rate that prevail one to two years in the future. The second factor, i.e. the forward guidance factor, reflects the information about the future path of monetary policy released by the announcement that go beyond the current interest rate decision (see for example Swanson, 2017).

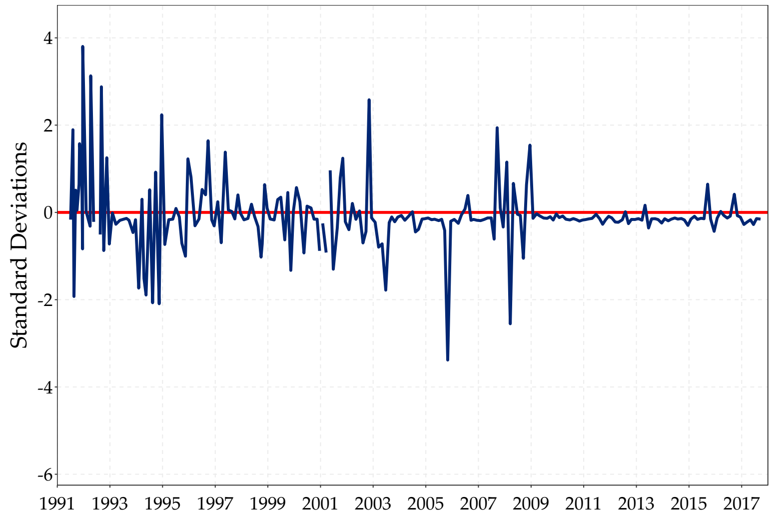
Finally, the third column of Table 1 reports the loadings of the information effect. Two things are notable. First, without restricting the loading for the current-month federal funds futures rate, the effect is almost zero. Similar to the forward guidance factor, the information effect represents information revealed during the announcement above and beyond the current interest rate decision. Second, the effect on the interest rates switches the sign on a horizon between one and two years. Compared to the monetary policy shocks, the information effect appears less persistent. With respect to the positive response of the Treasury yields, it is unclear without further inspection whether it is driven by higher term premia or higher expected short-term rates.

In Figure 1, the shock series are plotted. The shocks are measured in units of standard deviations. The time series exhibit remarkable differences. First, since the mid-2000s, the volatility in the target and the forward guidance shock seem to be reduced. This is especially true when one neglects the period of the Global Financial Crisis. As one would expect, the target factor is almost muted during the zero lower bound period. Forward guidance shocks, somewhat surprisingly, are also weak in this period. However, forward guidance seems to have played a more important role in the aftermath of the financial crisis as well as at the end of the zero interest rate period in 2015.[20] It is important to note that the shock series only reflect the sur-

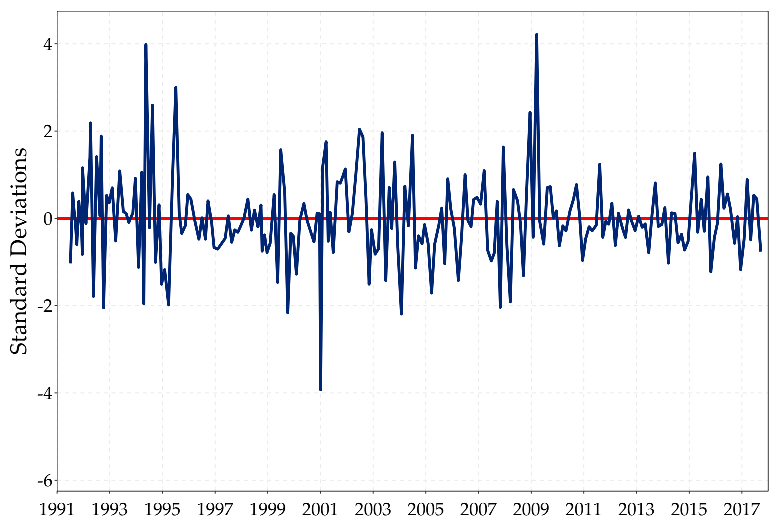
[20] The fact that forward guidance seems to be a major policy instrument of the Federal Reserve in the period before the financial crisis is consistent with the empirical results of Gürkaynak et al. (2005) and the historical accounts discussed in Campbell et al. (2012).

Figure 1: Estimated Factors (Sample Period: 1991-2017)

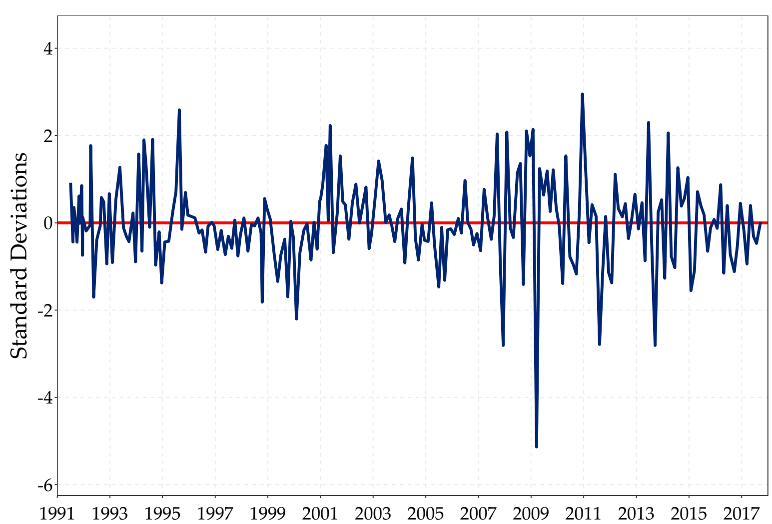
(a) Target Shock



(b) Forward Guidance Shock



(c) Information Effect



prise component of a certain policy action. Thus, the magnitude of the shocks does not have to reflect the efficacy of this measure.[21] The results of Lewis (2019) also imply that once forward guidance was issued, markets largely expected it to continue until informed otherwise. More generally, the declining volatility in the monetary policy shocks is in line with the findings of Ramey (2016). As monetary policy has become more systematic and transparent in recent years, market participants got less surprised by the central bank actions.

Second, the information effect, while already quite pronounced in the beginning of the sample period and in the years 2001 to 2003 as well, gained in strength during the financial crisis and the subsequent zero lower bound period. This emphasizes the importance to explicitly account for this effect particularly when analyzing the effect of monetary policy during the last years.

Third, while some of the largest realizations of the information effect are in the period before the Global Financial Crisis, the higher volatility of this factor coincides with the introduction of LSAP programs by the FOMC.[22] Basically, there are two main transmission mechanisms of LSAP discussed in the literature: the signaling channel and the portfolio rebalancing channel. Proponents of the former argue that LSAP affects long-term rates mainly by signaling future monetary policy (Bauer and Rudebusch, 2014), while advocates of the latter emphasize a direct effect of asset purchases by compressing the term premium through a reduction in duration risk (Gagnon et al., 2011). Moreover, LSAP can be also perceived as a commitment mechanism to reinforce central bank's forward guidance (Woodford, 2012). In terms of my identification strategy, LSAP would show up either as part of the forward guidance factor or in the information effect factor depending on whether market participants perceived the announcement of the purchase program as commitment to the future policy path or as warranted by the economic prospects.[23] As it will be discussed in the following, the higher volatility of the information effect during the Great Recession period most probably reflects higher volatility in the assessment of nominal risks. The asset-pricing model of Piazzesi and Schneider (2007) shows that news about higher inflation imply bad news for future consumption growth and, thus, cause a higher term premium required by investors. Moreover, the term premium increases in times when inflation news are harder to interpret. Consequently, I argue that the increased uncertainty during the zero lower bound period spiked the responsiveness of market participants to news about the economic prospects and, thus, led to the higher volatility in the information effect factor.

[21] In Appendix C, I discuss in more detail some of the larger realizations of the identified shock measures.

[22] Actually, as it is discussed in Section 3.4, only one of the 20 biggest information effect realizations coincides with the announcement of an asset purchasing program, i.e. QE1 on March 18, 2009.

[23] Theoretically, one could adopt the identification strategy proposed in this paper to separate a single LSAP factor. However, this is beyond the purpose of this paper. See Swanson (2017) for such an approach.

3.4 Information Content of Shock Measures

To test the identification of distinct dimensions of monetary policy announcements, I provide evidence about the information content of the identified shock measures. First, following the seminal work of Romer and Romer (2000), there is a broad literature questioning the information content of empirically identified monetary policy shocks. As shown in Section 2, if the Federal Reserve has more accurate information about the economic prospects than the public, monetary policy surprises estimated using financial market data will reflect more than just an exogenous monetary policy shock. Specifically, as the public learns about the economic state from the policy announcement, the induced change in the asset prices is partly driven by the systematic response of the central bank (Miranda-Agrippino, 2016; Nakamura and Steinsson, 2018). Using a Romer and Romer (2000) style regression, I provide evidence that my information effect shock reflects the private information that may have guided the FOMC decision. Second, using narrative accounts taken from the written FOMC statements, I investigate the information content of the information effect shock series.

If monetary policy announcements provide information about the economic prospects conditional on the monetary policy decision, then this should be caused by superior, or at least divergent, expectations about the future compared to the public. Following Barakchian and Crowe (2013) and Gertler and Karadi (2015), I regress my shock measures on a proxy for the private information of the FOMC. For every scheduled announcement date I take the difference between the Greenbook forecasts prepared by the Federal Reserve staff and the most recent one from the Survey of Professional Forecasters (SPF).[24] The regression equation reads like follows

$$mps_t^i = \alpha + \sum_{h=0}^{3} \beta_h (\hat{X}_{t+h|t}^{GB} - \hat{X}_{t+h|t}^{SPF}) + \epsilon_t, \tag{17}$$

where mps_t^i denotes the realization of shock i in t and $\hat{X}_{t+h|t}^{GB}$ and $\hat{X}_{t+h|t}^{SPF}$ denote the Greenbook and SPF forecasts of variable X for the horizon $t+h$, respectively. Specifically, I use the expected growth of real GDP and the GDP deflator in the current and the next three-quarters-ahead as well as the current month forecast of the unemployment level. Note, as the forecast dates of the Federal Reserve staff and the SPF are not perfectly aligned, the results have to be treated with some caution. The latter caveat is true especially for the nowcasts. The results are shown in Table 2.

Notably, the private information of the FOMC is only associated with the information effect measure.[25] Consequently, the identified target and forward guidance shock seem not to reflect systematic reactions of the FOMC to information unknown to the public.

[24] As the SPF forecasts shift from real GNP to real GDP in 1992 and given that Greenbook forecasts are only available with a publication lag of five years, the sample period is reduced to April 1992 to December 2012.

[25] The imperfect alignment between the dates when SPF forecast and Greenbook forecasts are made may cause the marginal significant impact of the GDP growth nowcast for all three shocks.

Table 2: Private Information content of Monetary Policy Shock Measures

	Target shock		Forward guidance		Information effect	
Δy_t	**-0.14***	(0.08)	**-0.18***	(0.11)	**0.17***	(0.10)
Δy_{t+1}	-0.05	(0.13)	0.06	(0.20)	**-0.43*****	(0.16)
Δy_{t+2}	-0.16	(0.16)	-0.08	(0.24)	-0.08	(0.15)
Δy_{t+3}	0.15	(0.15)	-0.16	(0.22)	0.31	(0.19)
π_t	-0.06	(0.08)	0.02	(0.15)	-0.08	(0.17)
π_{t+1}	0.21	(0.16)	-0.05	(0.17)	0.07	(0.15)
π_{t+2}	0.01	(0.21)	-0.05	(0.30)	-0.13	(0.32)
π_{t+3}	0.06	(0.17)	-0.10	(0.29)	**-0.63***	(0.38)
u_t	-0.21	(0.35)	0.26	(0.47)	**1.17****	(0.51)
Constant	-0.07	(0.10)	-0.07	(0.11)	**-0.30*****	(0.11)
Observations	167		167		167	
R^2	0.07		0.07		0.18	
F	1.33		1.24		3.94***	

Note: Independent variables: Greenbook forecast minus last SPF forecast for respective variable and quarter. Sample period: 04/1992 - 12/2012. Robust standard errors reported in brackets, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In order to shed more light on how to interpret the information effect factor, Table 3 reports some of the largest realizations together with a short description of the respective FOMC statement and quotes from major newspapers reporting about the FOMC meeting.[26] This overview reveals some notable observations. First, the identified information effect shock process reflects the information component in FOMC statements related to risks to the sustainable economic growth path and long-term price stability. In line with the aforementioned discussion about the information content of this factor, the FOMC highlights risks to the demand and the supply side in its written statements. This is also reflected in the newspaper quotes. In the late 1990s and early 2000s, the FOMC repeatedly expressed its concerns regarding increasing inflation pressure due to considerable excess demand in the booming economy which imperils the economic performance in the foreseeable future. During the Global Financial Crisis period, big information effect shocks correlate with changes in the FOMC statement about the assessment of the risks to economic prospects due to the financial turmoil and with new information about the weights in the policy reaction function. During the Great Recession, changes in the written statement about the expected path for the economic recovery seem to drive the information effect.

Second, while the sign of the information effect shock is uncorrelated to the announced changes in the policy measures, positive information effect realizations happened in every meet-

[26] In Appendix D, the ten biggest positive and negative realizations and the respective FOMC statements as well as newspaper quotes are presented.

Table 3: Information Content of Major Realizations of the Information Effect Shock Series

Date	Info Shock	∆FFR Target	FOMC Statement Details and Newspaper Quotes
15.10.1998	-1.82	-25 Bp	This policy measure was "warranted to sustain economic growth in the context of contained inflation."; "The Fed move was seen as insurance against a business downturn as well and the threat this would pose to corporate profits."(New York Times, Stocks Surge In Final Hour On Rate Cut, October 16, 1998)
15.05.2001	2.23	-50 Bp	Regular meeting after off-schedule one; "The Fed addressed concerns about inflationary risks for the first time in several months." (Financial Times, Fed makes another half-point cut US benchmark rate now 4%: * Hint of future reduction * Wall Street reaction muted, May 16, 2001).
18.09.2007	2.03	-50 Bp	Regular meeting after off-schedule one; "He [Tom Sowanick, chief investment officer of Clearbrook Financial] pointed out that the action had the potential to usher in a cycle of renewed inflation risks. "In our view, these risks are not small and, if realised, will be difficult to reverse."" (Financial Times Online, Cheering greets Fed announcement, September 19, 2007)
30.01.2008	2.08	-50 Bp	Regular meeting after off-schedule one; "In lowering its benchmark Federal funds rate by half a point, to 3 percent, the central bank acknowledged that it is now far more worried about an economic slowdown than rising inflation, and it left open the possibility of additional rate reductions." (New York Times, Fed Reduces Rate by Half-Point; 2nd Cut in 8 Days, January 30, 2008)
18.03.2009	-5.14	0 Bp	QE1; "Fed policy makers sharply reduced their economic forecasts in January, predicting that the economy would continue to experience steep contractions for the first half of 2009, that unemployment could approach 9 percent by the end of the year and that there was at least a small risk of a drop in consumer prices like those that Japan experienced for nearly a decade." (New York Times, FED will inject $1 trillion more to aid economy, March 19, 2009)
18.09.2013	-2.81	0 Bp	"The aggregation of forecasts showed that Fed officials now expect growth to remain sluggish for years to come, with persistent unemployment and little inflation." (New York Times, In Surprise, Fed Is to Maintain Pace of Stimulus, September 19, 2013)

ing succeeding an unscheduled meeting. This observation shows that the information effect represents a dimension of central bank communication which is independent of the conducted monetary policy action. Intermeeting decisions are usually a surprising response by the FOMC to extraordinary shocks and, thus, should affect market participants' expectations about the economic prospects. As the situation warranted additional actions by the FOMC in the subsequent regular meeting, the positive realization of the information shock reflects considerable risks to the economic prospects. Given that a positive information effect represents an increase in long-term inflation expectations and that these meetings where happening in times of recessions and crises, the respective positive information effect realizations appear to reflect news about negative supply shocks.[27]

4 Monetary Policy Announcements and the Term Structure

In this Section, I provide evidence on how the identified policy shock measures affect a variety of asset prices. Specifically, I estimate the effects on the components of the nominal yield curve as well as on the real term structure. By doing so, I shed light on two topical questions regarding monetary policy communication. First, does forward guidance work primarily by influencing market participants' expectations about the future policy rate path as stated by Bernanke (2013)? Or does it also reduce term premia by lowering the uncertainty about the future short-term rates as supposed by Woodford (2012) and Filardo and Hoffmann (2014)?

Second, Feroli et al. (2017) and Mishkin (2018) state that the Federal Reserve should condition their monetary policy communication on observable economic indicators instead of using time-contingent forward guidance. The main argument is that using calender time as guideline constrains the monetary policy maker when new information arrives and, potentially, may lead to an inferior commitment. As the FOMC used open-end, time-contingent, and state-contingent forward guidance during my sample period, I provide new evidence confirming this point of view.

To investigate these questions, I rely on an event-study approach. The baseline specification is an OLS regression of the form

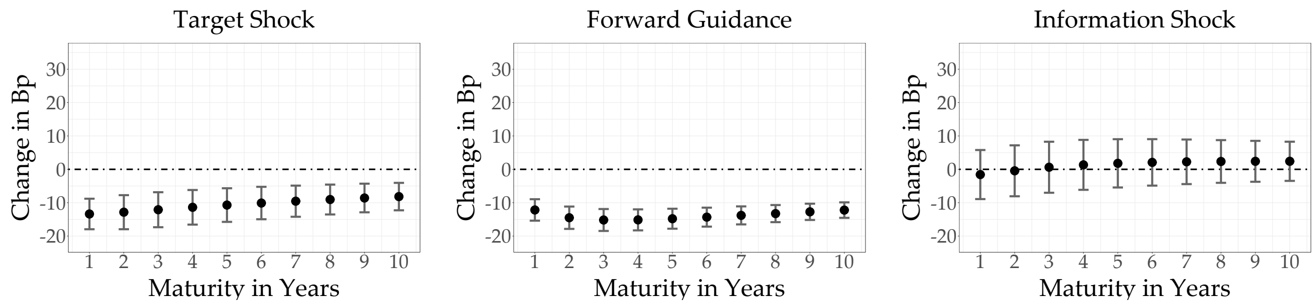
$$\Delta i_t^m = \alpha^m + \beta^m mps_t^i + \epsilon_t \tag{18}$$

where Δi_t^m denotes the daily change in a particular yield component or forward rate surrounding the FOMC meeting t. mps^i represents the monetary policy shock measure i, $i \in \{\text{Target}, \text{For-}$

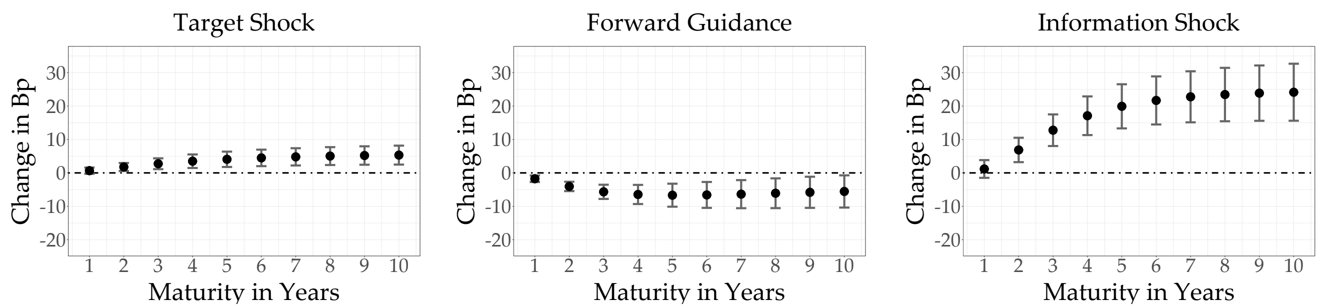
[27] Note, the information effect factor is positively correlated with the five-year, five-year inflation expectations by construction, while inflation expectations for short- to medium horizon are not restricted. Consequently, the information effect does not reflect changes in inflation expectations due to an exogenous monetary stimulus by the FOMC. Rather, the information effect is driven by news about the general inflation risk assessment or new information about the weight of inflation in the policy makers' reaction function.

Figure 2: Responses of Nominal Yield Curve Components to Shocks

Panel A: Expected average level of short-term interest rates



Panel B: Term premium



Notes: Figures show estimated coefficients and 95% robust confidence intervals (bars) from regressions of daily changes in the components of nominal yields across different maturities on the identified shock series. Sample period: 07/1991 - 09/2017.

ward Guidance, Information Effect}. The sample period is July 1991 to September 2017. I normalized the scale of the shock series so that a one unit increase in the target (forward guidance) shock lowers the current federal funds (one-year ahead Eurodollar) futures rate by 25 basis points. Further, a one unit increase in the information effect shock raises the 10-year Treasury yield by 25 basis points.

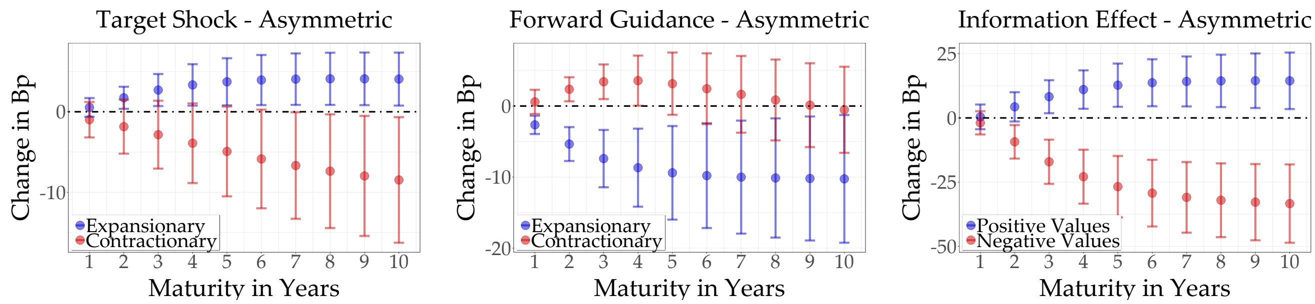
4.1 Nominal and Real Effects

Panel A and B of Figure 2 show the estimated coefficients β^m from the separate OLS regressions of the expected average short-term rates and the respective term premia for Treasuries with a maturity m between one and ten years along with their associated robust 95% confidence intervals. The data is taken from Adrian et al. (2013), which is publicly available from the web page of the Federal Reserve Bank of New York. The expansionary target shock measure leads to a decline of the expected average short-term interest path exhibiting considerable intertia.[28]

[28] As shown in Appendix E, all affects shown here are quite persistent.

Figure 3: Responses of Nominal Yield Curve Components to Shocks

Term premium



Notes: Figures show estimated coefficients and 95% robust confidence intervals (bars) from regressions of daily changes in the components of nominal yields across different maturities on the identified shock series. Sample period: 07/1991 - 09/2017.

Further, a rise in expected inflation due to the exogenous monetary policy loosening leads to a slight but significant increase in the term premium. Contrary, while showing a similar but lagged effect on the expected path of short-term interest rates, forward guidance lowers the average term premium across maturities. Thus, forward guidance seems to reduce uncertainty about the future path of the policy rate and, thus, affects the term premium of even long-term bonds. Bundick et al. (2017) provide similar results using Eurodollar options to measure the implied volatility about future short-term interest rates.[29]

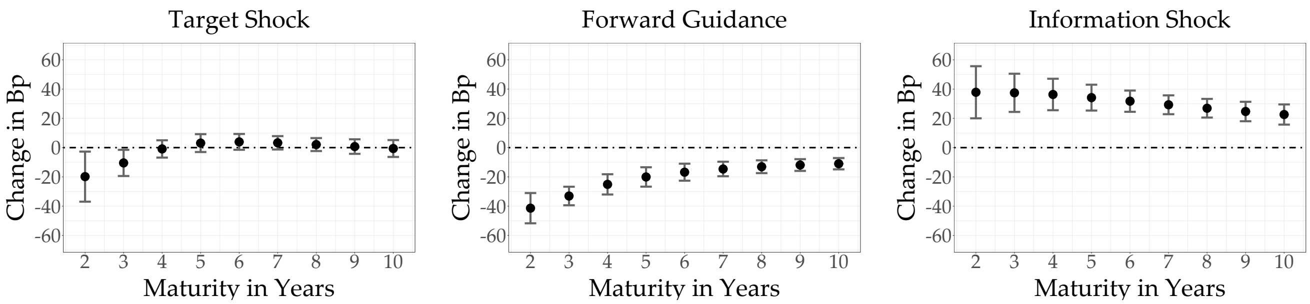
The information effect does not affect the expected average path of future short-term rates but heavily raises the term premium required by investors. This is in line with the interpretation that the information effect factor reflects nominal risk. According to the asset-pricing literature, news about the economic prospects and the future path of inflation cause positive term premia (see for example Piazzesi and Schneider, 2007). Rudebusch and Swanson (2012) demonstrate that supply shocks can produce positive nominal term premia in a DSGE model as they lead to a persistent increase of inflation exactly when consumption is low. In this case, nominal bond holders require a higher compensation for the rise in inflation risk due to its devaluing of nominal payoffs. To investigate whether the response is characterized by non-linear effects, I expand specification (18) to allow for asymmetric effects depending on the sign of the shock. The model specification is

$$\Delta i_t^m = \alpha^m + \beta_1^m I_t mps_t^i + \beta_2^m (1 - I_t) mps_t^i + \epsilon_t, \tag{19}$$

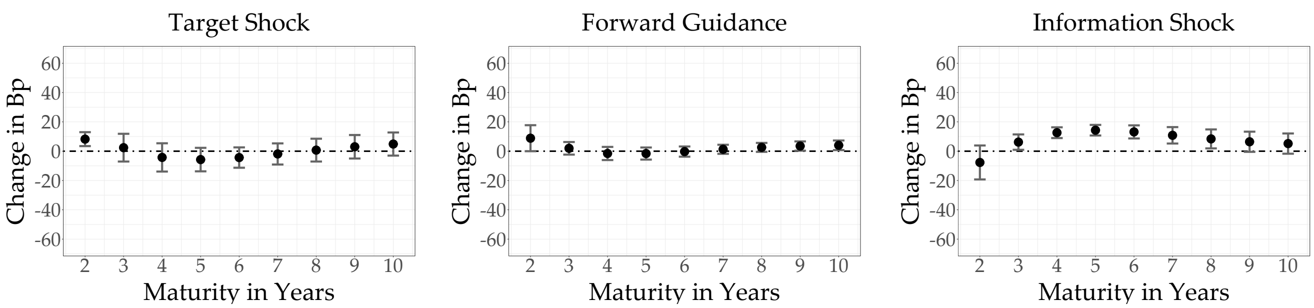
[29] In contrast to Gertler and Karadi (2015), Crump et al. (2016) also provide evidence that monetary policy actions affect long-term rates predominately through the expected path of the short-term rates rather than the term premium. For further details, see the discuss there. Further, comparing the results reported here with Gilchrist et al. (2015), one has to take into account that I explicitly differentiate between forward guidance and surprise changes in the current policy rate.

Figure 4: Responses of Real and Inflation Forward Rates to Shocks

Panel A: Real forward rates



Panel B: Inflation Compensation Forwards



Notes: Figures show estimated coefficients and 95% robust confidence intervals (bars) from regressions of daily changes in real and inflation compensation forwards across different maturities on the identified shock series. Sample period: 01/2004 - 05/2008 and 05/2009 - 09/2017.

where I_t equals one when the shock realization is positive. As the response of the expected average short-term rates does not indicate any significant asymmetric effects, Figure 3 only shows the reaction of the term premia.[30]

In line with the hypothesis that forward guidance lowers the degree of uncertainty about the future short-term interest rate path, the response shows considerable differences. While a contractionary forward guidance surprise significantly increases the term premium only on a short horizon, expansionary forward guidance surprises have a long-lasting effect on term premia. Importantly, the latter is the historically more relevant case for the practical monetary policy conduct, particular at the zero lower bound. Using the data of Gürkaynak et al. (2010b), I also regress daily changes in real and breakeven inflation instantaneous forward rates on the shock series. Due to the availability of TIPS data, the sample period for this exercise reduces to January 2004 to September 2017. Due to the discussed illiquidity in the TIPS market during the period 2008-2009, I additionally drop the period June 2008 to June 2009.[31]

[30] To make the plots more accessible, I multiplied the estimated coefficients for negative shock realizations by -1. Thus, the plot shows the response of the term premia to an expansionary and contractionary shock, respectively.
[31] Including the period June 2008 to June 2009 does not alter the results qualitatively.

The results presented in Figure 4 highlight three particular observations. First, similar to the evidence presented by Nakamura and Steinsson (2018) and Hanson and Stein (2015), the results show that monetary policy affects real forward rates several years in the future while the effect on inflation compensation is rather modest. Second, the effect of forward guidance on the real term structure is much more pronounced and long-lasting than a surprising change in the short-term interest rate. Third, the information effect also has a considerable impact several years into the real and inflation compensation term structure. The two monetary policy shocks affect inflation expectations significantly only on a short-term horizon.

More generally, the results reported in this Section support the interpretation that the information effect factor represents news about nominal risks. While the information effect is positively correlated with long-run inflation forwards by construction, the shocks also co-move with nominal and real rates due to its effect on term premia. This is fully in line with the findings of Crump et al. (2016), who highlight the role of equilibrium pricing of risks in the economy by documenting the effects of various macroeconomic shocks on the components of bond yields. In addition to the effects of supply shocks, they show that demand shocks may also cause positive term premia by altering investors' risk attitudes. Positive demand shocks could trigger a *search-for-yield* behavior, in contrast to a *flight-to-quality* effect in case of a negative demand shock, which incentivize investors to shift their portfolio from safe Treasuries to more risky asset classes. As a consequence, the term premium rises although investors may expect that the central bank is fighting the increased inflation pressure by higher short-term rates.

4.2 The Effectiveness of Different Types of Forward Guidance

During the sample period, the FOMC used different ways to implement forward guidance. Following Ehrmann et al. (2019), I distinguish between three different types. Between December 2008 and June 2011 and between March 2014 and the sample end in September 2017, the FOMC made only vague statements about the likely future policy path. Specifically, in the first years the statement reads:

> *[...] the Committee anticipates that weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time.*

I will call this kind of central bank communication open-ended forward guidance.

Starting in August 2011, the FOMC used a more explicit phrase in their guidance by referring to a specific time period:

> *The Committee currently anticipates that economic conditions [...] are likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013.*

This so-called time-contingent forward guidance represents a stronger commitment by the central bank as it implicitly specifies a certain calender date for the lift-off from the zero lower bound. Consequently, this type of forward guidance should have a stronger effect on the market participants' expectations.

Finally, in December 2012, the FOMC switched to state-contingent forward guidance by stating that

> *[...] the Committee [...] currently anticipates that this exceptionally low range for the federal funds rate will be appropriate at least as long as the unemployment rate remains above 6-1/2 percent, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2 percent long-run goal, and longer-term inflation expectations continue to be well anchored.*

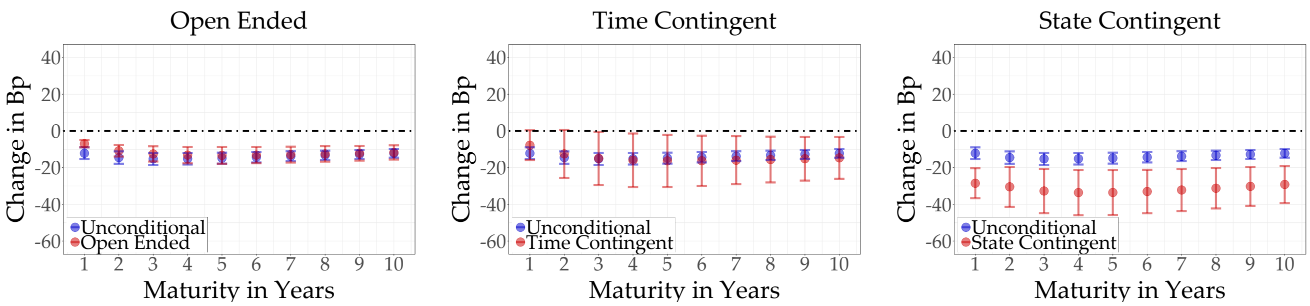
The FOMC communicated the path of the short-term interest rate as a function of observable economic indicators. Thus, it indirectly explained its policy reaction function to the public. As argued by Feroli et al. (2017) and Mishkin (2018), this type of forward guidance should be more effective than the time-contingent forward guidance. To quantify the effectiveness of these different types of central bank communication, I rely on specification (18) but set all forward guidance shocks outside of the specific time period to zero. Of course, the results have to be treated with caution as the sample size for time-contingent and state-continent forward guidance is quite small, 11 and 10 observations, respectively.

Figure (5) shows the respective results for the nominal yield curve components and the real forward rates already used in Section 4.1. All plots superimpose the response of interest rates to the specific forward guidance type with the baseline response estimated for all shock realizations. In line with the argumentation of Feroli et al. (2017) and Mishkin (2018), my results show that the impact of the forward guidance shocks during the state-contingent regime was much more pronounced than during the open-ended and the time-contingent regime. The short-term increase in the nominal term premium after a state-contingent forward guidance shock may reflect the uncertainty about the exact date when the conditions for the lift-off will be met. Contrary, the higher degree of transparency about the reaction function seems to lower the term premium for longer maturities.

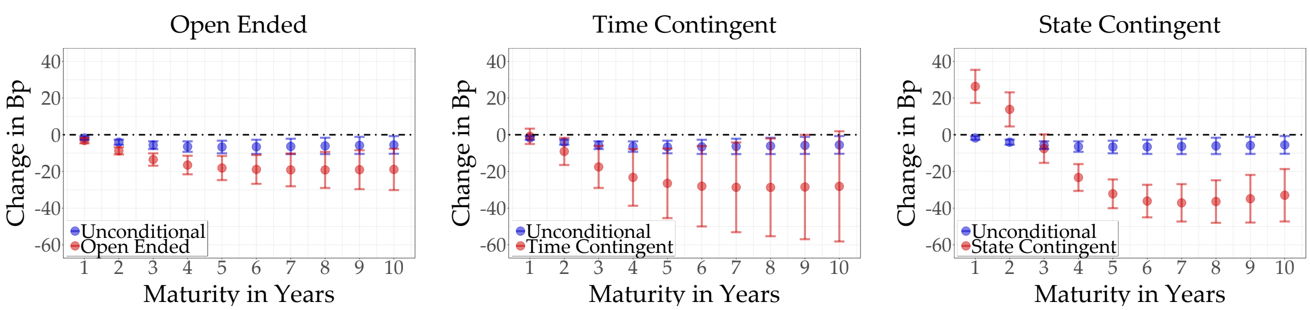
In sum, the reduced-form evidence provided in this Section shows that the identified shock measures affect the term structure quite differently. In particular, the two dimensions of monetary policy, i.e. the target factor and the forward guidance factor, have strong and long-lasting impacts on the expected average short-term rates. Further, these shocks have contrary effects on the term premium. The information effect factor, in contrast, represents all information about the economic prospects above and beyond the future path of the policy rate. It works predominantly through altering the risk compensation required by bond holders, i.e. the term premium. Lastly, central bank communication about the future path of the short-term interest rate has a stronger impact on market participants' expectations when the forward guidance is a function of observable economic indicators.

Figure 5: Forward Guidance and the Term Structure

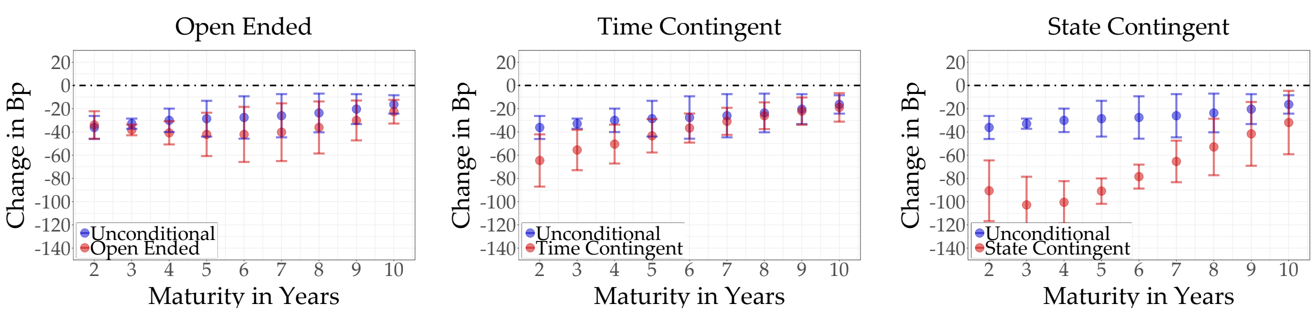
Panel A: Expected average level of short-term interest rates



Panel B: Term premium



Panel C: Real Forward Rates



Notes: Figures show estimated coefficients and 95% robust confidence intervals (bars) from regressions of daily changes in the components of nominal yields and real forward rates across different maturities on the identified forward guidance shock series.

5 Macroeconomic Effects of Monetary Policy Announcements

This Section presents estimates of the dynamic macroeconomic effects of the information released during monetary policy announcements. The time series constructed in the previous Section represent measures of different dimensions of these announcements, but do not account for the structural shocks themselves. Thus, the dynamic effects are estimated using local projection estimations instrumented by these shock measures (LP-IV). In Appendix G, I use a proxy SVAR model as a robustness check. The results are qualitatively similar.

5.1 Macroeconomic Data

My baseline specification includes four macroeconomic and financial variables and is estimated for the sample period July 1991 to September 2017 using monthly data. I use the index of industrial production in log first-differences as the measure of output growth and the log first-difference of the consumer price index. As financial market variable, I include Moody's Baa spread on the 10-Year Treasury rate. As shown by Caldara and Herbst (2019), credit spread indicators are necessary to account for the systematic response of monetary policy to financial market conditions. As policy indicator, I use either the federal funds rate, i.e. when analyzing the effect of a target shock, or the ten-year, three-month term spread, i.e. when analyzing forward guidance.[32] All asset price series are end-of-month data. Further, I use principal components estimated from the FRED-MD data set as additional covariates (McCracken and Ng, 2016).[33]

The daily proxy variables are simply aggregated by summing the surprises within a month. Whenever there was no scheduled FOMC announcement in a given month, the shock instrument is zero. While Gertler and Karadi (2015) construct the average monthly surprise of their daily policy instrument, the findings of Ramey (2016) and Miranda-Agrippino and Ricco (2017) cast doubts on this procedure.

5.2 Estimation of Impulse Response Functions

Based on Jordá (2005), Stock and Watson (2018) as well as Ramey (2016) show that LP-IV provides a valid alternative to the estimation of impulse response functions using a SVAR model. Specifically, I use the shock measures estimated in the previous Sections as external instruments.

[32] Following the strategy of Gertler and Karadi (2015), I searched for the policy variables by maximizing the F-statistic of the first-stage regression. Further, I also experimented with the shadow rate of Wu and Xia (2016) instead of the federal funds rate. However, as the target shock measure is almost zero during the zero lower bound period, the estimated impulse response functions are quite close. Results are available upon request.

[33] To be precise, I use the manufacturing industrial production index (NAICS) and the consumer price index for all urban consumers less food and energy as a measure of core inflation. All Measures are taken from FRED.

Presumably, they are correlated with the structural shocks of interest but uncorrelated with all other shocks potentially driving the variables of interest.

As LP-IV impulse response functions are not functions of underlying structural coefficients governing the data generating process, the estimates are more robust to model misspecification compared to their counterparts computed from VAR models.[34] In particular, the dynamic causal effects of exogenous shocks can be identified even if the system does not fulfill the strong assumption of invertibility. Instead, LP-IV requires a strong lead-lag exogeneity of the instruments to be valid. As it is formally demonstrated by Stock and Watson (2018) and Plagborg-Møller and Wolf (2019), the LP-IV framework does not only require that the external instruments are relevant and contemporaneously uncorrelated, but these instruments have to be uncorrelated with all shocks at all leads and lags.

Let $Y_{i,t+h}$ be a variable of interest from the vector of variables Y_t and let W_t be a vector of control variables. The dynamic response of the variables $Y_{i,t+h}$ can be estimated as follows:

$$Y_{i,t+h} = \alpha_{i,h} + \gamma_{i,h} W_t + \theta_{i,h} Y_{1,t} + \xi_{i,t+h}, \tag{20}$$

where the external instrument $m_{j,t}$ is used as an instrument for $Y_{1,t}$. Consequently, $\theta_{i,h}$ represents the estimate of the impulse response of Y_i at horizon h to the shock $\varepsilon_{j,t}$. The vector of control variables includes six lags of Y_t, m_t, and the first four principal components estimated from the FRED-MD data set. Moreover, I include three leads of $m_{j,t}$.[35] Given the theoretical justification provided for the identification strategy of the shock measures, the instruments are assumed to be correlated with the true shocks but mutually uncorrelated (by construction) and contemporaneously uncorrelated to other shocks (due to the high-frequency identification approach). In order to account for potential time series correlation, the regression specification includes lags of the other identified shock measures as well.[36].

In order to estimate Equation (20), I use the replication files of Stock and Watson (2018), where I update the data to the sample period July 1991 to September 2017. The confidence bands are constructed using Newey-West standard errors with $h + 1$ lags.

5.3 Response of Macroeconomic Variables to Monetary Policy Shocks

An expansionary target shock, shown in Figure 6, leads to an immediate and persistent decrease in the federal funds rate.[37] While industrial production does not show any significant response,

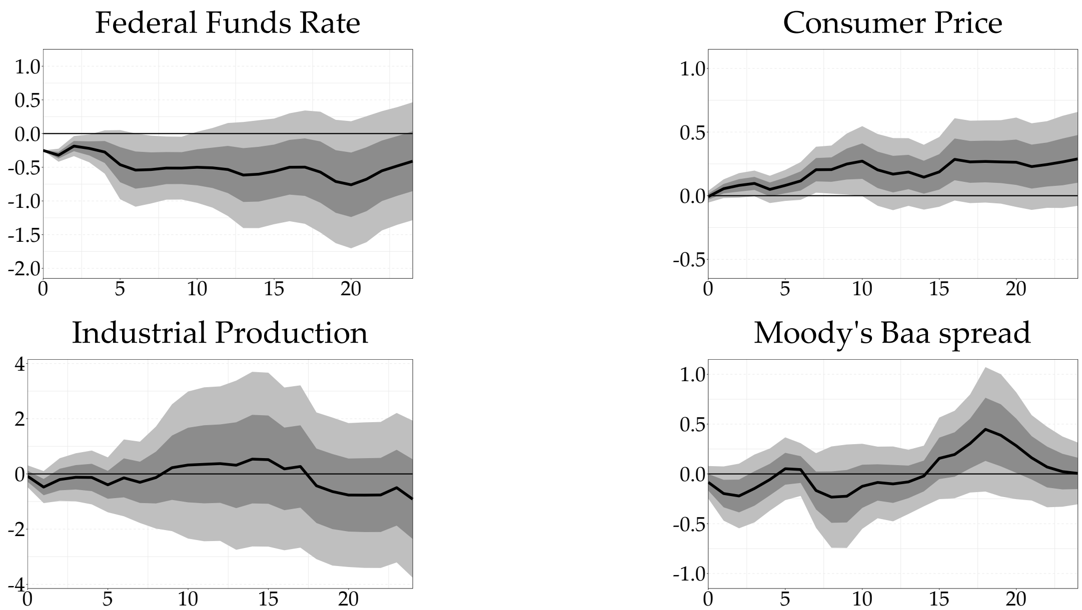
[34] See Caldara and Herbst (2019) for an example of the consequences related to misspecified SVAR models. See Ramey (2016) and Stock and Watson (2018) for a recent review of LP-IV as well as proxy SVARs.

[35] All results are qualitatively robust to having less leads and lags of the control variables. Results are available upon request.

[36] Except for the lags of the other two shock measures, the setup is in line with the specification of Stock and Watson (2018)

[37] The first-stage F-statistic is 35.2 for the target shock, and 11.1 for the forward guidance shock measure, respectively. Both F-statistics are above the threshold value of 10 suggested by Stock and Yogo (2005).

Figure 6: Responses to an Expansionary Target Shock



Notes: Figures show responses to a target shock that lowers the federal funds rate by 25 Bp on impact. Solid black lines are point estimates, gray areas represent 68% and 95% confidence intervals. Sample period: 07/1991 - 09/2017.

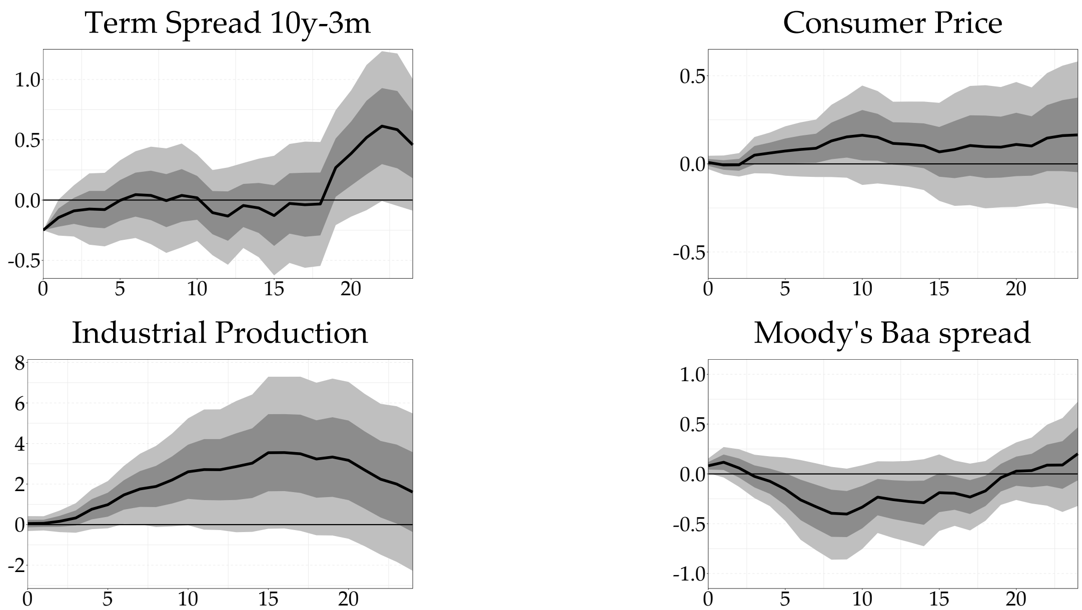
the rise in inflation leads to a significant and long-lasting increase in the price level. Financial tensions, as measured by the credit spread, seem to raise about one and a half year after the shock. Albeit, the latter response is only marginally significant.

The expansionary forward guidance shock, shown in Figure 7, is identified by an immediate flattening of the yield curve. By signaling a more expansionary monetary policy stance in the future, the Federal Reserve lowers the spread between short- and long-term interest rates. Theoretically, this could be the result of either an increase in the short-end of the yield curve or a lowering of the long-end. However, the event-study result presented in Section 4 points rather to the latter.[38] Compared to the target shock, forward guidance leads to a slight and barely significant increase in the consumer price level, while the effect on the output measure is statistically and economically relevant. The rise in industrial product is hump-shaped, peaking about one year after the shock. Further, forward guidance reduces the credit spread measure around seven months after the announcement. As one would expect, all responses, except of the policy indicator, are delayed by a few periods.

Overall, the dynamic responses due to the identified monetary policy shocks are in line with the economic intuition. The insignificant effect of conventional monetary policy shocks on output is in line with the findings of Barakchian and Crowe (2013) and Ramey (2016). Reviewing different identification schemes for monetary policy shocks, both studies find inconclusive re-

[38] In a robustness exercise using only shocks since December 2008, the decrease in the term spread is considerably more long-lasting. Results are available upon request.

Figure 7: Responses to an Expansionary Forward Guidance Shock



Notes: Figures show responses to a forward guidance shock that lowers the 10-Year, 3-Month term spread by 25 Bp on impact. Solid black lines are point estimates, gray areas represent 68% and 95% confidence intervals. Sample period: 07/1991 - 09/2017.

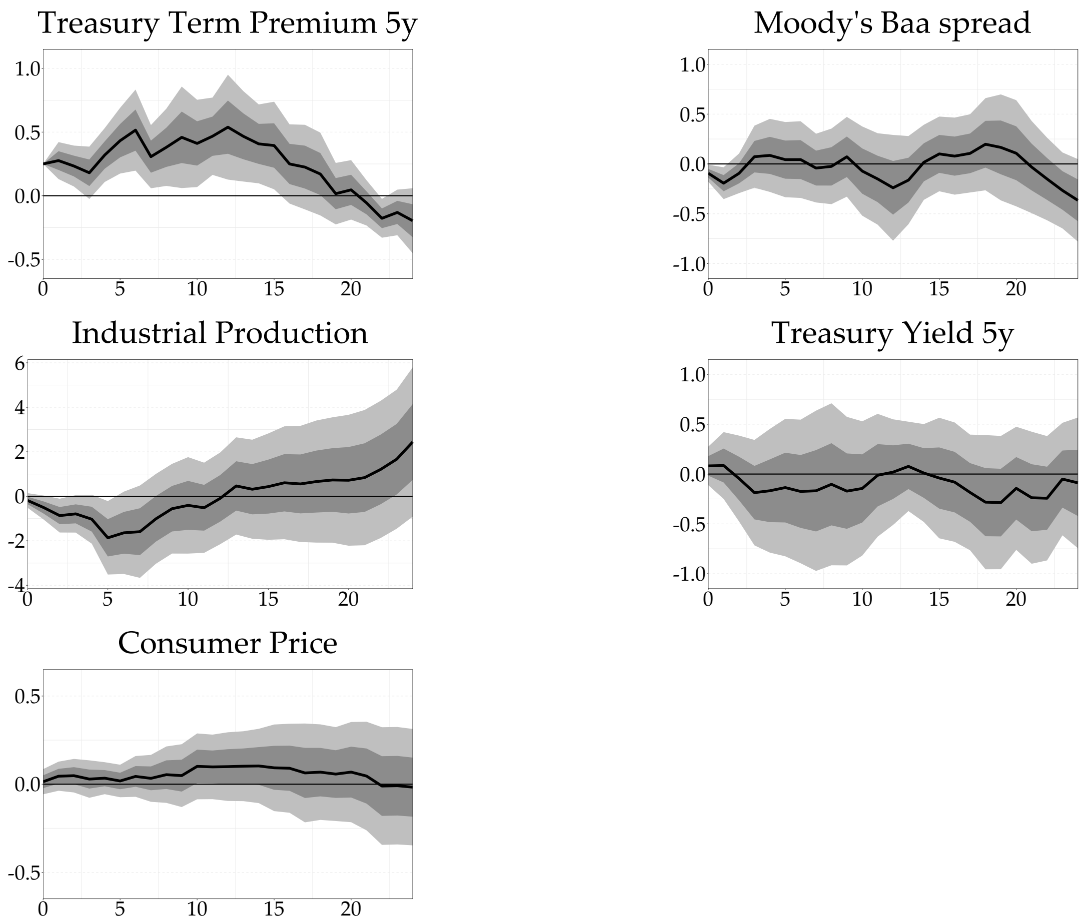
sults for the effect of unexpected interest rate cuts when the sample period includes more recent data. Additionally, I do not find any evidence for a price or quantity puzzle. This is in contrast to Lakdawala (2019) who finds a contractionary output effect for expansionary forward guidance using a shock instrument that does not account for an information effect. In particular, building on the identification strategy of Gürkaynak et al. (2005), he provides evidence that asymmetric information between the FOMC and the public drive his results. In Appendix F, I report the responses of additional variables by sequentially augmenting the baseline specification.

5.4 Response of Macroeconomic Variables to the Information Effect

In the remainder of this Section, I provide evidence for the macroeconomic impact of the information effect. The information effect differs from the monetary policy shocks discussed before as it does not represent a causal change in fundamentals, but rather a change in market participants' expectations. While this may raise invertibility concerns, Plagborg-Møller and Wolf (2019) show that LP-IV correctly identifies the relative structural impulse response functions whether or not the shock of interest is invertible.[39]

[39] As indicated by Stock and Watson (2018), there would be also two other options to account for the issue of invertibility. First, one could include appropriate forward-looking variables in the VAR. Second, one could enlarge the number of variables in the VAR by means of a dynamic factor model or a factor-augmented VAR.

Figure 8: Responses to a Positive Information Effect Shock



Notes: Figures show responses to an information effect that increases the term premium of five-year Treasury bonds by 25 Bp on impact. Solid black lines are point estimates, gray areas represent 68% and 95% confidence intervals. Sample period: 07/1991 - 09/2017.

In order to give the information effect shock a structural interpretation, I build on the insights gained in Section 4. As shown there, the information effect represents all information released during the FOMC announcement above and beyond the future path of the policy rate. While representing news about future nominal risks that are priced in by bond holders today, a positive information effect realization affects the term structure by increasing the term premium. As the findings by Gertler and Karadi (2015) indicate, movements in the term premium are one of the main drivers of private credit costs and, thus, should have a contractionary effect on output. For the baseline specification, I use the term premium series for five-year Treasury bonds estimated by Adrian et al. (2013). Moreover, I add the five-year Treasury rate as additional control variable. Besides this, the specification is identical to the monetary policy shock exercise reported in the previous Section. The first-stage F-statistic is 10.5.

Figure 8 presents impulse response functions for an information effect shock that increases the term premium by 25 basis points. In line with the aforementioned reasoning, the increase in the term premium leads to an immediate decrease in industrial production. This contraction in output prevails for about six months. The consumer price index and the credit spreads indicator do not respond significantly except for a short-lived financial markets relaxation on impact. While it appears counter-intuitive that news about nominal risk do not lead to an increase in credit spreads, this seems to be driven by the early periods in the sample. Using only data since January 2000, the credit spread indicator increases significantly after about six months. Results are available upon request. The term premium shock is orthogonal to any monetary policy activity as indicated by the completely insignificant response of the Treasury rate.[40] The immediate decrease in output due to the news about future nominal risk can be rationalized by precautionary saving motives of households. As the increase in the nominal term premium indicates that households expect inflation to be high when consumption will be low, they may cut down their spending today to compensate for the future effective income loss. As shown in the first row of Figure 9, real personal consumption expenditures decrease.[41]

As discussed, the information effect reflects changes in market participants' expectations about the economic prospects. In order to investigate the dynamic effects, I augment the baseline specification by survey data compiled by Consensus Economics. The responses are computed by adding time series, one at a time. Given that the survey data provides expectations over the current and the next calendar year, I follow Dovern et al. (2012) to construct fixed-horizon forecasts for the next twelve months.[42] Figure 9 reports the responses of the median expectations about real GDP, CPI, and consumption growth one-year-ahead. In line with the response of the actual data, market participants' expectations about real GDP and consumption growth decreases significantly over the next year. Inflation expectations seem to decrease over the same horizon, though, only significant at a 68% level. Similar to the findings reported by Miranda-Agrippino and Ricco (2017), private sector expectations respond with a delay compared to the actual data.

To summarize, the results reported in this Section provide evidence for a link between central bank communication and the real economy via bond risk premia. Importantly, this effect is not limited to new information about the monetary policy stance, but also works if the central bank reveals news about future nominal risks. Ireland (2015) reports similar findings using a

[40] In not reported robustness exercises, I replaced the five-year Treasury rate by other measures of monetary policy, e.g. one- and two-year Treasury rates as well as the shadow rate of Wu and Xia (2016). The results are qualitatively very similar.

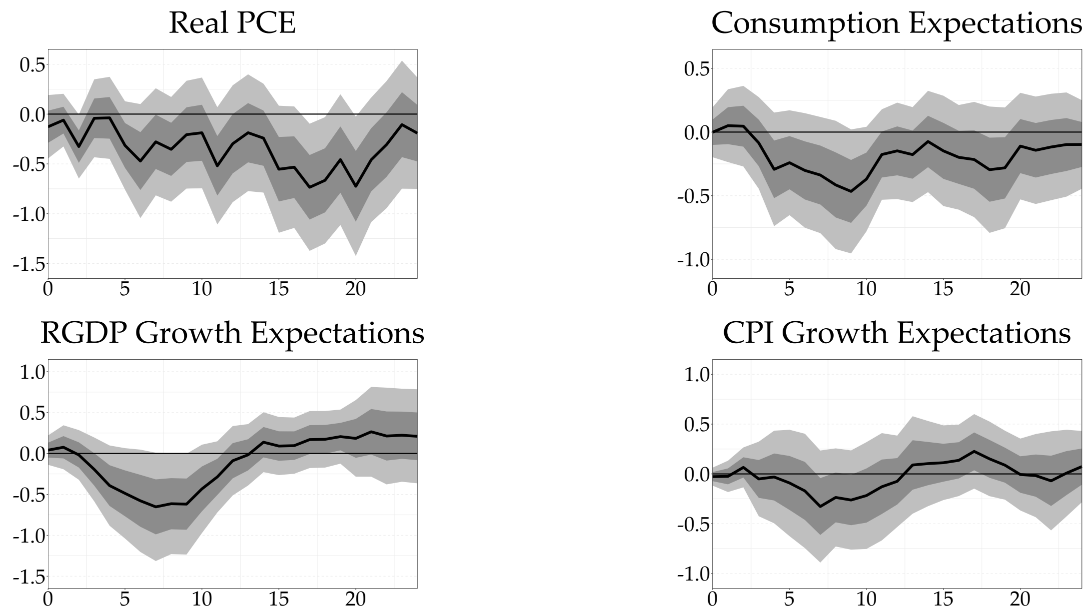
[41] Kliem and Meyer-Gohde (2017) show a similar rational in a DSGE model featuring exogenous variations in the inflation target.

[42] Dovern et al. (2012) approximate the one-year-ahead expectation by weighting the current and next year forecast as follows:

$$\tilde{\hat{x}}_{t+12|t} = \frac{k}{12}\hat{x}_{t+k|t} + \frac{12-k}{12}\hat{x}_{t+12+k|t},$$

where k denotes the forecast horizon in months.

Figure 9: Responses to a Positive Information Effect Shock



Notes: Figures show responses to an information effect that increases the term premium of 5-year Treasury bonds by 25 Bp on impact. Solid black lines are point estimates, gray areas represent 68% and 95% confidence intervals. Sample period: 07/1991 - 09/2017.

multivariate time series model that features exogenous shocks to the bond term premium. The main difference is that in his model nominal term premium shocks affect the economy similarly to aggregated demand shocks. Based on the empirical evidence shown in this Section, the information effect impacts the macroeconomy rather like a supply shock: while long-term inflation forwards rise by construction, industrial production and output expectations decrease.

6 Conclusion

Based on the presumption that monetary policy announcements do not only convey information about the current and future path of monetary policy but also about the central bank's assessment of the economic outlook, the identification of monetary policy shocks has to account for the potential interference of the contrary effects. In this paper, I propose a new method to disentangle the effects of monetary policy announcements on market participants' expectations about the future path of monetary policy from a potential information effect. The identification strategy is motivated by using a standard New Keynesian model and builds on the assumption that monetary policy is first and foremost a commitment to price stability.

I present reduced-form evidence indicating that surprise changes to the monetary policy rate, forward guidance, and the information effect have very distinct effects on the components of the yield curve. Importantly, the findings highlight the role of term premia for the transmission of monetary policy and for the understanding of how an information effect may impact the economy. Analyzing the dynamic effects of the identified components of FOMC announcements, the results point towards a considerable impact of forward guidance on economic output. Further, news about nominal risk dampen the effectiveness of monetary policy as it negatively affects output.

My findings have important implications for the conduct of monetary policy. While it is already established in the literature that central bank communication matters, my results specifically emphasize the role of the term premium for the expectation management of central banks in three ways. First, by lowering the uncertainty about the future path of the short-term interest rate, the impact of forward guidance on long-term interest rates is amplified by a compression of the term premium. Second, monetary policy announcements can alter the nominal risk assessment of bond holders above and beyond the expected path of the short-term interest rate. By signaling news about inflation risks, central banks may alter the term premium and, thus, potentially dampen the effectiveness of their policy measures. Finally, I show that unconditionally state-contingent forward guidance is more effective in shaping the term structure. Taken together with the insights about the information effect, these results provide additional evidence for optimal central bank communication strategy. In line with the argumentation of Feroli et al. (2017) and Mishkin (2018), data-dependent forward guidance can reduce uncertainty among market participants about how monetary policy is conducted and, thus, increase the effectiveness of monetary policy in general.

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A Number of Latent Factors

In this Appendix, I provide additional reduced-form evidence for the number of latent factors driving the cross-section of asset prices changes on FOMC announcement days. Gürkaynak et al. (2005) and Swanson (2017) use the rank test of Cragg and Donald (1997) to determine the number of factors. Using conventional monetary policy shocks gained from an estimated SVAR, I show that the information contained in the third principal component adds considerable explanation power compared to the first two factors, while adding more principal components does not improve the fit significantly. Thus, my results are in line with the findings of Swanson (2017) who uses the same asset price series over a similar sample period but with intra-daily data. The monetary policy shocks are obtained from a monthly monetary policy SVAR using

Table 4: Variance of Classical Monetary Policy Shocks Explained by Factors

	Exogenous innovation to the policy rate				
1^{st} Factor	**0.26*****	**0.26*****	**0.26*****	**0.26*****	**0.26*****
	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)
2^{nd} Factor		-0.15	**-0.16****	**-0.15****	**-0.15****
		(0.10)	(0.06)	(0.06)	(0.06)
3^{rd} Factor			**0.31*****	**0.30*****	**0.30*****
			(0.07)	(0.07)	(0.07)
4^{th} Factor				-0.08	-0.08
				(0.06)	(0.06)
5^{th} Factor					0.03
					(0.07)
Obs.	216	216	216	216	216
R^2	0.06	0.08	0.17	0.18	0.18
Adj. R^2	0.06	0.07	0.16	0.16	0.16
F	14.36	9.61	14.34	11.16	8.93

Note: Dependent variables: Monetary policy innovation computed from a SVAR including industrial production, producer prices, unemployment, federal funds rate/shadow rate (Wu and Xia, 2016), Moody's credit spread indicator (in that order; Cholesky decomposition). Constants are not presented for brevity. Robust standard errors reported in brackets, * p < 0.1, ** p < 0.05,*** p < 0.01.

the log of industrial production, the log of producer prices, unemployment, the Shadow rate of Wu and Xia (2016), and Moody's seasoned Baa corporate bond yield relative to the yield on ten-year treasury constant maturity. The lag length is set to 12, the sample period is January 1990 to September 2017. The list of variables and the lag length corresponds to Caldara and

Herbst (2019), while I extended their setting by the shadow rate to capture the monetary policy conduct of the Federal Reserve during the zero lower bound period. The principal components are aggregated to a monthly frequency by summing up all realization in a particular month. Whenever there was no FOMC meeting the shock realization is set to zero.

Table 4 shows the results of regressing the monetary policy shock series over the principal components. The first three principal components seem to be optimal in explaining the variation of the conventional monetary policy shock series.

B Identification of the Rotation Matrix

As presented in Section 3.2, the rotation matrix is identified by using external information combined with a zero restriction. This Appendix provides additional information on this procedure.

Before extracting the first three principal components, the data matrix X is normalized so that all eight asset price responses on FOMC announcement days have a zero mean and a unit standard deviation. As indicated by Equation (15), an orthogonal 3×3 matrix U governs the rotation of the three latent factors. Consequently, three restrictions about the behavior of the factors are sufficient to uniquely identify U. For convenience, Equation (15) is restated here:

$$X = F\Lambda + \xi = \tilde{F}\tilde{\Lambda} + \xi,$$

where $\tilde{F} = FU$ and $\tilde{\Lambda} = U'\Lambda$.

The two assumption described in Section 3.2 yield in total three restrictions on the rotation matrix U. Following the rationale demonstrated in Section 2, the first assumption imposes that both monetary policy shocks are uncorrelated with the five-year, five-year forward breakeven inflation rate while the second assumption restricts the forward guidance shock to not affect the current-month federal funds futures rate. These restrictions can be implemented as follows.[43]

Employing the response of the long-term forward breakeven inflation rate as an external instrument, one can use the closed-form solution derived by Mertens and Ravn (2013) and reproduced in Appendix G to identify one column of U. Specifically, suppose the following partitioning of U:

$$\underset{(3\times1)}{f_t} = \underset{(3\times3)}{U}\underset{(3\times1)}{\tilde{f}_t}$$

$$f_t = U_{12}\begin{bmatrix}\tilde{f}_{1,t} \\ \tilde{f}_{2,t}\end{bmatrix} + U_3\tilde{f}^*_{3,t},$$

where, without loss of generality, the column vector U_3 governs the information factor. Denoting the external instrument as m_t, the assumption that

$$\mathbb{E}\left(m_t\begin{bmatrix}\tilde{f}_{1,t} \\ \tilde{f}_{2,t}\end{bmatrix}'\right) = 0$$

$$\mathbb{E}(m_t\tilde{f}^*_{3,t}) = \phi$$

[43] See Swanson (2017) for a similar procedure.

solves for U_3 up to a scale and sign convention.

$$\begin{aligned}\mathbb{E}(m_t f_t) &= \mathbb{E}\left(m_t(U_{12}\begin{bmatrix}\tilde{f}_{1,t}\\ \tilde{f}_{2,t}\end{bmatrix} + U_3\tilde{f}^*_{3,t})'\right)\\ &= U_{12}\mathbb{E}\left(m_t\begin{bmatrix}\tilde{f}_{1,t}\\ \tilde{f}_{2,t}\end{bmatrix}'\right) + U_3\mathbb{E}(m_t\tilde{f}^*_{3,t})\\ &= U_3\phi\end{aligned}$$

Technically, I use the matrix closed-form solution of Mertens and Ravn (2013) to solve for U_3 just as it is used to partially identify B^{mp}.[44] Note that in the case of one shock series of interest and one corresponding proxy variable, the matrix S_1S_1' determined by Equation (35) reduces to a scalar and the column vector of interest, here U_3, can be computed up to the sign using Equation (33). I normalize the sign so that the information effect has a positive correlation with the inflation forward and I rescale the vector so that it has a unit length. Note that I use the external instrument only for the subsample January 2001 to August 2016, except the period June 2008 to June 2009, due to liquidity concerns for the TIPS market. Consequently, I truncate the vector f_t accordingly.

The second assumption can be implemented using the loadings of the current-month futures contract as computed by the principal component analysis. Supposing the time series is ordered first in the data matrix X, this would yield the first column of Λ. The assumption combined with the imposed orthogonality to the column U_3 can be formulated in matrix notation as

$$\begin{bmatrix}\Lambda_1'\\ U_3'\end{bmatrix}U_2 = \begin{bmatrix}0\\ 0\end{bmatrix}. \tag{21}$$

Normalizing one element of U_2 to any fixed value, for example suppose that $u_{32} = 1$, reduces the system to a problem of two unknowns and two equations. Similarly, U_1 can be computed by solving the system

$$\begin{bmatrix}U_2'\\ U_3'\end{bmatrix}U_1 = \begin{bmatrix}0\\ 0\end{bmatrix}, \tag{22}$$

where the element u_{31} is normalized to unity. Finally, all column vectors of U are rescaled to have a unit length as this preserves the unit variance normalization of the factors $\tilde{F}$.

[44] See Equations (35) and (33) in Appendix G for the closed-form solution.

C Narrative Plausibility of the Proxy Variables

In a narrative analysis, I use four selected FOMC announcements that are also discussed in the literature to assess the plausibility of the above derived decomposition, i.e. the announcements in December 2008, March 2009, August 2011, and January 2012. Table 5 reports the realizations of the three estimated factors at these dates. Given that the factors are normalized to have mean zero and unit variance, the observations reported in Table 5 are in units of standard deviations. It may be worth remembering that positive realizations of the shocks represent expansionary monetary policy, respectively, good news for the economic prospects (as perceived by the public).

Table 5: Realizations of the Factors at Selected FOMC Announcements

Date	Target Factor	Forward Guidance Factor	Information Effect Factor
December 16, 2008	1.54	2.43	1.53
March 18, 2009	−0.03	4.21	−5.14
August 9, 2011	−0.14	1.24	−2.79
January 25, 2012	−0.12	0.35	−1.38

Note: Factors are normalized to have unit variance. Accordingly, the observations reported in this Table are in units of standard deviations.

I do not discuss the events in a chronological order as the last two observations are more clear-cut while the first two are interesting from an academic point of view. In the statement on August 9, 2011, the FOMC used calender-based forward guidance for the first time. Specifically, the FOMC replaced the phrase that low interest rates would remain for an "extended period" by the more concrete "at least through mid-2013". The results presented in Table 5 show that market participants where not so much surprised by the fact that short-term interest rates will remain at the zero lower bound but by the implications for the economic prospects. This is in line with the findings of Del Negro et al. (2015) who find that market participants revised their GDP growth expectations downwards because of the bad news revealed by the announcement. Additionally, Swanson and Williams (2014) note that this announcement leads to a jump in the median forecast of the length of time that the target rate would remain at the zero lower bound using data from the Blue Chip survey of professional forecasters. In contrast, Del Negro et al. (2015) do not find any conclusive evidence for a change in expectations due to the FOMC announcement on January 25, 2012 while my results indicate a substantial amount of bad news. On that meeting, the FOMC revised its calender-based forward guidance by postponing the lift-off from the zero lower bound to "late 2014". Given that the New York Times online article on that day about the FOMC meeting was captioned as "Fed Signals That a Full Recovery Is Years

Away", the results in Table 5 seem reasonable (see also the discussion in Woodford, 2012).

The results for the FOMC announcements in December 2008 and March 2009 are also quite remarkable. At the December 16, 2008 meeting, the federal funds target was cut to the 0 to 25 basis point band at which it remained until 2015.[45] Further, the FOMC statement reads that the target remains at this exceptional low level "for some time". This phrase was changed to "for an extended period" at the March 18, 2009 meeting. Further, the FOMC announced to expand the LSAP program that was already in place since November 2008 considerably. As it is shown in Table 5, on both dates the realizations of most of the factors are at least one standard deviation. This highlights how surprised financial markets were by the content of both announcements. Given the announced changes in the current monetary policy stance and the signaled future path of monetary policy, the observed increases in the target factor and the forward guidance factor seem quite uncontroversial. However, both FOMC announcement are intensively discussed in other event studies. Most importantly, Woodford (2012) notes that the December 2008 announcement had a much stronger impact on very short money market rates than on long-term Treasury rates, while the effect of the March 2009 meeting on long-run rates was extraordinarily large.[46] The results provided here reflect these observations. Apparently, market participants' were surprised by the intensity of the measures taken by the FOMC on December 16, 2008, and assessed these as good news for the recovery from the financial crisis. On the contrary, the additional measures announced in March 2009 seem to have had the inverse effect on the expectations of market participants (see also Krishnamurthy and Vissing-Jorgensen, 2011).

[45] This date marks also the last target shock realization larger than one standard deviation.

[46] Actually, the effect on long-run rates was that pronounced that Campbell et al. (2012) disregard the meeting as an outlier.

D Information Shock – Major Events

Table 6: Information Content of Major Realizations of the Information Effect Shock Series

Date	Info Shock	ΔFFR Target	FOMC Statement Details and Newspaper Quotes
20.05.1992	-1.70		No written statement
16.08.1994	1.91	+50 Bp	*"These measures were taken against the background of evidence of continuing strength in the economic expansion and high levels of resource utilization. The actions are intended to keep inflationary pressures contained, and thereby foster sustainable economic growth. [...] But these actions are expected to be sufficient, at least for a time, to meet the objective of sustained, noninflationary growth."*
22.08.1995	2.59		No written statement
15.10.1998	-1.82	-25 Bp	This policy measure was "warranted to sustain economic growth in the context of contained inflation."; "The Fed move was seen as insurance against a business downturn as well and the threat this would pose to corporate profits."(New York Times, Stocks Surge In Final Hour On Rate Cut, October 16, 1998)
05.10.1999	-1.70	0 Bp	"But it decided against an immediate change in rates, saying the strengthening productivity growth that had so far damped inflationary pressures had apparently been sustained." (Financial Times,Fed hints at future interest rate rise, October 6, 1999)

Continued on next page

Date	Info Shock	ΔFFR Target	FOMC Statement Details and Newspaper Quotes
02.02.2000	-2.20	+25 Bp	"The Committee remains concerned that over time increases in demand will continue to exceed the growth in potential supply, even after taking account of the pronounced rise in productivity growth. Such trends could foster inflationary imbalances that would undermine the economy's record economic expansion. […] *the Committee believes the risks are weighted mainly toward conditions that may generate heightened inflation pressures in the foreseeable future.*"
15.05.2001	2.23	-50 Bp	Regular meeting after off-schedule one; "The Fed addressed concerns about inflationary risks for the first time in several months." (Financial Times, Fed makes another half-point cut US benchmark rate now 4%: * Hint of future reduction * Wall Street reaction muted, May 16, 2001).
30.06.2005	-1.47	+25 Bp	"Federal Reserve officials, expressing confidence about the economy's strength and concern about price pressures, raised their key short-term interest rate yesterday and indicated they are likely to keep lifting it gradually higher to keep the lid on inflation." (Washington Post, Fed Lifts Benchmark Interest Rate to 3.25%; Officials Remain Concerned About Inflation, July 1, 2005)
18.09.2007	2.03	-50 Bp	Regular meeting after off-schedule one; "He [Tom Sowanick, chief investment officer of Clearbrook Financial] pointed out that the action had the potential to usher in a cycle of renewed inflation risks. "In our view, these risks are not small and, if realised, will be difficult to reverse."" (Financial Times Online, Cheering greets Fed announcement, September 19, 2007)

Continued on next page

Date	Info Shock	ΔFFR Target	FOMC Statement Details and Newspaper Quotes
11.12.2007	-2.81	-25 Bp	"But the committee did not explicitly change its view of how the risk of inflation is balanced against that of slower growth, which would have indicated a strong likelihood that it will cut rates again at its Jan. 30 meeting. It appeared more inclined to keep its options open." (Washington Post, Fed Cuts Key Interest Rate By Quarter Point; Stocks Fall; Board Cites Slowing Growth but Gives No Sign of Future Cut, December 12, 2007)
30.01.2008	2.08	-50 Bp	Regular meeting after off-schedule one; "In lowering its benchmark Federal funds rate by half a point, to 3 percent, the central bank acknowledged that it is now far more worried about an economic slowdown than rising inflation, and it left open the possibility of additional rate reductions." (New York Times, Fed Reduces Rate by Half-Point; 2nd Cut in 8 Days, January 30, 2008)
29.10.2008	2.10	-50 Bp	Regular meeting after off-schedule one (there: joint action by leading central banks on Oct. 8, 2008) "*Recent policy actions, including today's rate reduction, coordinated interest rate cuts by central banks, extraordinary liquidity measures, and official steps to strengthen financial systems, should help over time to improve credit conditions and promote a return to moderate economic growth.*"

Continued on next page

Date	Info Shock	ΔFFR Target	FOMC Statement Details and Newspaper Quotes
28.01.2009	2.14	0 Bp	”Conditions in some financial markets have improved, in part reflecting government efforts to provide liquidity and strengthen financial institutions; nevertheless, credit conditions for households and firms remain extremely tight. The Committee anticipates that a gradual recovery in economic activity will begin later this year, but the downside risks to that outlook are significant. […] the Committee sees some risk that inflation could persist for a time below rates that best foster economic growth and price stability in the longer term.”
18.03.2009	-5.14	0 Bp	QE1; ”Fed policy makers sharply reduced their economic forecasts in January, predicting that the economy would continue to experience steep contractions for the first half of 2009, that unemployment could approach 9 percent by the end of the year and that there was at least a small risk of a drop in consumer prices like those that Japan experienced for nearly a decade.” (New York Times, FED will inject $1 trillion more to aid economy, March 19, 2009)
14.12.2010	2.95	0 Bp	”Some analysts worry that part of the rise in interest rates is due to worries that the Fed is being feckless and will allow inflation or other negative side effects to emerge. Did these rates move higher because the economy is getting stronger - or because bond investors fear the Fed is about to err by continuing to pump too much money into an economy that is in the midst of accelerating?” said Bernard Baumohl, chief global economist of the Economic Outlook Group, a consultancy. ”Our concern . . . is that it’s the latter.” (Washington Post, Uptick in interest rates puts Fed on alert, December 15, 2010)

Continued on next page

Date	Info Shock	ΔFFR Target	FOMC Statement Details and Newspaper Quotes
09.08.2011	-2.79	0 Bp	Time-contingent forward guidance; FOMC revised down their expectations for the economic recovery. The introduced time-contingent forward guidance, thus, appears to be warranted by the economic conditions rather than being an exogenous stimulus.
19.06.2013	2.30	0 Bp	"Bernanke has stressed that the Fed could leave the rate unchanged even longer than that, particularly if inflation remains low." (Washington Post, Rate spike causing concern for Fed, June 27, 2013)
18.09.2013	-2.81	0 Bp	"The aggregation of forecasts showed that Fed officials now expect growth to remain sluggish for years to come, with persistent unemployment and little inflation." (New York Times, In Surprise, Fed Is to Maintain Pace of Stimulus, September 19, 2013)
19.03.2014	2.06	0 Bp	Extension of expansionary monetary policy stance, although unemployment is at the target rate. "The Federal Open Market Committee said on Wednesday, in a statement issued after a two-day meeting,that it planned to keep short-term rates near zero "for a considerable time" after the bond buying ends,particularly if inflation remains sluggish. That guidance replaced the Fed's 15-month-old declaration that it planned to wait at least until the unemployment rate fell below 6.5 percent." (New York Times, Fed Cuts Bond Buying by Another $10 Billion, March 20, 2014)

Continued on next page

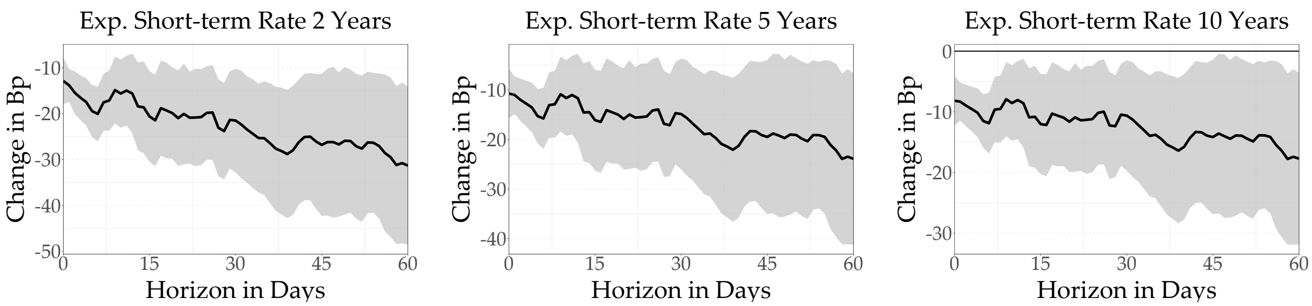
Date	Info Shock	ΔFFR Target	FOMC Statement Details and Newspaper Quotes
28.01.2015	-1.55	0 Bp	”But the optimistic tone was tempered by the Fed’s acknowledgment that inflation has slowed markedly in recent months and is likely to slow even more, making it harder for the Fed to determine how quickly to retreat from its stimulus campaign. […] We are surprised markets seem more interested in the acknowledgment of the (obvious) near-term downside inflation risks.” (New York Times, Fed Won’t Raise Rates Before June, at Earliest, January 29, 2015)

E Persistency of Term Structure Response

$$i_{t+h}^m = \alpha_h^m + \gamma_h^m i_{t-1}^m + \beta_h^m mps_t^i + \epsilon_t^h \tag{23}$$

Figure 10: Responses of Nominal Yield Curve Components to a Target Shock

Panel A: Expected average level of short-term interest rates



Panel B: Term premium

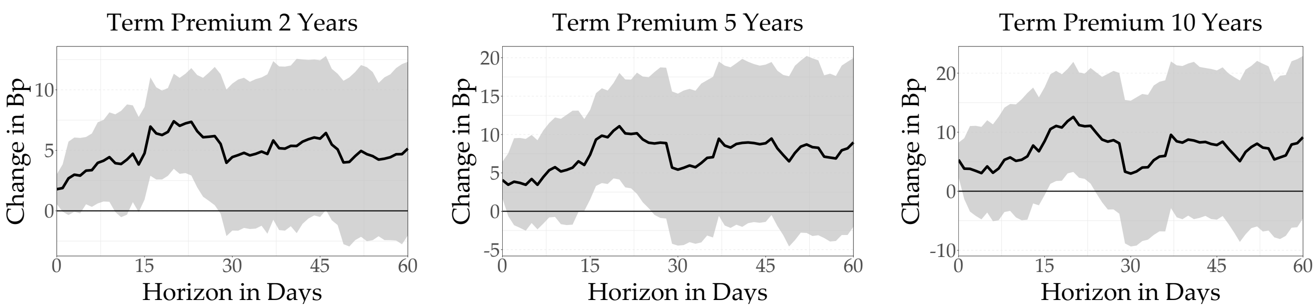
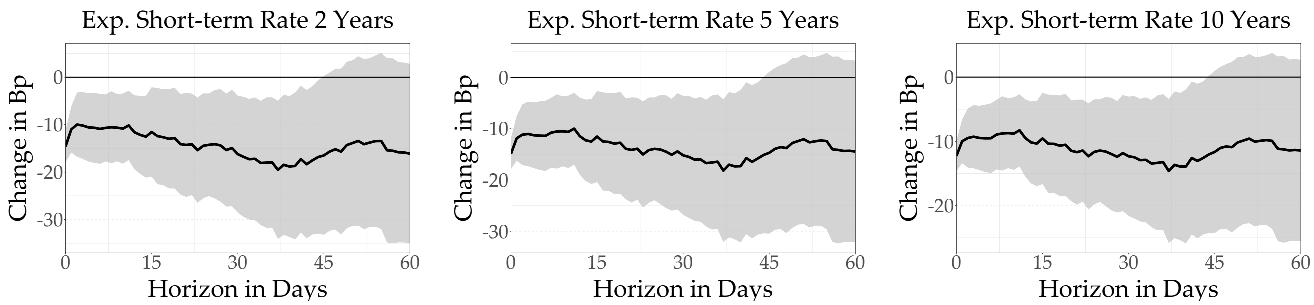


Figure 11: Responses of Nominal Yield Curve Components to Forward Guidance

Panel A: Expected average level of short-term interest rates



Panel B: Term premium

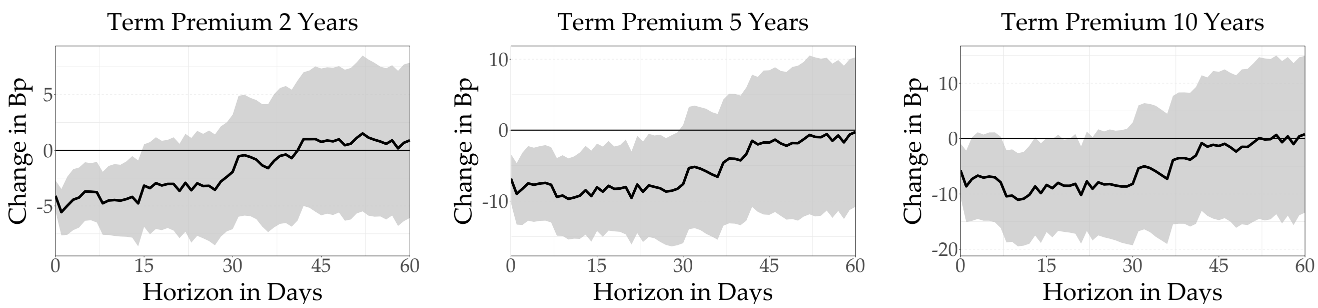
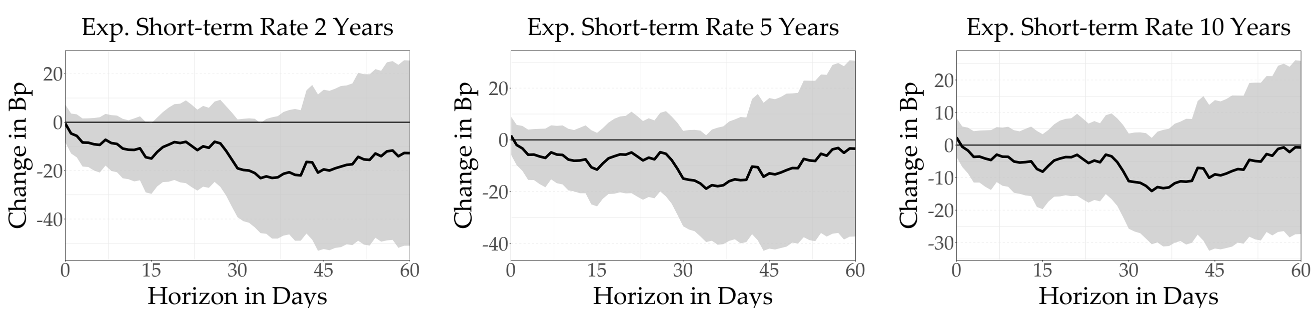
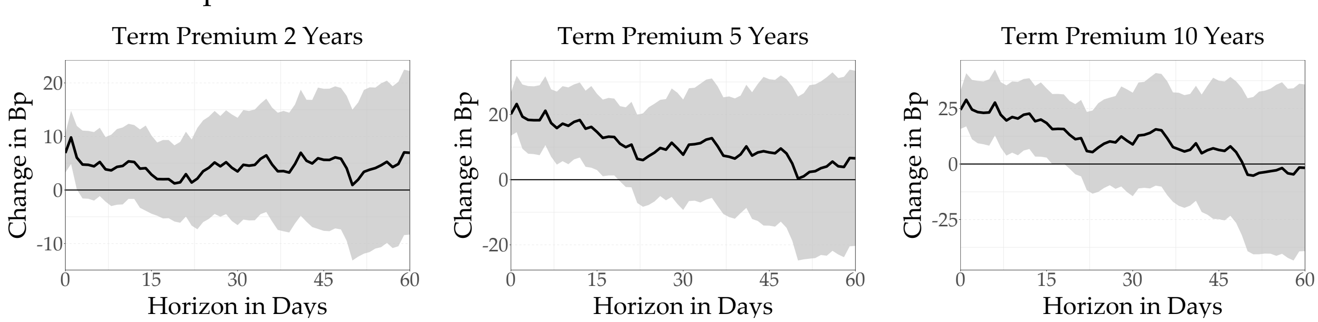


Figure 12: Responses of Nominal Yield Curve Components to a Information Effect Shock

Panel A: Expected average level of short-term interest rates



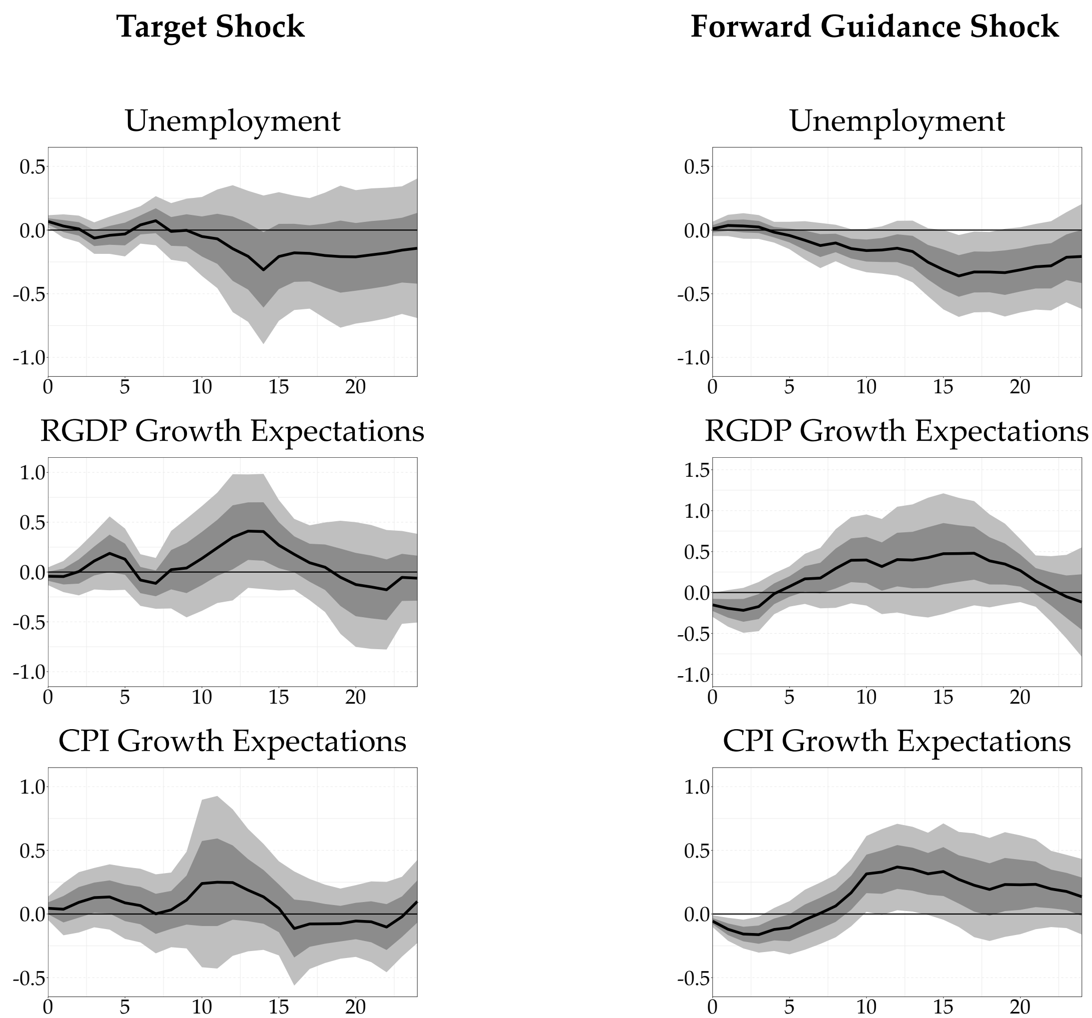
Panel B: Term premium



F Macroeconomic Effects of Monetary Policy Announcements - Additional Variables

In this Section, I provide additional evidence on the transmission of the identified monetary policy shock measures using the LP-IV approach. For that, I add an additional variable one by one and rerun the estimation. Figure 13 only shows the additional responses as the baseline results are almost not affected.

Figure 13: Responses to Expansionary Monetary Policy Shocks



Notes: Figures show responses to a target shock that lowers the 10-Year, 3-Month term spread by 25 bp on impact. Solid black lines are point estimates, gray areas represent 68% and 95% confidence intervals. Sample period: 07/1991 - 09/2017.

G Identification of Monetary Policy Shocks: Proxy SVAR

As a robustness check, I analyze the dynamic macroeconomic effects of the identified monetary policy shock measure, i.e. the target shock and the forward guidance measure, using the proxy SVAR methodology introduced in Olea et al. (2012), Stock and Watson (2012) and Mertens and Ravn (2013), and recently applied to the identification of monetary policy shocks in Gertler and Karadi (2015). For the estimation, I use the same data as in Section 5.

The main idea of this approach is that external information can be used to identify the structural impact multiplier matrix, i.e. B in the following. In particular, let u_t be the vector of reduced-form innovations estimated from a linear projection of a vector Y_t of macroeconomic variables on their past values. These reduced-form innovations can be expressed as a linear combination of structural, mutually uncorrelated shocks, ε_t, where B governs the impact response of the observable variables, Y_t, caused by the exogenous shocks.

$$u_t = B\varepsilon_t \tag{24}$$

The $n \times n$ variance-covariance matrix of the reduced-form innovations Σ_u is estimated by

$$\Sigma_u = E(u_t u_t') = BB'. \tag{25}$$

Assuming that a vector m_t of external instruments is i) contemporaneously correlated with a set of structural shocks and ii) orthogonal to the remaining shocks, one can use these instruments, m_t, to identify the matrix B partially for the respective shocks they are correlated with.

As the shocks of interest are only the k shocks related to monetary policy, it suffices to identify only the k columns of B related to these shocks. Without loss of generality, the following derivation assumes that the shocks of interest are ordered first in the vector ε_t. Thus, let ε_t^{mp} be the $k \times 1$ vector that includes the shocks of interest, while ε_t^x of size $(n-k) \times 1$ comprises the other shocks. Similarly, B can be divided into $B = [B^{mp}\ B^x]$, where B^{mp} and B^x are of size $n \times k$ and $n \times (n-k)$, respectively.

As shown in Olea et al. (2012), Stock and Watson (2012) and Mertens and Ravn (2013), the structural multiplier matrix of interest B^{mp} can be identified using covariance restrictions implied by external instruments. Let m_t be a $k \times 1$ vector of instrumental variables that are assumed to be mean zero ($E(m_t) = 0$). For the set of instruments, m_t, to be valid, the proxies have to be relevant for identifying the monetary policy shocks, ε_t^{mp}, and orthogonal to the other shocks, ε_t^x.

$$E(m_t \varepsilon_t^{mp\prime}) = \Phi \tag{26}$$

$$E(m_t \varepsilon_t^{x\prime}) = 0 \tag{27}$$

Accordingly, the conditions (26) and (27) state that the instruments have to be correlated with the shocks of interest, while they are uncorrelated with all other shocks. The only restriction imposed on Φ is non-singularity. Further, to improve the identification, it is also assumed that the instruments are orthogonal to the information contained in the lagged dependent variables, $X_t = \sum_{i=1}^{p} Y_{t-i}$.

$$E(m_t X_t) = 0 \tag{28}$$

Condition (28) can be implemented by simply projecting the set of raw instruments on X_t, while using the residuals for the shock identification.

To clarify how the restrictions (26)-(28) can be used for identification, the structural impact multiplier matrix B has to be partitioning further.[47] Consider the following representation of Equation (24)

$$\begin{bmatrix} \underset{(k\times 1)}{u_t^1} \\ \\ \underset{((n-k)\times 1)}{u_t^2} \end{bmatrix} = \begin{bmatrix} \underset{(k\times k)}{B^{1,mp}} & \underset{(k\times(n-k))}{B^{1,x}} \\ \\ \underset{((n-k)\times 1)}{B^{2,mp}} & \underset{((n-k)\times(n-k))}{B^{2,x}} \end{bmatrix} \begin{bmatrix} \underset{(k\times 1)}{\varepsilon_t^{mp}} \\ \\ \underset{((n-k)\times 1)}{\varepsilon_t^{x}} \end{bmatrix}, \tag{29}$$

where the diagonal matrices, $B^{1,mp}$ and $B^{2,x}$, are assumed to be non-singular. Without loss of generality, u_t^1 is the $k \times 1$ vector of reduced-form innovations associated with the variables necessary to identify the effect of monetary policy actions.

Using the partitioning performed by (29), conditions (26) and (27) can be rewritten as

$$E(m_t u_t^{1\prime}) = \Phi B^{1,mp\prime} \tag{30}$$

$$E(m_t u_t^{2\prime}) = \Phi B^{2,mp\prime}. \tag{31}$$

Alternatively, both restrictions can be combined to

$$B^{2,mp} B^{1,mp^{-1}} = \left(\left(E(m_t u_t^{1\prime}) \right)^{-1} E(m_t u_t^{2\prime}) \right)'. \tag{32}$$

Note that the moments $E(m_t u_t^{1\prime})$ and $E(m_t u_t^{2\prime})$ can be estimated from the data and, thus, provide an estimate for $B^{2,mp} B^{1,mp^{-1}}$. As it is shown in Mertens and Ravn (2013), combining the restrictions (25) and (32) yields the following closed form solution

$$B^{1,mp} S_1^{-1} = (I - B^{1,x} B^{2,x^{-1}} B^{2,mp} B^{1,mp^{-1}})^{-1} \tag{33}$$

$$B^{2,mp} S_1^{-1} = B^{x,1} B^{1,mp^{-1}} (I - B^{1,x} B^{2,x^{-1}} B^{2,mp} B^{1,mp^{-1}})^{-1}. \tag{34}$$

Note that all matrices on the right can be estimated using the moments (25) and (30)-(32). Accordingly, the estimation of $B^{mp} = [B^{1,mp\prime}\ B^{2,mp\prime}]'$ depends on identifying the $k \times k$ matrix S_1. Combining (33) and (34) yields

$$\begin{aligned} S_1 S_1' = (I - B^{1,x} B^{2,x^{-1}} B^{2,mp} B^{1,mp^{-1}}) \ldots \\ \times B^{1,mp} B^{1,mp\prime} (I - B^{1,x} B^{2,x^{-1}} B^{2,mp} B^{1,mp^{-1}})'. \end{aligned} \tag{35}$$

[47] The derivation closely follows Jentsch and Lunsford (2016).

In case of $k = 1$, $S_1 S_1'$ becomes a scalar and B^{mp} could be solved up to a sign convention (see for example Gertler and Karadi (2015)). In case of $k > 1$, however, $\frac{(k-1)k}{k}$ additional restrictions are required. Fortunately, Equation (29) can be rewritten to make this task straight forward as well.

$$u_t^1 = B^{1,x} B^{2,x^{-1}} u_t^2 + S_1 \varepsilon_t^{mp} \tag{36}$$

Here, again, $B^{1,x} B^{2,x^{-1}}$ can be estimated using the moment conditions. Let s_{ij} be the row i column j element of S_1. Then, s_{ij} determines the direct effect of j^{th} structural shock, e.g. ε_t^j while $0 < j < k$, on the i^{th} reduced-form innovation in u_t^1.[48] Alternatively, one can think of Equation (36) as that S_1 captures the contemporaneous interdependence of the policy instruments. As demonstrated in Mertens and Ravn (2013) and Piffer and Podstawski (2017), economic theory and timing assumptions can be used to motivate conventional identification strategies like a recursive ordering or sign restrictions.

In the following, the identification strategy relies on imposing a lower triangular structure on S_1. Consequently, one additional restrictions about the contemporaneous responses of specific variables to the surprise shocks is necessary. Note, while the specific ordering of the variables does not affect the identification, it eases the explanation to assume that the monetary policy indicators, i.e. the federal funds rate and the ten-year, three-month term spread, are order first.

Accordingly, Equation (36) can be restate as

$$\begin{pmatrix} u_t^{\text{ff}} \\ u_t^{\text{term}} \end{pmatrix} = \eta u_t^2 + \begin{bmatrix} s_{11} & s_{12} \\ s_{21} & s_{22} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{\text{target}} \\ \varepsilon_t^{\text{fwg}} \end{pmatrix}, \tag{37}$$

where $\eta = B^{1,x} B^{2,x^{-1}}$, u_t^{ff} and u_t^{term} denote the reduced-form innovations of the first two Equations in the VAR, while $\varepsilon_t^{\text{target}}$ and $\varepsilon_t^{\text{fwg}}$ denote the two structural monetary policy shocks, respectively. Fortunately, the theoretical discussion in Section 2 combined with the reduced-form evidence reported in Section 3 provides useful information how to restrict S_1.

A forward guidance shock represents the component of monetary policy that does not affect the current federal funds rate. While forward guidance signals information about the future path of monetary policy, it should be orthogonal to the effect of current changes in the policy rate. This restriction is akin to the restriction used in Gürkaynak et al. (2005). Accordingly, the element $s_{12} = 0$ implying a lower triangular structure for S_1. A simple Choleski decomposition of $S_1 S_1'$ yields a measure for S_1 (see Lakdawala, 2019).[49] Finally, I regress the proxy variables obtained in Section 3 on the lags of Y_t and use the residual series as instruments. Consequently, the instruments used to identify impact matrix B are orthogonal to the history of Y_t.

Figure 14 shows the impulse responses of the five variables in the VAR to the two monetary policy shock, i.e. the monetary policy rate shock and the forward guidance shock. All graphs are

[48] Further, there is an indirect effect due to the endogenous contemporaneous reaction through u_t^2.

[49] Note, however, restricting the direct effect of a given shock on a specific variable does not exclude any contemporaneous responses of that variable. As indicated by Equation (36), the imposed restrictions require that the effect is zero after allowing for a contemporaneous feedback through u_t^s (Mertens and Ravn, 2013).

estimated for a 25 basis point decrease in the respective policy indicator. To test for potentially weak instruments, I regress the reduced-form innovations of the instrumented variables on the instruments. The F-statistics of these regressions are 13.7 for the federal funds rate and 12.9 for the term spread. Both values are above the threshold value of 10 proposed by Stock and Yogo (2005). The plotted confidence intervals are computed using the bootstrap procedure discussed in Mertens and Ravn (2013) using 5000 replications. The main idea is to use a recursive-design wild bootstrap following Gonçalves and Kilian (2004) to account for conditional heteroskedasticity. However, the LS estimates are corrected for a small-sample bias using the bias-adjusted bootstrap method proposed in Kilian (1998). The reduced-form VAR is estimated with 12 lags and the sample period is July 1990 to September 2017.

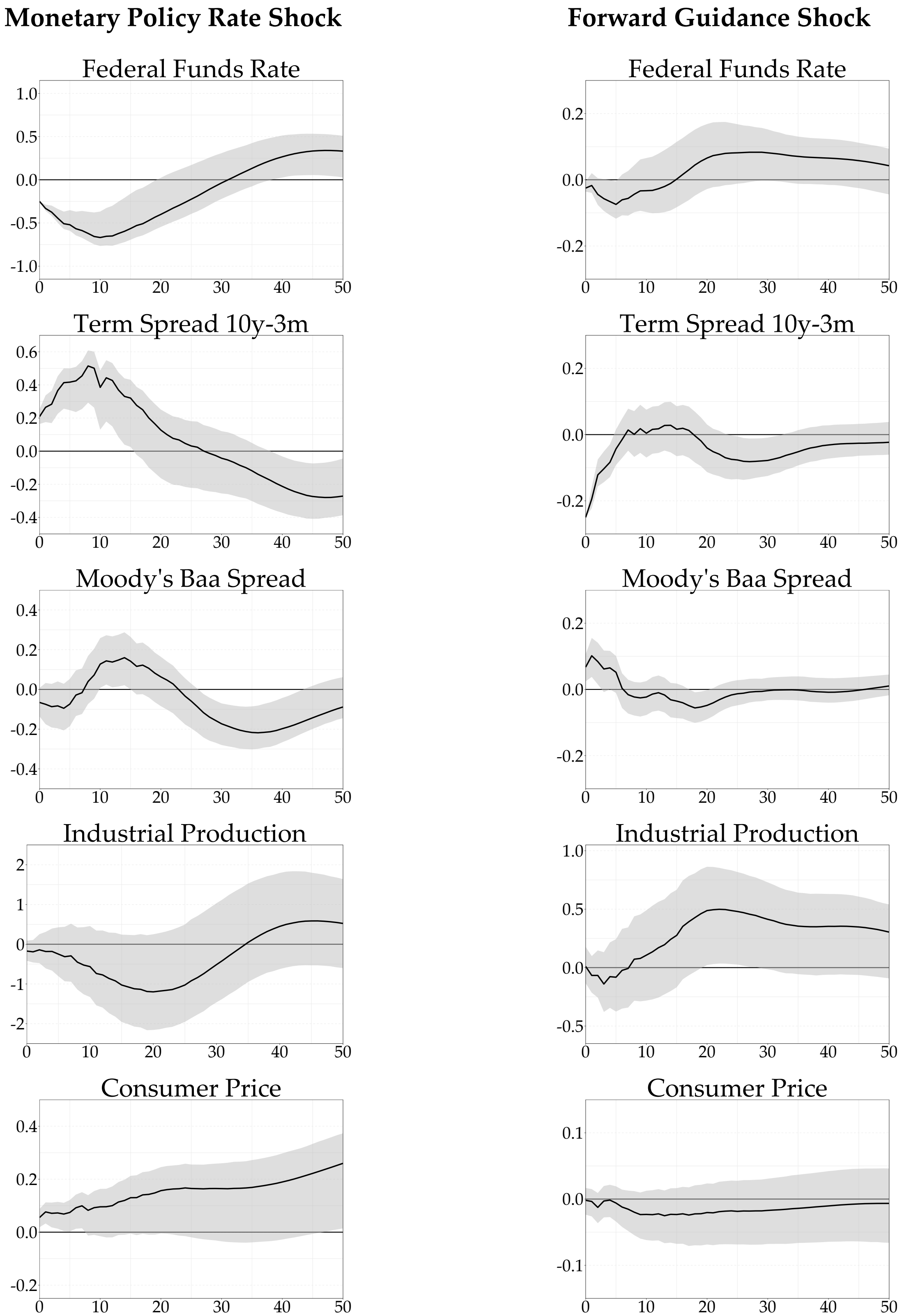
Due to an expansionary monetary policy rate shock, the federal funds rate decreases immediately and remains negative for the next two years. While industrial production does not show any significant response, inflation increases leading to a significant and long-lasting raise in the price level. Financial tensions, as measured by the credit spread, increase over the first year but turn significantly negative two years after the shock.

The expansionary forward guidance shock is identified by an immediate flattening of the yield curve. By signaling an expansionary deviation from its monetary policy rule in the future, the Federal Reserve lowers the spread between short- and long-run interest rates by decreasing expected future short-term rates. The credit spread increases on impact but turns negative after about six months. The effect of the forward guidance shock on the output measure is positive and marginally significant after about two years. Further, the impulse response function is hump-shaped. The effect on the consumer price index is not significant at all. Overall, the results support the findings obtained with the LP-IV approach.

Compared to the results obtained with the LP-IV approach, the results presented in this section are strikingly similar.[50] Only the insignificant responses of industrial production to a target shock and consumer prices to a forward guidance shock have a qualitatively different nature.

[50] Please note the different time horizon of the impulse response functions.

Figure 14: Responses to Monetary Policy Loosening Shocks



Notes: Figures show responses to a 25bp expansionary monetary policy shock (left) and to a 25bp expansionary forward guidance shock (right). Solid lines are point estimates, grey areas represent 90 percent confidence intervals.