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## Disentangling the Information and Forward Guidance Effect of Monetary Policy Announcements on the Economy

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# Disentangling the Information and Forward Guidance Effect of Monetary Policy Announcements on the Economy

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## Abstract

When monetary policy announcements not only induce market participants to update their expectations about the future path of monetary policy but also about economic prospects, the identification of exogenous monetary policy shocks becomes challenging. Taking into account an information effect regarding economic prospects, this paper presents a novel strategy to decompose the information content of central bank announcements. Based on a formally derived prediction of the standard New Keynesian model, the identifying assumption reads that the information effect should be correlated with movements in 5-Year, 5-Year breakeven inflation rates on announcement days. Separating distinct dimensions of monetary policy with a clear structural interpretation, the effects of monetary policy announcements on the macroeconomy are investigated using a vector autoregression identified with external instruments. My results highlight the effectiveness of forward guidance in influencing output.

**JEL Classification:** E44, E52, E58

**Keywords:** Monetary Policy Shocks, High-Frequency Identification, Forward Guidance, Central Bank Information, Proxy VAR

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# 1. Introduction

Effective monetary policy does not only consist of having optimal control over short-term interest rates. For decades, central bankers and researchers alike have shown that monetary policy affects the real economy mainly through its impact on market participants' expectations (see Woodford, 2001; Blinder et al., 2008, and references cited there in). The importance of central bank communication and transparency has increased, particularly as a result of the exceptionally low interest rates in recent years.<sup>1</sup> However, while there is a large literature on how unexpected interest rate changes transmit to the real economy, the effect of central bank announcements is less clear-cut. Hence, there is no trivial solution regarding the assessment of the effectiveness of this latter aspect of monetary policy. The aim of this paper is to provide a theoretically grounded approach to empirically disentangle the information revealed by central bank announcements and to investigate its impact on the real economy.

Despite the fact that there is a wide-range of approaches proposed in the literature to investigate the implications of monetary policy announcements, common ground is to quantify these effects by means of high-frequency financial market data. Asset price changes, e.g. interest rate futures, in sufficiently short time windows around monetary policy meetings are frequently causally linked to the content of these announcements. However, as recent research by Campbell et al. (2012) and Nakamura and Steinsson (forthcoming) shows, central bank announcements do not only convey information about the current and future path of monetary policy but also about the state of the economy.<sup>2</sup> By that, conventional identification strategies are challenged, especially concerning the effectiveness of forward guidance. Consider, for example, an unexpected announcement by the central bank to deviate from the interest rate path expected by market participants in the near future. Market participants may perceive this either as an expansive stimulus to strengthen the economy or, contrary, as a systematic response by the central bank to negative economic news unknown to the public. Assuming standard economic transmission channels, those two readings of the hypothetical central bank announcement imply quite opposed effects onto real economic variables. In this paper, I propose that these two effects of central bank communication can be separated by using the change in

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<sup>1</sup> Gürkaynak et al. (2005), Campbell et al. (2012), and Campbell et al. (2016), demonstrate that the FOMC has influenced financial market expectations about the future path of their monetary policy quite effectively as early as the 1990s.

<sup>2</sup> Note that, the literature on the information effect of monetary policy announcements dates back at least to Romer and Romer (2000). Other recent contributions include Barakchian and Crowe (2013), Hanson and Stein (2015), Campbell et al. (2016), Andrade et al. (2017), Miranda-Agrippino (2016), Miranda-Agrippino and Ricco (2017).

long-run inflation expectations as instrument for the news component of central bank announcements about the state of the economy rather than the current and future path of the interest rate.

The contribution of this paper to the literature is twofold. First, I present a novel decomposition of the information content of Federal Open Market Committee (FOMC) announcements accounting explicitly for a non-monetary policy information effect. Using a standard New Keynesian model to rationalize the identification strategy, the obtained measures represent distinct components of monetary policy announcements that have a clear structural interpretation. Specifically, I identify surprise changes that can consist of three dimensions: changes in the federal funds rate, forward guidance, and an information effect. The latter two dimensions represent the change in market participants' expectations regarding the future path of monetary policy and the state of the economy, respectively. The identification strategy exploits theoretical predictions about the co-movement of interest rates for different maturities and long-run inflation expectations. These measures provide evidence for the role played by the different monetary policy dimensions over the last decades. In a preliminary analysis, I show that these time paths fit reasonably narrative accounts. Most interestingly, news related to the economic prospects appear to be the dominate component of FOMC announcements during the zero lower bound period.<sup>3</sup>

Second, I assess the effects of the different dimensions of monetary policy on output and prices by applying a vector autoregression (SVAR) model to US data. In the proxy SVAR methodology developed by Stock and Watson (2012) and Mertens and Ravn (2013), shocks are identified by exploiting the information content of appropriate instruments. Using the measures discussed before, I am able to provide new evidence for the effectiveness of unexpected changes in the federal funds rate and forward guidance. In particular, I find that forward guidance has a statistically significant impact on output about one year after the announcement while there is no evidence for a price puzzle. This highlights the importance of explicitly accounting for the information effect of central bank announcements.

To assess the effect of monetary policy announcements on market participants' expectations, I use the high frequency identification method 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 July 1991 - September 2017 and rotate them appropriately. Based on the theoretical argument derived also in this paper, I use a novel method to identify a part of the rotation matrix. Specifically, I borrow the external instrument identification

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<sup>3</sup> This is in line with the observation of Woodford (2012) with respect to the information content of FOMC announcements between 2008 and 2012.

procedure from the proxy SVAR literature. I use high-frequency variations in 5-Year, 5-Year forward breakeven inflation rates derived from the TIPS market as proxy variable. This allows me to identify the very part of the yield curve response caused by the FOMC meetings that is driven by information unrelated to the current or future path of monetary policy. In reference to the literature, I call this component the information effect of monetary policy communication. 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 a second component that represents surprise changes in the future path of monetary policy. I call the latter effect forward guidance. In general, the presumption that monetary policy announcements systematically affect the yield curve through at least three factors is supported by the findings of Swanson (2017).

In a second step, these distinct components of monetary policy announcements are used as instruments to identify structural shocks in a proxy SVAR model. While ending in August 2016<sup>4</sup>, my analysis covers both the period of the great moderation and the zero lower bound period. Consequently, I extend the work of Gertler and Karadi (2015) with respect to the time dimension and, more importantly, by explicitly taking into account a potential information effect.

The existence of a central bank information effect is the focus of a rich literature dating back to Romer and Romer (2000). The general presumption for such an effect is that there is some kind of information asymmetry between central banks and the public. Romer and Romer (2000) attribute this to the FOMC's superior ability in processing and interpreting information potentially also available to the markets. In a similar line of reasoning, Barakchian and Crowe (2013), Campbell et al. (2016), and Miranda-Agrippino (2016) provide evidence implying that the information difference between fed's forecasts of the economic prospects and private sector forecasts induces the latter to update their beliefs about the state of the economy. However, as pointed out by Nakamura and Steinsson (forthcoming), such an effect on the expectations of market participants does not have to imply that central banks have superior information. Using evidence from the finance literature, they interpret this information effect rather as the consequence of an opinion leader position that is attributed to central banks. In any case, the existence of a non-monetary policy related information effect constitutes a challenge for the empirical identification of exogenous monetary policy shocks.

Note, that the approach used in this paper does not identify specific unconventional monetary policy measures, e.g. explicit calender-based forward guid-

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<sup>4</sup> Note that the divergent sample periods for the SVAR analysis and the construction of the instruments is due to the availability of data.

ance or large-scale asset purchase programs (LSAPs), and how they impact the economy. When decomposing the effect of actual monetary policy measures, I only disentangle surprise changes in the current monetary policy stance and changes in the expected path of monetary policy in the future. 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, Nakashima et al. (2017), Swanson (2017), and Ciccarelli et al. (2017).

The remainder of the paper is organized as follows. Section two presents a brief overview of the related literature and derives the central identification assumption for the information effect from a standard New Keynesian model. In section three, the general methodology of the proxy SVAR is presented. The external instrument approach is used in section four to decompose the effect of FOMC announcements onto the yield curve. In section five, the dynamic effects of the three different dimensions of monetary policy are estimated using a proxy SVAR for the US economy. Section six concludes.

## **2. Theoretical Background**

### **2.1. Literature Review**

In general, the paper is related to three different strands of the literature in monetary economics. As the main objective of this paper is to empirically disentangle the effects of monetary policy on expectations about the future path of monetary policy from the effect of non-monetary policy related information released by central banks during regularly policy announcements, this paper relates first and foremost to the growing literature on the fed information effect.

In their seminal paper, Romer and Romer (2000) argue that the policy announcement of the fed may affect the expectations of market participants beyond their signal about the future path of monetary policy. They provide evidence for a potential information advantage on the side of the fed and by this means explain why monetary policy shocks may induce market participants to update their beliefs about fundamentals and economic prospects. Using survey data, Campbell et al. (2012) and Nakamura and Steinsson (forthcoming) show that surprising monetary tightening shocks lead to a decrease in the expected unemployment rate and an increase in output growth, respectively. Campbell et al. (2012) explain their results by introducing the distinction between Delphic and Odyssean forward guidance. While the former indicates a public statement

by the monetary authorities about their expectation regarding the prospects of the economy and potential responses by the central bank, it does not bind monetary policy in any way. Contrary, Odyssean forward guidance binds future monetary policy to an announced path that may potentially be time-inconsistent as time passes by. Based on the theoretical work of Campbell et al. (2012), Campbell et al. (2016) and Andrade and Ferroni (2016) try to quantify these distinct components of central bank communication for the Fed and the ECB, respectively. Most closely related to this paper is Jarociński and Karadi (2018). They use the high-frequency co-movement of interest rates and stock prices around announcements of the FOMC and the ECB to identify the effect of non-monetary policy related information on the economy. Using a Bayesian VAR with sign restrictions, they assess the impact of information effect shocks to the economy. Further, they formally explain the observed responses using a New Keynesian model with financial frictions. Nakamura and Steinsson (forthcoming) use a structural model that explicitly accounts for the fed information effect by allowing monetary policy to affect market participants' expectations about the future path of the natural rate of interest. Monetary policy affects the real economy in this model by both their leverage over the real interest rate in the short run and their effect on the expectations about the current and future fundamentals of the economy.

As in the high-frequency identification literature, I use several different money market instruments to identify the distinct components of monetary policy. Following the seminal work of Kuttner (2001), Gürkaynak et al. (2005) provides evidence that monetary policy affects asset prices of different maturities not only through surprising changes in the federal funds target but also through additional information about the future path of their policy instrument that is released with their statements. Since then, their method to differentiate between a target dimension and a path dimension of monetary policy has been widely adopted in the academia.<sup>5</sup> More recently, Campbell et al. (2012) and Swanson (2017) extend the analysis of Gürkaynak et al. (2005) to post-crisis data and show that yields of medium- to long-term securities are still significantly affected by the forward guidance shocks of FOMC meetings at the zero lower bound. Moreover, Swanson (2017) shows that a three factor model is required to adequately describe the effect of monetary policy on the yield curve covering the pre-crisis and zero lower bound period. This is discussed in great detail in section 3 where I construct instruments for the different dimensions of monetary policy using yield curve data.

Given the methodology employed, the paper relates also to the growing literature that uses proxy SVARs to analyze the dynamic effects of monetary pol-

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<sup>5</sup> See for example Brand et al. (2010), Wright (2012), Kim and Other (2018).

icy. Gertler and Karadi (2015) show that monetary policy while causing only small nominal short-term interest rate variation has a considerable impact on long-term credit costs. With respect to the modeling of monetary policy shocks, Gertler and Karadi (2015) exploit the information of a single instrument, i.e. changes in the four quarter ahead fed funds futures, to identify shocks to the one year treasury yield. More recent approaches, e.g. Kim (2017) and Lakdawala (2016), try to decompose the effects of conventional monetary policy working through variations in short-term interest rates and forward guidance by allowing for two shocks instrumented by two measures representing two distinct dimensions of monetary policy. Both papers have in common that they find rather counterintuitive responses of output and prices to forward guidance shocks which they explain with Delphic forward guidance.

## 2.2. Theoretical Effect of Monetary Policy

The goal of this section is to justify the identification strategy pursued in the following chapters within the framework of the basic New Keynesian model (NKM). In the basic textbook representation, monetary policy is assumed to affect the real economy because of nominal rigidities. A central bank sets the short-term nominal interest rate and thus influences the real interest rate at a horizon where nominal prices need to readjust. However, as Nakamura and Steinsson (forthcoming) show, central banks may also affect market participants' expectations through non-monetary information. While this complicates the empirical identification of monetary policy shocks, as I will address more deeply in section 3, theoretical implications of the dynamic effects of these two shocks, a monetary policy announcement shock and an information shock, can be used to disentangle their effect on the yield curve.

Starting from a non-stochastic steady state, the NKM can be expressed by the following three equations that represent the log-linearized intertemporal first order conditions around this steady state.<sup>6</sup>

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

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa \tilde{y}_t \quad (2)$$

$$i_t = \phi_\pi \pi_t + \phi_y \tilde{y}_t + \varepsilon_t^{mp} \quad (3)$$

$\tilde{y}_t$  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

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<sup>6</sup> For a textbook presentation of the NKM see Galí (2008).



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. The nominal interest rate  $i_t$  is the gross return on a risk-free nominal bond with a one-period maturity.  $\pi_t$  denotes inflation. Finally,  $\varepsilon_t^{mp}$  denotes an unexpected monetary policy shock in period  $t$ . All variables are denoted in percentage deviations from the steady state.

Equation (1) is the dynamic IS curve and can be derived from the linearized intertemporal Euler equation. It relates the current output gap to the expected future output gap and the wedge between the real rate (using the Fisher equation) and the natural rate of interest. The second equation represents the New Keynesian Phillips curve and links the current and expected inflation rate to the output gap. The last equation is a simple interest rate rule. In absence of any exogenous shocks, and assuming that the interest rate is determined optimally by the monetary authorities, the paths for inflation and the output gap will be constantly zero. This can be seen easily by re-writing (1)-(3) as system of difference equations

$$\mathbb{E}_t x_{t+1} = Ax_t + z_t, \quad (4)$$

where

$$x_t = \begin{bmatrix} \tilde{y}_t \\ \pi_t \end{bmatrix} \quad A = \begin{bmatrix} \sigma(\phi_\pi - \frac{1}{\beta}) & 1 + \sigma(\phi_y + \frac{\kappa}{\beta}) \\ \frac{1}{\beta} & -\frac{\kappa}{\beta} \end{bmatrix} \quad z_t = \begin{bmatrix} \sigma(\varepsilon_t^{mp} - r_t^n) \\ 0 \end{bmatrix}.$$

Assuming that the Taylor principle holds, solving (4) forward we get

$$x_t = - \sum_{j=0}^{\infty} A^{-j-1} \mathbb{E}_t z_{t+j}. \quad (5)$$

Two things can be learned from this exercise. First, both inflation and the output gap today are determined by the expected path of the exogenous shocks. Second, as shown in Nakamura and Steinsson (forthcoming) among others, monetary policy may also affect the economy by altering the expectations about future shocks to  $r_t^n$ . To operationalize the latter for the subsequent empirical investigation, it is beneficial to recast the interest rate rule in terms of optimal monetary policy. The following derivation builds on Andrade and Ferroni (2016).

Suppose the central bank is able to manage the nominal interest rate so that the real interest rate tracks the natural rate of interest perfectly. Moreover, assume 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. Then, equation (3) can be replaced by

$$r_t = i_t - \mathbb{E}_t \pi_{t+1} = r_t^n + \varepsilon_{t,t-j}^{mp}, \quad (6)$$

where  $\varepsilon_{t,t-j}^{mp}$  denotes a monetary policy tightening or accommodation in period  $t$  as already announced in period  $t-j$ . Additionally, equations (1) and (2) can be solved forward assuming that the economy eventually converges to its steady state.

$$\tilde{y}_t = -\sigma \mathbb{E}_t \sum_{i=0}^{\infty} (i_{t+i} - \pi_{t+1+i} - r_{t+i}^n) \quad (7)$$

$$\pi_t = \kappa \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i \tilde{y}_{t+i} \quad (8)$$

Similar to (5), equations (7) and (8) indicate that the current output gap equals the sum of expected future deviations of the real rate from the natural rate of interest, and that current inflation is the discounted sum of current and future output gaps.

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  $E_t r_{t+N} < E_t r_{t+N}^n$ . According to (7), this leads to a positive output gap, e.g.  $\tilde{y}_t = -\sigma \varepsilon_{t+N,t}^{mp}$ . Additionally, the expected output gap for the subsequent periods until  $t+N$  are positive. With respect to inflation, equation (8) can be solved to

$$\begin{aligned} \mathbb{E}_t \pi_{t+j} &= -\kappa \sigma \frac{1 - \beta^{N+1-j}}{1 - \beta} \varepsilon_{t+N,t}^{mp} & \text{for } j \leq N \\ &= 0 & \text{for } j > N \end{aligned} \quad (9)$$

using the expected path for the output gap. Up to period  $t+N$ , current and expected inflation is 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  $r_t^n$ . Thus, inflation returns to its steady state value of zero. The effect on the expected path for inflation can be translated into the effect on the path for the nominal interest rate using equation (6).

$$\begin{aligned} \mathbb{E}_t i_{t+j} &= \mathbb{E}_t r_{t+j}^n - \kappa \sigma \frac{1 - \beta^{N+1-j}}{1 - \beta} \varepsilon_{t+N,t}^{mp} & \text{for } j < N \\ \mathbb{E}_t i_{t+N} &= \mathbb{E}_t r_{t+N}^n + \varepsilon_{t+N,t}^{mp} \end{aligned} \quad (10)$$

As discussed,  $r_t^n$  is assumed to be a function of 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 of the fundamentals,  $\Omega_t$ ,

$$\mathbb{E}_t r_{t+j}^n = \phi_j \Omega_t. \quad (11)$$

Combining (11) and (10), one can express the expected nominal interest rate in period  $t + j$  as

$$\mathbb{E}_t i_{t+j} = \phi_j \Omega_t - \psi_j \varepsilon_{t+N,t}^{mp}, \quad (12)$$

where  $\psi_j = \kappa \sigma \frac{1 - \beta^{N+1-j}}{1 - \beta} > 0$  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

$$\mathbb{E}_t [i_{t+N} - i_{t+j}] = (\phi_N - \phi_j) \Omega_t + (1 + \psi_j) \varepsilon_{t+N,t}^{mp}. \quad (13)$$

Given that monetary policy announcement shocks could be fairly well assumed to occur predominantly during policy meetings, these shocks can be modeled as discrete events. Thus, following Andrade and Ferroni (2016), the change in the slope of the term structure due to the monetary policy announcement can be expressed as

$$\Delta_\epsilon (\mathbb{E}_t i_{t+N} - \mathbb{E}_t i_{t+j}) = \Delta_\epsilon (\phi_N - \phi_j) \mathbb{E}_t \hat{\Omega}_t + (1 + \psi_j) \varepsilon_{t+N,t}^{mp}, \quad (14)$$

where  $\Delta_\epsilon (\mathbb{E}_t i_{t+N} - \mathbb{E}_t i_{t+j})$  denotes the change in the slope of the term structure in a narrow window around the announcement date and  $\mathbb{E}_t \hat{\Omega}_t$  denotes the potential revision of the expected current state of the fundamentals due to the information revealed in the monetary policy meeting. The conventional high-frequency identification approach consists in assuming that  $\Delta_\epsilon (\phi_N - \phi_j) \mathbb{E}_t \hat{\Omega}_t = 0$ .<sup>7</sup> Thus, an observed 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 a direct monetary policy shock (if  $N = 0$ ) or as a forward guidance shock (if  $N > 0$ ).<sup>8</sup> However, as shown in Campbell et al. (2012) and Nakamura and Steinsson (forthcoming) using survey data, monetary policy surprises seem to affect market participants' expectations about the real economy. Consequently, the assumption that observed variations in nominal interest rates can be directly mapped into the surprise component of monetary policy shocks seems rather restrictive.

However, the fact that monetary policy meetings may affect the term structure beyond changes in the expected path of monetary policy can be used to

<sup>7</sup> See Kuttner (2001), Gürkaynak et al. (2005), and Gertler and Karadi (2015) among many others.

<sup>8</sup> In reference to Gürkaynak et al. (2005) these shocks are commonly named *target shock* and *path shock*.

identify these non-monetary shocks. For the following derivation, two assumptions have to be imposed. First, it is that the monetary policy meeting is the single event that may affect the term structure in the narrow window around the meeting. Second, central banks could manage the expectations about the future path of their monetary policy only up to a certain horizon. While the first assumption is rather conventional in the high-frequency literature, the latter reflects the fact that monetary authorities may not be able to credibly communicate a path for their policy several years into the future.<sup>9</sup> Assuming that central bank announcements may convey non-monetary information about the state of the economy or the future prospects, these information should affect market participants' expectations on a longer horizon. Such an information effect of monetary policy announcements dates back to Romer and Romer (2000).

In terms of the NKM developed before, suppose that the information released during the monetary policy meeting that lead to  $\Delta_\epsilon(\phi_N - \phi_j)\mathbb{E}_t\hat{\Omega}_t$  also lead to a change in  $(\phi_T - \phi_{N+1})\mathbb{E}_t\hat{\Omega}_t$ , where  $T > N + 1$ . Then we should also observe a change in the nominal interest rates of corresponding maturities.

$$\Delta_\epsilon(\mathbb{E}_t i_{t+T} - \mathbb{E}_t i_{t+N+1}) = \Delta_\epsilon(\phi_T - \phi_{N+1})\mathbb{E}_t\hat{\Omega}_t \quad (15)$$

Assuming that the period  $N + 1$  is beyond the horizon where monetary policy can effectively communicate its policy path, the variation at the long end of the yield curve should not be driven by any announced policy actions, i.e.  $\varepsilon_{t+x,t}^{mp} = 0, \forall x > N$ . While the object here is to decompose the variation in interest rates, and given that  $\Delta_\epsilon(\phi_T - \phi_{N+1})\mathbb{E}_t\hat{\Omega}_t$  is not observable, equation (15) can be rearranged in order to find an instrument for  $\Delta_\epsilon(\phi_T - \phi_{N+1})\mathbb{E}_t\hat{\Omega}_t$ . Using the Fisher equation, one can derive

$$\Delta_\epsilon(\mathbb{E}_t[r_{t+T} - r_{t+N+1}]) + \Delta_\epsilon(\mathbb{E}_t[\pi_{t+T} - \pi_{t+N+1}]) = \Delta_\epsilon(\phi_T - \phi_{N+1})\mathbb{E}_t\hat{\Omega}_t. \quad (16)$$

Moreover, for a sufficiently high  $N + 1$ ,  $\Delta_\epsilon(\mathbb{E}_t[r_{t+T} - r_{t+N+1}]) \neq 0$  would imply an implausibly high degree of nominal rigidities. Accordingly, (16) collapses to

$$\Delta_\epsilon(\mathbb{E}_t[\pi_{t+T} - \pi_{t+N+1}]) = \Delta_\epsilon(\phi_T - \phi_{N+1})\mathbb{E}_t\hat{\Omega}_t. \quad (17)$$

Consequently, equation (17) implies that variations in long run inflation expectation rates, like 5-Year, 5-Year forward breakeven inflation rates, in a narrow

<sup>9</sup> Based on the arguments provided in Swanson and Williams (2014) and Hanson and Stein (2015) it seems plausible to assume that the forward guidance policy operates on a two-year horizon. Indeed, during the meeting in August 2011, the FOMC announced that the exceptionally low levels of the funds rate would remain in place "at least through mid-2013" (see for more on that Campbell et al., 2016). So, in the empirical investigation in section 3, the second assumption will be operationalized such that monetary policy may not be able to announce credibly actions five years or more into the future.

window around a monetary policy meeting result from market participants' revisions of their perception of the current state of the economy and their revisions of the projections about the future. In addition, assuming that  $\Delta_\epsilon(\phi_T - \phi_{N+1})$  is somehow correlated with  $\Delta_\epsilon(\phi_N - \phi_j)$  would yield that the left hand side of (17) 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 (14). Thus, in section 3, I will use changes in 5-Year, 5-Year forward breakeven inflation rates on meeting days of the FOMC to identify a clean measures of monetary policy shocks as well as a measure of the fed information effect.

### 3. Methodology of the Proxy SVAR

In this section, I present the proxy SVAR approach as 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). Using the matrix oriented notation of Mertens and Ravn (2013), the section describes the general framework how external instruments can be used to pin down the subspace of certain structural shocks within the space spanned by the reduced-form innovations. The next section discusses the empirical approach used to construct the instrument variables.

Let  $Y_t$  be a  $n \times 1$  vector of observables. Further, consider that the dynamics of the observables can be modeled by a vector autoregression process. In a general structural form this can be express as

$$A_0 Y_t = \sum_{i=1}^p A_i Y_{t-i} + \varepsilon_t, \quad (18)$$

where the coefficient matrices  $A_i$  are of the dimensions  $n \times n$  and are non-singular.<sup>10</sup> The matrix  $A_0$  is assumed to be invertible.  $\varepsilon_t$  is a  $n \times 1$  vector of structural shocks with  $E(\varepsilon_t) = 0$ ,  $E(\varepsilon_t \varepsilon_t') = I$ , and  $E(\varepsilon_t \varepsilon_s') = 0$  for any  $s \neq t$ . As usual, pre-multiplying both sides of (18) by  $A_0^{-1}$  one gets the reduced form representation

$$Y_t = \sum_{i=1}^p C_i Y_{t-i} + u_t, \quad (19)$$

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<sup>10</sup>In the following, any deterministic terms and exogenous regressors are omitted for notational brevity.

where  $C_i = A_0^{-1}A_i$  and  $u_t$  is the  $n \times 1$  vector of reduced form innovations. While the structural shocks  $\varepsilon_t$  are of the main interest in the following, only the reduced form residuals  $u_t$  can be directly estimated from the data. The relation between both is determined by the matrix  $A_0^{-1}$ . In the following, the matrix is renamed in  $B$  to simplify notation. Thus, it holds true that

$$u_t = B\varepsilon_t. \quad (20)$$

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

$$\Sigma_u = E(u_t u_t') = BB'. \quad (21)$$

The structural impact multiplier matrix  $B$  is the key to identify the responses of the observables  $Y_t$  to the structural shocks  $\varepsilon_t$ . 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  $\varepsilon_t$ . Thus, let  $\varepsilon_t^{mp}$  be the  $k \times 1$  vector that includes the shocks of interest, while  $\varepsilon_t^x$  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<sup>11</sup> 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,  $\varepsilon_t^{mp}$ , and orthogonal to the other shocks,  $\varepsilon_t^x$ .

$$E(m_t \varepsilon_t^{mp'}) = \Phi \quad (22)$$

$$E(m_t \varepsilon_t^{x'}) = 0 \quad (23)$$

Accordingly, the conditions (22) and (23) 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  $\Phi$  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,  $X_t = \sum_{i=1}^p Y_{t-i}$ .

$$E(m_t X_t) = 0 \quad (24)$$

Condition (24) can be implemented by simply projecting the set of raw instruments on  $X_t$ , while using the residuals for the shock identification.

<sup>11</sup> As discussed in Mertens and Ravn (2013), among others, the number of instruments subsumed by  $m_t$  could exceed the dimensions of  $\varepsilon_t^{mp}$ .

To clarify how the restrictions (22)-(24) can be used for identification, the structural impact multiplier matrix  $B$  has to be partitioning further.<sup>12</sup> Consider the following representation of equation (20)

$$\begin{bmatrix} u_t^1 \\ (k \times 1) \\ u_t^2 \\ ((n-k) \times 1) \end{bmatrix} = \begin{bmatrix} B^{1,mp} & B^{1,x} \\ (k \times k) & (k \times (n-k)) \\ B^{2,mp} & B^{2,x} \\ ((n-k) \times 1) & ((n-k) \times (n-k)) \end{bmatrix} \begin{bmatrix} \varepsilon_t^{mp} \\ (k \times 1) \\ \varepsilon_t^x \\ ((n-k) \times 1) \end{bmatrix}, \quad (25)$$

where the diagonal matrices,  $B^{1,mp}$  and  $B^{2,x}$ , are assumed to be non-singular. While it is not necessary to order the vector of observables  $Y_t$  accordingly to the structural shocks  $\varepsilon_t$  (Kim, 2017), it simplifies the subsequent description of how to disentangle the  $k$  structural shocks of interest from each other. Thus, 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 (25), conditions (22) and (23) can be rewritten as

$$E(m_t u_t^{1'}) = \Phi B^{1,mp'} \quad (26)$$

$$E(m_t u_t^{2'}) = \Phi B^{2,mp'}. \quad (27)$$

Alternatively, both restrictions can be combined to

$$B^{2,mp} B^{1,mp^{-1}} = \left( \left( E(m_t u_t^{1'}) \right)^{-1} E(m_t u_t^{2'}) \right)'. \quad (28)$$

Note that the moments  $E(m_t u_t^{1'})$  and  $E(m_t u_t^{2'})$  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), the restrictions (21) and (28) yield the following closed form solution

$$B^{1,mp} S_1^{-1} = (I - B^{1,x} B^{2,x^{-1}} B^{2,mp} B^{1,mp^{-1}})^{-1} \quad (29)$$

$$B^{2,mp} S_1^{-1} = B^{x,1} B^{1,mp^{-1}} (I - B^{1,x} B^{2,x^{-1}} B^{2,mp} B^{1,mp^{-1}})^{-1}. \quad (30)$$

Note that all matrices on the right can be estimated using the moments (21) and (26)-(26). Accordingly, the estimation of  $B^{mp} = [B^{1,mp'} B^{2,mp'}]'$  depends on identifying the  $k \times k$  matrix  $S_1$ . Combining (29) and (30) yields

$$\begin{aligned} S_1 S_1' &= (I - B^{1,x} B^{2,x^{-1}} B^{2,mp} B^{1,mp^{-1}}) \dots \\ &\quad \times B^{1,mp} B^{1,mp'} (I - B^{1,x} B^{2,x^{-1}} B^{2,mp} B^{1,mp^{-1}})'. \end{aligned} \quad (31)$$

<sup>12</sup>The derivation follows closely 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 (25) can be rewritten to make this task straight forward as well.

$$u_t^1 = B^{1,x} B^{2,x^{-1}} u_t^2 + S_1 \varepsilon_t^{mp} \quad (32)$$

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.  $\varepsilon_t^j$  while  $0 < j < k$ , on the  $i^{th}$  reduced form innovation in  $u_t^1$ .<sup>13</sup> Alternatively, one can think of equation (32) 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.

## 4. Decomposition of the Dimensions of Monetary Policy Announcements

### 4.1. Data and Information Content of Asset Prices

In this section, I discuss the estimation of the external instruments used in the subsequent VAR analysis to identify the different monetary policy shocks. The estimation builds on the assumption that one can extract the information content of a monetary policy announcement from its effect on the yield curve. Following the approach of Gürkaynak et al. (2005), the responses of asset prices in a narrow window around a scheduled FOMC meeting are interpreted as causal effects of the information provided by the interest rate decision and the corresponding statement. As discussed in section 2.2, from a theoretical point of view, central bank announcements may not only convey information about the current and future path of monetary policy, but they may also signal policy makers' expectations about the current and future state of the economy. Quite similar to the identification problem in SVAR analyses, I will use restrictions supported by the theoretical deliberations derived in section 2.2 to separately identify different dimensions of monetary policy announcements.

In order to measure the impact of FOMC decisions and statements on financial markets and, thus, eventually on the real economy, I use mainly the sur-

<sup>13</sup>Further, there is an indirect effect due to the endogenous contemporaneous reaction through  $u_t^2$ .



prise component in federal funds futures and Eurodollar futures. These financial market instruments can be used to proxy for expected changes in the policy rate over respective horizons.<sup>14</sup> While looking at changes in these asset price 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 dimensions. 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 the data for short-term interest rate expectations. Thus, and in accordance with Wright (2012), I also consider the changes in treasury yields. Moreover, 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.<sup>15</sup> Due to data availability issues, I have to rely on daily data. The dates of FOMC meetings are taken from the website of the Federal Reserve Board.<sup>16</sup> In general, I consider only scheduled meetings to mitigate the risk that the extracted monetary policy shocks may actually be responses of the fed to non-monetary policy shocks hitting the economy.<sup>17</sup>

## 4.2. Factor Model and Identification of Proxy Variables

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  $n = 8$  due to the eight asset series. Following Gürkaynak et al. (2005),  $X$  can be

<sup>14</sup>See the monetary policy event-study literature dating back to Kuttner (2001).

<sup>15</sup>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.

<sup>16</sup>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 (forthcoming).

<sup>17</sup>An evident example for this procedure is the unscheduled FOMC meeting on September 17, 2001, which was a direct reaction to the financial market turbulences caused by the September 11, 2001 terrorist attacks. Further, in the preceding days, US financial markets were closed for several days.

represented with a simple factor model

$$X = F\Lambda + \xi, \quad (33)$$

where  $F$  is a  $T \times k$  matrix consisting of  $k \leq n$  unobserved factors,  $\Lambda$  is a  $k \times n$  matrix of factor loadings, and  $\xi$  is a  $T \times n$  matrix of white noise disturbances. As shown in Swanson (2017), at least three latent factors underlie the response of the considered asset prices to monetary policy announcements when the sample includes the pre- and post-crisis period.<sup>18</sup> Consequently,  $k = 3$ , meaning that the information revealed by monetary policy announcements affect the yield curve through three different dimensions. The latent factors can be estimated through principal components. 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  $X$ .

While the principal component analysis is a simple statistical procedure to reduce the dimensionality of a given data set, it comes at a price. In order to estimate the factors, no causal explanation is required why monetary policy meetings lead to the observed reactions in the asset prices. These factors just represent the responses as if they would be systematic reactions to three orthogonal shocks.<sup>19</sup> However, akin to reduced-form 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 factors  $F$  have an economic interpretation as outlined in section 2. To be precise, it is assumed that the yield curve responds to the information about the current and future path of monetary policy as well as to the signal by the FOMC about the current state of the economy. Thus, the three factors can be interpreted as two distinct monetary policy shocks, a *target* and a *path shock*, and a non-monetary *information shock*. Equation (33) can be rewritten as

$$X = F\Lambda + \xi = \tilde{F}\tilde{\Lambda} + \xi, \quad (34)$$

where  $\tilde{F} = FU$  and  $\tilde{\Lambda} = U'\Lambda$  for any  $k \times k$  orthogonal matrix  $U$ . Thus, to give the factors a structural interpretation, a rotation matrix  $U$  has to be identified. As  $k = 3$ , three restrictions about the behavior of the factors are sufficient to uniquely identify  $U$ . The identifying assumptions are motivated by the theoretical argumentation derived in section 2.2. First, the factor representing the information effect is the single factor that is correlated with changes in the 5-Year, 5-Year forward breakeven inflation rate on announcement days. Second,

<sup>18</sup>He use the same set of financial market instruments but over a slightly shorter sample period. However, he utilize intra-daily data.

<sup>19</sup>See Swanson (2017) for a more in depth discussion of this issue.

with respect to the two monetary policy shocks, only the target shock loads into the current-month federal funds futures rate.

As implied by equation (17), the information effect can be separated from monetary policy shocks through its impact on long run inflation expectations. Assuming that the fed is unable to credibly communicate any deviation from its policy rule several years into the future, changes in long run inflation expectations should not be caused by monetary policy related information released in a FOMC announcement.<sup>20</sup> Accordingly, the two factors representing the current and future path of monetary policy should be uncorrelated with changes in long run inflation expectations.

Let  $\tilde{F}_3 = FU_3$  be the information effect factor, while  $U_3$  denotes the third column of the rotation matrix  $U$ . The first identification assumption can be expressed as

$$\begin{aligned} E(m_t \tilde{F}'_{1,t}) &= 0 \\ E(m_t \tilde{F}'_{2,t}) &= 0 \\ E(m_t \tilde{F}'_{3,t}) &= \phi, \end{aligned} \tag{35}$$

where, using the notation used in section 3,  $m_t$  denotes a single external instrument variable. Having a suitable proxy variable, one can use the closed-form solution presented in Mertens and Ravn (2013) and reproduced in section 3 to identify  $U_3$  just as it is used to partially identify  $B^{mp}$ . Note that in the case of one shocks series of interest and one corresponding proxy variable, the matrix  $S_1 S_1$  determined by equation (31) reduces to a scalar and the column vector of interest, here  $U_3$ , can be computed up to the sign using equation (29).

As implied by the discussion in section 2.2, the proxy variable should be the revision in the difference between two inflation expectation forward rates with a horizon beyond what is targeted by fed forward guidance. Accordingly, I propose to use the changes in the 5-Year, 5-Year forward breakeven inflation rate as five years should be sufficiently out of the range where monetary policy is effective. The daily data is taken from the data set constructed in Gürkaynak et al. (2010) as available on the website of the fed and in the replications files of Nakamura and Steinsson (forthcoming).<sup>21</sup> Combining the information from both sources, I have data for the period between January 1999 and September

<sup>20</sup> A change in the long-run inflation target of the central bank may 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, forthcoming). Indeed, this change in the slope of the responses of long run inflation expectations is what is imposed by equation (17).

<sup>21</sup> The forward breakeven inflation rate is the inflation rate that equates nominal and real Treasury spot rates at a given maturity in dollar terms.

2017. Due to the initially poor liquidity discussed by the authors, I use only data for the subsample beginning with the FOMC meeting on February 2, 2000. This implies that  $U_3$  can be only identified for the post 2000 period. Thus, all results for the pre 2000 period derived in section 4 are conditional on the assumption that the information effect has the same effects on the yield curve in both periods.<sup>22</sup>

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 fed 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*.<sup>23</sup>

The described two assumption yields in total three restrictions on the rotation matrix  $U$ . The first assumption imposes that the both monetary policy shocks are uncorrelated with the external instrument while the second assumption restricts the forward guidance shock to not affecting the current-month federal funds futures rate. These restrictions can be implemented as following.<sup>24</sup> As described, one can use the equations (31) and (29) to compute one of the column vectors of  $U$  up to a sign normalization. Without loss of generality, I call this vector  $U_3$ . 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 order first in the data matrix  $X$ , this would yield the first column of  $\Lambda$ . The assumption combined with the imposed orthog-

<sup>22</sup>The forward breakeven inflation rates do not only reflect expected inflation, but also the inflation risk premium and the liquidity premium present in the TIPS market. Consequently, I further have to impose the assumption that the latter two are constant within the daily windows around the FOMC announcements.

<sup>23</sup>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*.

<sup>24</sup>See Swanson (2017) for a similar procedure.

onality to the  $U_3$  can be formulated in matrix notation as

$$\begin{bmatrix} \Lambda'_1 \\ U'_3 \end{bmatrix} U_2 = \begin{bmatrix} 0 \\ 0 \end{bmatrix}. \quad (36)$$

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

$$\begin{bmatrix} U'_2 \\ U'_3 \end{bmatrix} U_1 = \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \quad (37)$$

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 factors'  $\tilde{F}$  unit variance normalization. While the restrictions solve uniquely for  $U$  and  $\tilde{F}$  up to the sign of the individual factors, I follow Gürkaynak et al. (2005) and Swanson (2017) by assuming that the target factor has a positive effect on the current-month futures contract, the forward guidance factor has a positive effect on the four-quarter-ahead Eurodollar futures, and the third factor has a positive effect on the 10-year Treasury yield. Thus, a positive realization of the information effect factor leads to an increase in long-run interest rate expectations.

### 4.3. Resulting Proxy Variables

In table 1 the loadings of  $\tilde{\Lambda}$  of the three factors are reported. As discussed, 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. Given that these loadings can be interpreted as the impact of the respective dimension of a monetary policy announcement on the yield curve, they should reflect the assumption imposed for identification.

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 increase in the current-month federal funds futures rate. Further, the effect on the other interest rates decreases with increasing maturity. By construction these changes result from a surprise change of the respective rates. Additionally, changes in the implied rates of the current-month futures contracts track quite 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. Given that monetary policy decisions are persistent in the sense that they

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

	Target Factor	Forward Guidance Factor	Information Effect Factor
FF1	0.98	0.00	−0.18
FF2	0.56	0.66	−0.34
EDF2	0.63	0.73	−0.07
EDF3	0.54	0.81	−0.01
EDF4	0.47	0.86	0.10
2y-TR	0.51	0.78	0.22
5y-TR	0.39	0.73	0.54
10y-TR	0.28	0.65	0.67

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.

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. Consequently, the second factor reflects the information about the future path of monetary policy released by the announcement that go beyond the current interest rate decision. This should conform with the general definition of forward guidance (see for example Swanson, 2017).

Finally, the third column of table 1 reports the loadings of the information effect. Two things are noticeable. First, despite a small peak with respect to the three-months-ahead federal funds futures rate, the third factor has a small impact on the short end of the yields curve. Second, the effect on the interest rates switches the sign at a horizon of roughly one year. In contrast to the target and forward guidance factor, the last factor affects the long end of the yield curve stronger than the short end. This corresponds with the predictions of the behavior of an information effect derived in section 2.2. By construction, the in-

formation effect factor is defined as affecting long-run interest rates positively. Consequently, it represents information unrelated to the future path of monetary policy released during an announcement that induce market participants to assess economic prospects more positively.

In figure 1, the shock series are plotted. The shocks are measured in units of standard deviations. Again, the time series exhibit remarkable differences. As one would expect, the target factor is quite damped during the zero lower bound. The forward guidance shocks, surprisingly, is similarly weak in the period between mid-2009 and 2015. 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. The fact that forward guidance seems to be a major policy instrument of the fed 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).

The information effect, while pronounced in the beginning of the sample period and in the years 2001 to 2003, appears as dominant force 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. Omitting this would lead to a less clear identification of the target shock and the forward guidance shock.

#### **4.4. Narrative Plausibility of the Proxy Variables**

In a preliminary analysis, I use the 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 2 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 2 are in units of standard deviations.

I discuss the events not 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 calendar-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 2 show that market participants were 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

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

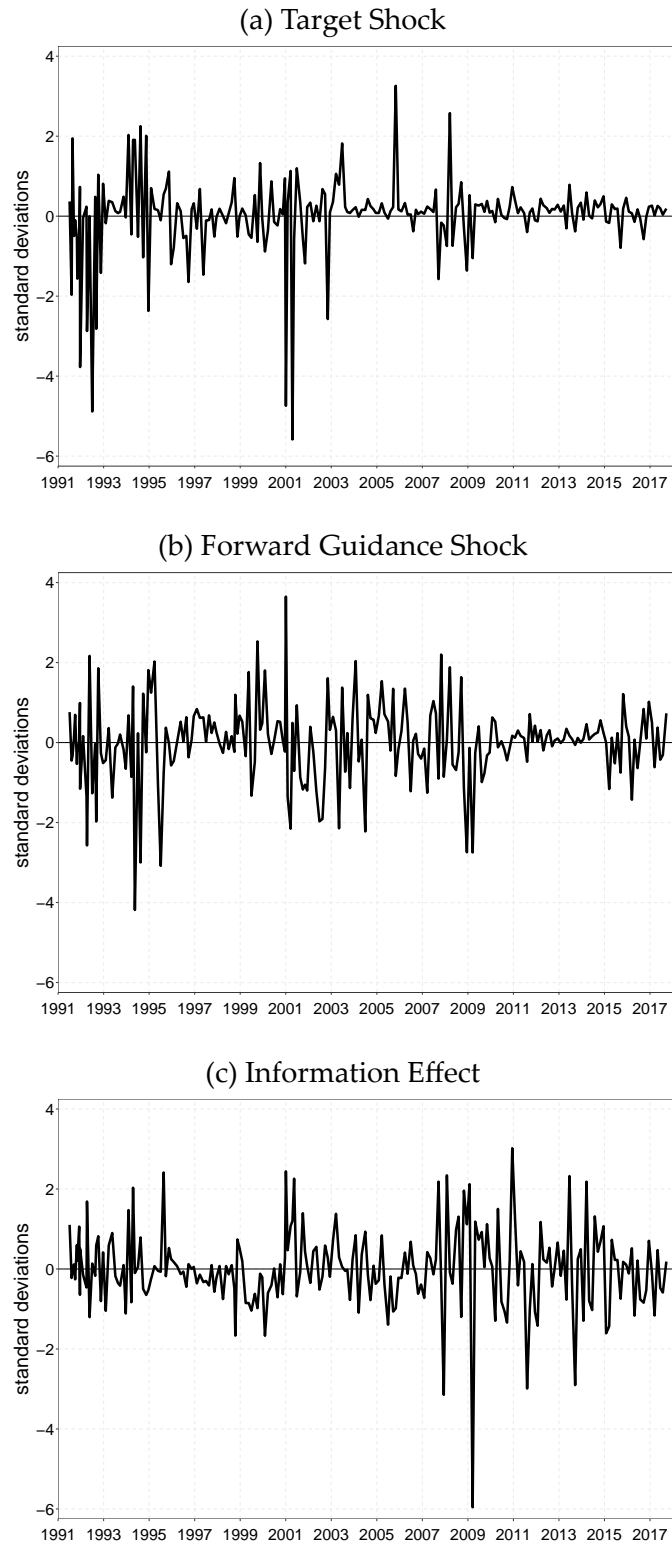




Table 2: Realizations of the Factors at Selected FOMC Announcements

Date	Target Factor	Forward Guidance Factor	Information Effect Factor
December 16, 2008	−1.36	−2.74	1.12
March 18, 2009	−1.05	−2.75	−5.96
August 9, 2011	−0.40	−0.48	−2.99
January 25, 2012	−0.13	0.02	−1.42

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

downwards because of the bad news revealed by the announcement. Additionally, Swanson and Williams (2014) note that this announcement lead 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 their 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 2 seem reasonable (see also the discussion in Woodford, 2012).

The results for the FOMC announcements in December 2008 and March 2009 are also quite remarkably. 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. Further, the FOMC stated that it expected 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 considerably expand the the LSAP program that was already in place since November 2008. As it is shown in table 2, on both dates the realizations of all three 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 decreases in the target factor and the forward guidance factor seem quite uncontroversial. However, both FOMC announcement are highly 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 extraordinary large.<sup>25</sup> 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 this as good news for the recovery from the financial crisis. On the contrary, the additional measures announced in March 2009 seem to had the inverse effect on the expectations of market participants (see also Krishnamurthy and Vissing-Jorgensen, 2011).

## 5. SVAR Evidence for the Effect of Monetary Policy

### 5.1. Macroeconomic Data

The baseline reduced-form VAR model includes five macroeconomic and financial variables and is estimated for the sample period June 1990 to August 2016 using monthly data. I use the index of industrial production (IP) in logs as the output measure and the log of the consumer price index (CPI). As a financial market variable, I include the excess bond premium of Gilchrist and Zakrajšek (2012). This credit spread measure has been adjusted to eliminate predictable default risk and, thus, accounts more cleanly for the risk perception in financial markets.<sup>26</sup> To independently identify the effects of conventional monetary policy and forward guidance, the VAR includes two indicator for monetary policy activity. The federal funds rate is the policy rate of the fed and reflects the current monetary policy stance. Additionally, the spread between the ten-year Treasury rate and the three-month treasury rate represents the slope of the term structure and should reflect the effect of forward guidance. In accordance with Coibion (2012) and Gertler and Karadi (2015), the lag order equals 12.

The sample period begins 12 periods before the proxy variables start to account for the lag length of the VAR and ends with the last observation available for the excess bond premium. The daily proxy variables are simply aggregated by summing the surprises within a month. 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.

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<sup>25</sup> Actually, the effect on long-run rates was that pronounced that Campbell et al. (2012) disregard the meeting as an outlier.

<sup>26</sup> Given that the excess bond premium data ends in August 2016, the sample period is limited by this date.

## 5.2. Identifying Monetary Policy Shocks and the Information Effect

As discussed in section 3, the proxy SVAR framework requires additional restrictions to disentangle the causal effects of the shocks of interest. Using the proxy variables derived in section 4, one can separate the two monetary policy shocks and the information effect shock from the non-structural shocks. This is expressed by equation (32). To compute the impulse response functions of these shocks, one has to solve for the matrix  $S_1$ . However, as indicated by equation (31), the covariance restrictions from the proxy variables are only sufficient to estimate  $S_1 S_1'$ . There is no reason why one could assume that  $3 \times 3$  matrix  $S_1$  is diagonal. Thus, three additional restrictions about the contemporaneous responses of specific variables to the surprise shocks are necessary. Note, while the specific ordering of the variables in the reduced-form VAR is not important for identification, it eases the explanation to assume that the federal funds rate, the ten-year, three-month term spread, and the excess bond premium are order first. As described in the following, I use the excess bond premium as a measure for market participants' expectations about future economic prospects. This may be justified given that Gilchrist and Zakrajšek (2012) provide extensive evidence that the excess bond premium reflects shifts in the effective risk aversion of financial market investors.

Accordingly, equation (38) can be restate as

$$\begin{pmatrix} u_t^{\text{ff}} \\ u_t^{\text{term}} \\ u_t^{\text{ebp}} \end{pmatrix} = \eta u_t^2 + \begin{bmatrix} s_{11} & s_{12} & s_{13} \\ s_{21} & s_{22} & s_{23} \\ s_{31} & s_{32} & s_{33} \end{bmatrix} \begin{pmatrix} \varepsilon_t^{\text{target}} \\ \varepsilon_t^{\text{fwg}} \\ \varepsilon_t^{\text{info}} \end{pmatrix}, \quad (38)$$

where  $\eta = B^{1,x} B^{2,x-1}$ ,  $u_t^{\text{ff}}$ ,  $u_t^{\text{term}}$ , and  $u_t^{\text{ebp}}$  denote the reduced-form innovations of the first three equations in the VAR, while  $\varepsilon_t^{\text{target}}$ ,  $\varepsilon_t^{\text{fwg}}$ , and  $\varepsilon_t^{\text{info}}$  denote the two structural monetary policy shocks and the information effect, respectively. Fortunately, the theoretical discussion in section 2.2 combined with the reduced-form evidence reported in section 4 provides useful information how to restrict  $S_1$ .

First, 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  $s_{12} = 0$ . Second, I assume that the information effect shock does not contemporaneously affect the monetary policy instruments. By construction, the information effect shock represents all information revealed during a monetary policy

announcement that affect market participants' expectations about future economic prospects above and beyond the effect of monetary policy measures. The information effect shock should only impact the excess bond premium directly. Consequently, the elements  $s_{13} = s_{23} = 0$ .<sup>27</sup>

Taken together, these restrictions imply a lower triangular structure for  $S_1$ . A simple Choleski decomposition of  $S_1 S_1'$  yields a measure for  $S_1$ .

### 5.3. Results

Figure 3 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. The impulse responses to an information effect shock are reported in figure 5. All graphs are estimated for a one percentage point decrease in the respective shock variable. The plotted confidence intervals are computed using the bootstrap procedure discussed in Mertens and Ravn (2013) using 1000 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).

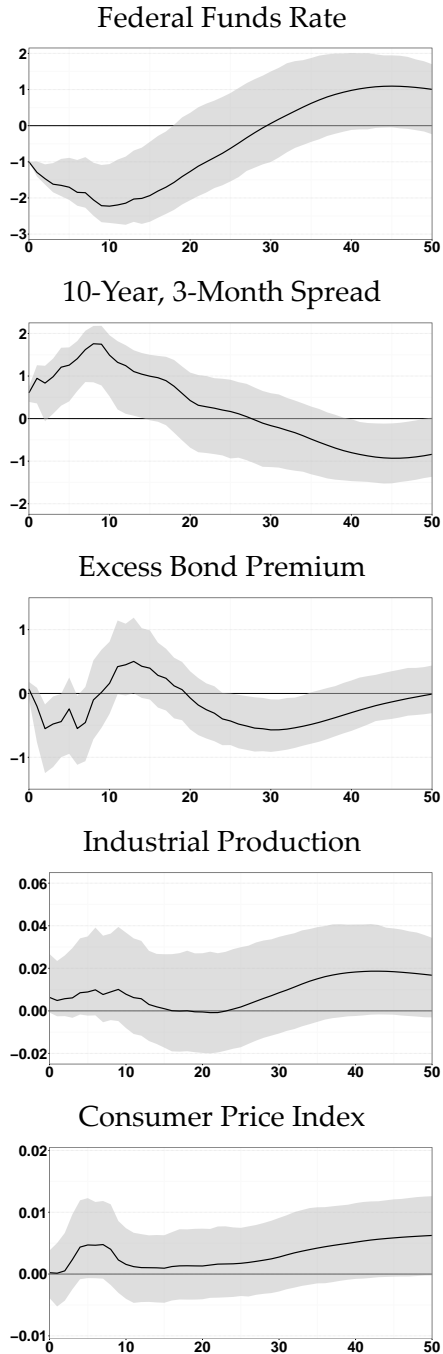
The left column of figure 3 shows the effect of an expansionary monetary policy rate shock. By construction, the federal funds rate decreases immediately by one percent and remains significant negative for the next roughly 20 months. The shock steepens the term structure over the next year. The effect on industrial production is positive but weakly significant over the first few months. However, the impulse response turns positive again after about 35 months. The consumer price index does not show any significant response at all.

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 fed lowers the spread between short- and long-run interest rates by decreasing expected future short-term rates. The hump-shaped response of the federal funds rate with its peak about two years after the shock supports this interpretation. As one would expect, the excess bond premium appears to decrease in the first months after the shock. However, the response is not significant. The effect of the forward guidance shock on the output measure is positive and significant for about 20 periods starting in one year after the shock. Further, the impulse response function is hump-shaped. Again, the

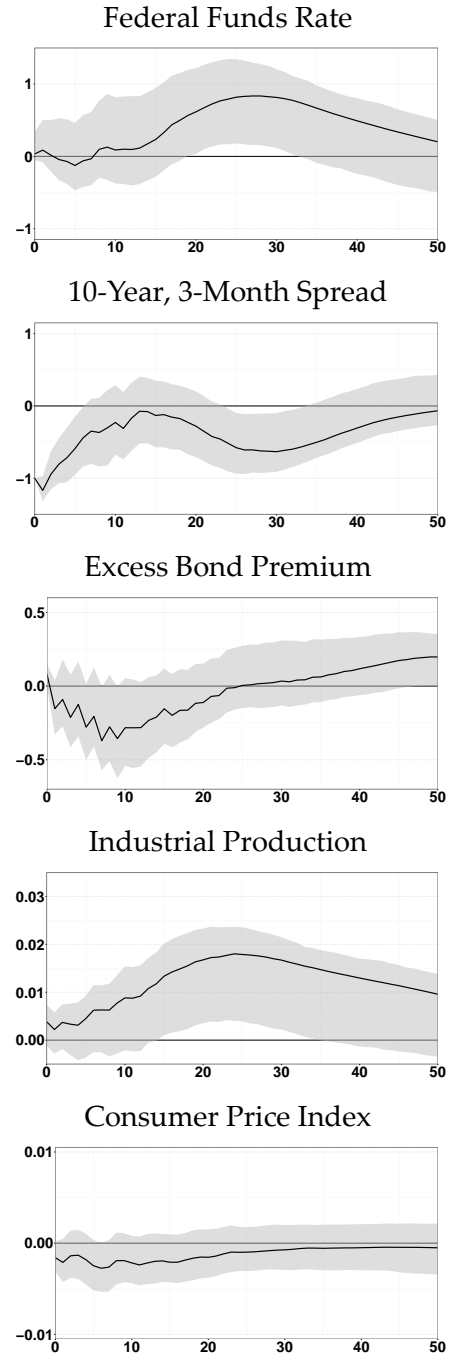
<sup>27</sup>Note, however, that restricting the direct effect of a given shock on a specific variable does not exclude any contemporaneous responses of that variable. As indicated by equation (32), the imposed restrictions require that the effect is zero after allowing for a contemporaneous feedback through  $u_t^s$  (Mertens and Ravn, 2013).

Figure 3: Responses to Monetary Policy Shocks

**Monetary Policy Rate Shock**

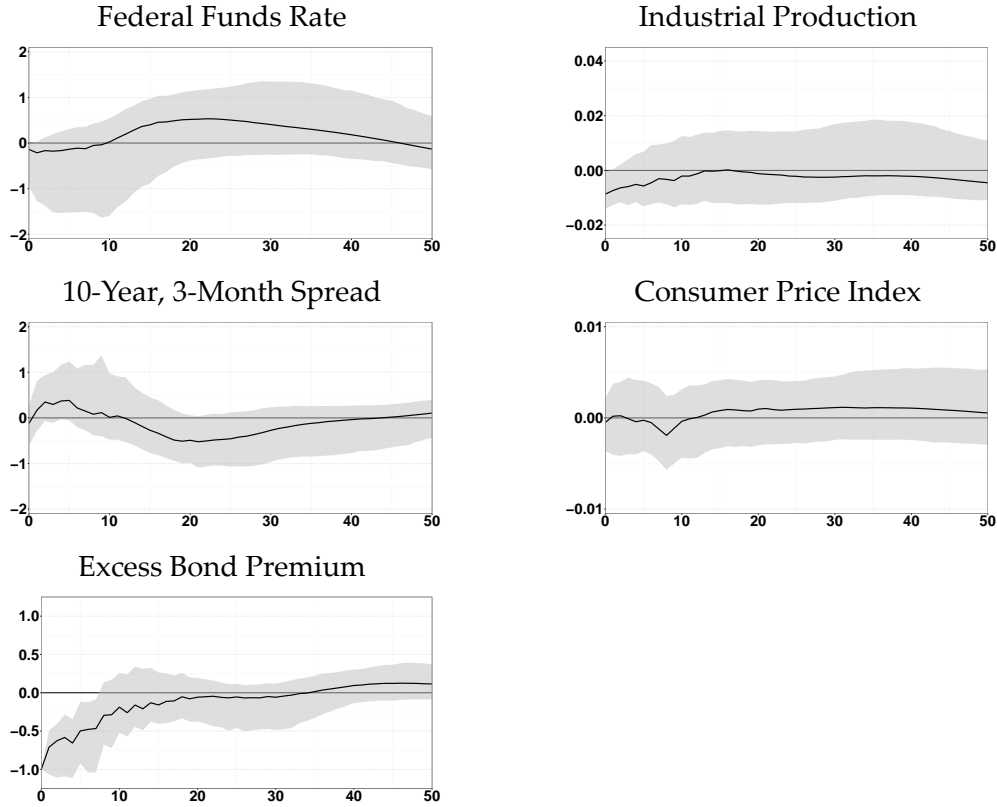


**Forward Guidance Shock**



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

Figure 5: Responses to an Information Effect Shock



Notes: Figure shows responses to a one percent information effect shock. Solid lines are point estimates, grey areas represent 90 percent confidence intervals.

effect on the consumer price index is not significant and dies out rather quickly.

Figure 5 shows the responses to an information effect shock. The shock is modeled as an decrease of the excess bond premium by one percent. Accordingly, the shock represents a decreased risk premium required by financial market investors. The excess bond premium remains significantly negative for up to seven months. While affecting the term spread positively over the first periods and negatively at a horizon of about two years, the information effect does not seem to have any systematic effect on the real economy.

Overall, the identification strategy provides reasonable results. Both a surprising cut of the policy rate and the announcement of a future expansionary deviation from the policy rate lead to an increase of the industrial production. The weak effect of conventional monetary policy shocks 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 results 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 puzzle with respect to the response of the consumer price index.

## **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 proposed a method how to disentangle the effect of monetary policy announcements on market participants' expectations about the future path of monetary policy from an potential information effect. While the identification strategy is motivated using a standard New Keynesian model, the dynamic effects of the distinct dimension of monetary policy announcement are analyzed using a SVAR. I show that forward guidance has a significant impact on output about one year after the shock.

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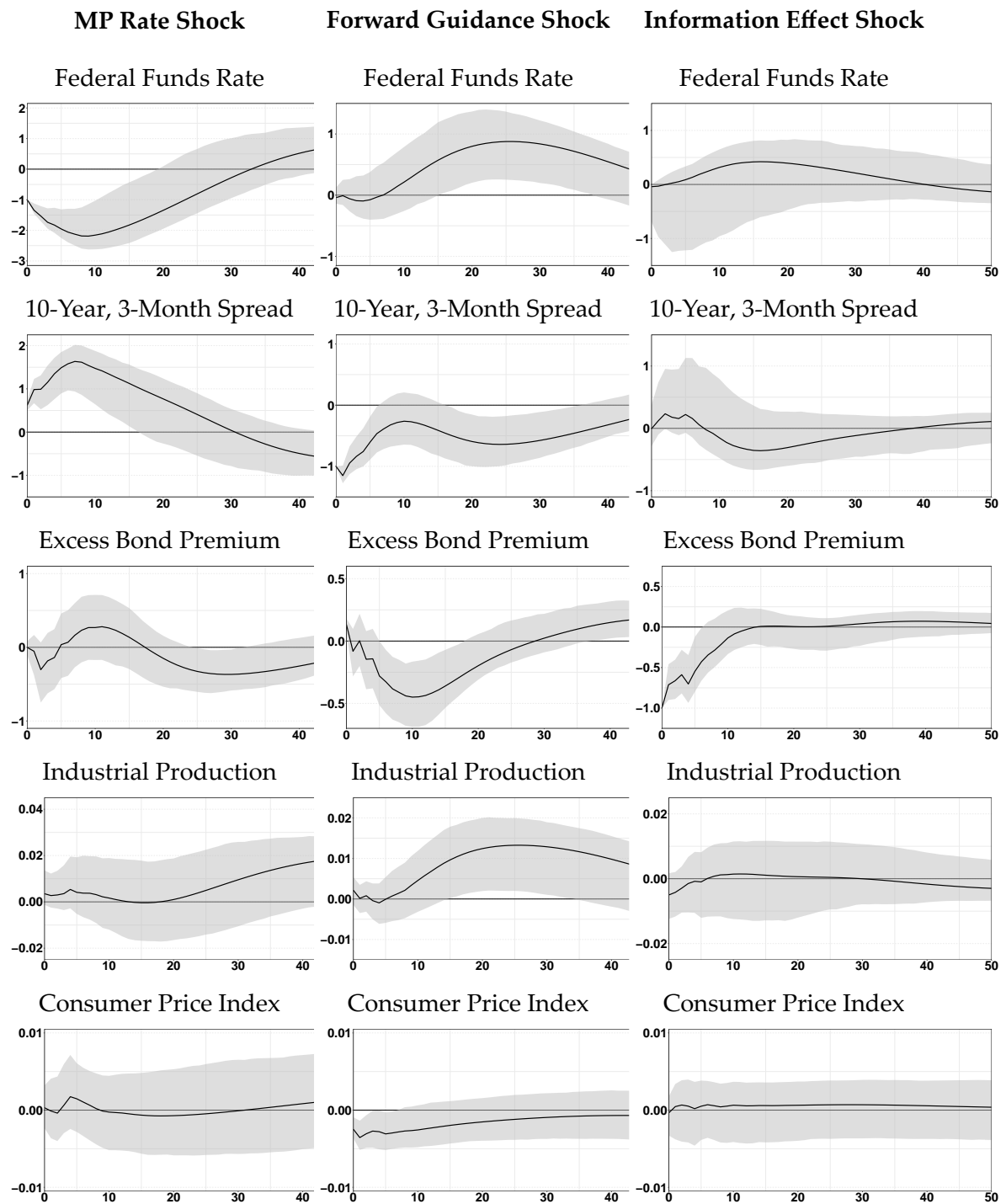
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## **A. Robustness Checks for the SVAR Analysis**

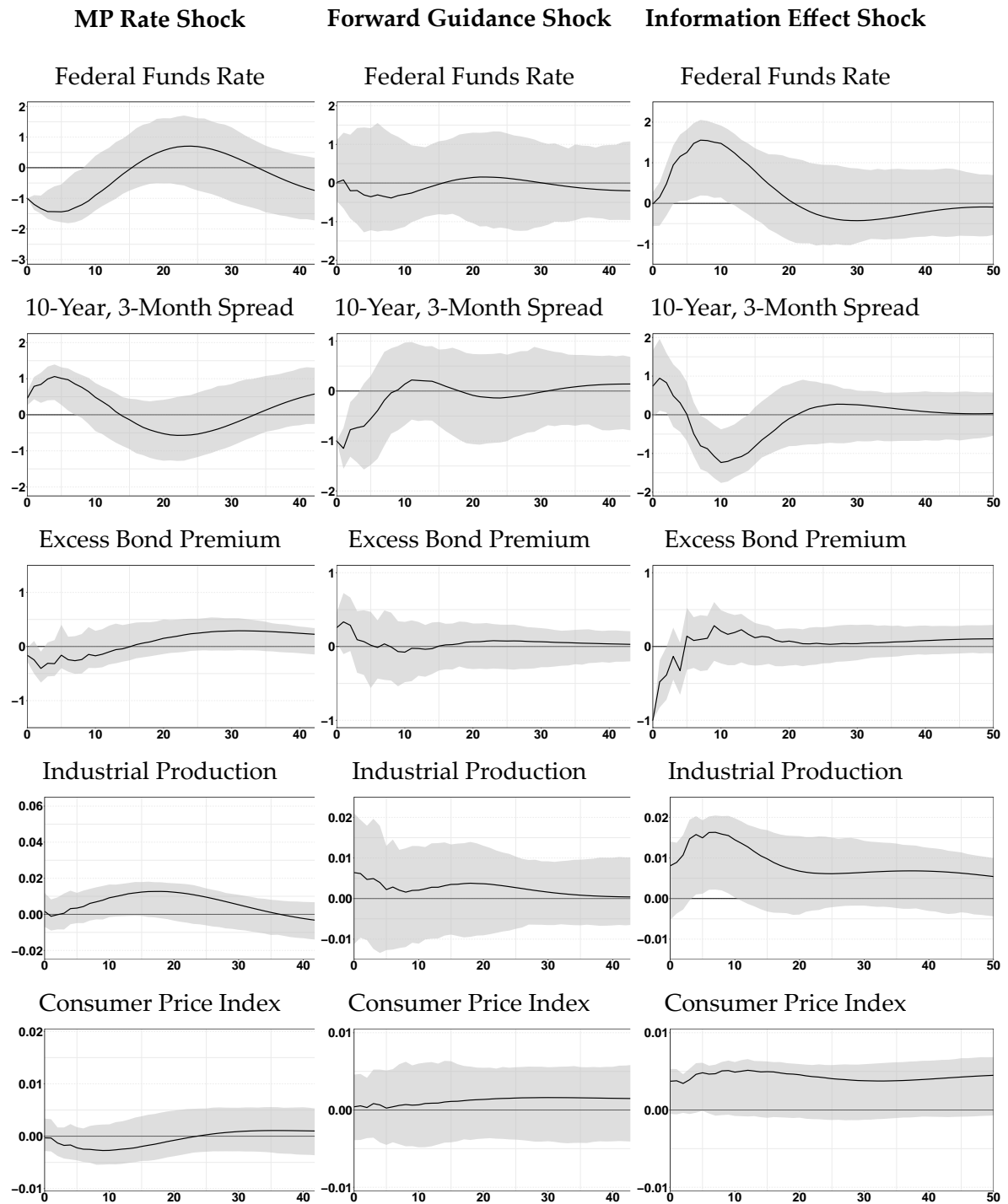
This appendix provides additional evidence for the obtained results discussed in the main text. First, figure 7 repeats the SVAR exercise but with a lag length of 6 instead of 12 lags. Second, the results reported in figure 9 are obtained for the sample period July 1991 to June 2002. This sample length is the shortest sample period possible without evident indications of a too small sample size.

Figure 7: Responses to Monetary Policy Shocks



Notes: Figures show responses to a one percent expansionary monetary policy shock (left), a one percent expansionary forward guidance shock (middle), and one percent information effect shock. Solid lines are point estimates, grey areas represent 90 percent confidence intervals. Lag length: 6, sample period: January 1991 - August 2016

Figure 9: Responses to Monetary Policy Shocks



Notes: Figures show responses to a one percent expansionary monetary policy shock (left), a one percent expansionary forward guidance shock (middle), and one percent information effect shock. Solid lines are point estimates, grey areas represent 90 percent confidence intervals. Lag length: 6, sample period: January 1991 - June 2002