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# DECOMPOSING THE EFFECTS OF MONETARY POLICY USING AN EXTERNAL INSTRUMENTS SVAR\*

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## ABSTRACT

We study the effects of monetary policy on economic activity separately identifying the effects of a conventional change in the fed funds rate from the policy of forward guidance. We use a structural VAR identified using external instruments from futures market data. The response of output to a fed funds rate shock is found to be consistent with typical monetary VAR analyses. However, the effect of a forward guidance shock that increases long-term interest rates has an expansionary effect on output. This counterintuitive response is shown to be tied to the asymmetric information between the Federal Reserve and the public.

**Keywords:** Monetary policy, Forward Guidance, Identification with External Instruments

**JEL:** E31, E32, E43, E52, E58

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# 1 INTRODUCTION

The Federal Reserve has been increasingly using unconventional policy tools in addition to its more conventional policy tool of setting a target for the federal funds rate. One important new tool is forward guidance, where the Fed has tried to guide expectations of market participants about the future path of the fed funds rate. Moreover, the use of forward guidance has been considered especially important in recent years by policymakers and academics alike.<sup>1</sup> While there is theoretical motivation for its use,<sup>2</sup> whether or not the Fed’s use of forward guidance policy has been empirically effective remains an open question. In this paper we aim to study the effects of monetary policy on economic activity with a focus on disentangling the effect of forward guidance from conventional policy actions.

Following the work of [Gürkaynak, Sack, and Swanson \(2005\)](#) (henceforth GSS), several studies have found significant effects of forward guidance on asset prices using high-frequency financial data. But identifying the effects of forward guidance on measures of economic activity –which are typically available at a monthly or lower frequency– is more challenging. At this lower frequency, monetary policy actions are likely to be endogenous with respect to macroeconomic variables and identifying restrictions are required to estimate the transmission mechanism. A key contribution of this paper is the use of a structural vector autoregression (SVAR) that not only allows us to estimate the effects of forward guidance on economic activity but also to compare it with the effects of conventional monetary policy. We explicitly model two monetary policy tools; a short-term interest rate capturing conventional policy and a longer term interest rate capturing forward guidance policy. Identification is achieved through restrictions imposed using the external instruments framework.

We build on the work of [Gertler and Karadi \(2015\)](#) (henceforth GK) that uses federal funds futures data as an instrument for the structural monetary policy shock in a SVAR. But they have one monetary policy tool that captures the joint effect of conventional policy and forward guidance. Extending their framework to two monetary policy tools (with two instruments) requires one additional identifying restriction. In this paper we lay out two alternative ways of obtaining this extra restriction. The first

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<sup>1</sup>Federal Reserve officials have put more emphasis on the importance of forward guidance in their communication with the public in the past decade. A good example is the following quote from a 2011 speech by then chairman Ben Bernanke “Forward guidance about the future path of policy rates, already used before the crisis, took on greater importance as policy rates neared zero”. The topic has also received significant attention from the academic literature, see [Blinder, Ehrmann, Fratzscher, De Haan, and Jansen \(2008\)](#) for an excellent survey.

<sup>2</sup>For theoretical support, see the early work of [Eggertsson and Woodford \(2003\)](#) and the more recent work of [Del Negro, Giannoni, and Patterson \(2015\)](#).

strategy relies on placing a zero restriction on the relationship between the structural shocks and the reduced form residuals. This amounts to a less restrictive version of the recursive ordering commonly used in the literature. On the other hand, the second strategy involves putting a zero restriction directly on the relationship between the structural shocks and the instruments. We show how the factor rotation of futures data proposed by GSS results in instruments that naturally satisfy the requirements of this second identification strategy.<sup>3</sup>

For the baseline results in the paper we consider a simple SVAR with output, prices and the two monetary policy tools: the fed funds rate and the 1 year Treasury rate. A forward guidance shock is defined as the structural shock to the 1 year rate that is orthogonal to the contemporaneous structural shock to the fed funds rate. In this framework, any Federal Reserve announcement (on FOMC meeting days) about future monetary policy decisions that moves long term interest rates (and is orthogonal to current rate changes) will be captured as forward guidance. This means that we do not explicitly separate out announcements about large scale asset purchases (i.e. quantitative easing) from forward guidance. One strand of the literature finds that the main effect of the Fed’s quantitative easing was actually through forward guidance about keeping interest rates lower for an extended period of time, see for example [Bauer and Rudebusch \(2014\)](#). While others find differential effects of quantitative easing and forward guidance, see for example [Swanson \(2016\)](#). This distinction turns out not to be crucial here as we show that our results are not very sensitive to excluding the post 2008 sample when quantitative easing was prevalent.

The response of the economy to a contractionary federal funds rate shock displays an inverted hump shaped response for output but a more muted price response. The dynamics of output are consistent with conventional macroeconomic theory (see for example [Galí \(2008\)](#)) and also consistent with standard results from VAR analyses of monetary policy (see for example [Christiano, Eichenbaum, and Evans \(1999\)](#)).<sup>4</sup> However, the response of the economy to a forward guidance shock does not fit this pattern. Output rises in response to a “contractionary” forward guidance shock, i.e. a shock that raises the 1 year interest rate. This result also holds when we exclude FOMC meetings that were not accompanied by an explicit statement, use narrower or broader windows to construct the instruments,

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<sup>3</sup>Reassuringly, we find that the results are similar for both identification strategies.

<sup>4</sup>We found the response of output to be robust in a variety of different specifications but the response of prices often displays the price-puzzle. Thus in this paper we focus primarily on the response of output.

and when we expand the information set of the VAR to include financial variables.<sup>5</sup>

We find that this counterintuitive response is driven by the information differences between the Federal Reserve and the general public, implying a role for Delphic forward guidance as proposed by [Campbell, Evans, Fisher, and Justiniano \(2012\)](#). They suggest that the Delphic component of the Fed’s communication about their future intentions also embodies a signal about future economic conditions. To account for this information effect in the SVAR, we construct a measure of Federal Reserve private information using Greenbook and Bluechip forecast data. We then regress our instruments from futures market data on this measure and use the residuals as the new instruments. With the instruments cleansed of the Fed’s private information, we find that output falls in response to a contractionary forward guidance shock. In a recent survey, [Ramey \(2016\)](#) estimates several VARs and finds that for certain specifications there exists a similar expansionary effect of “contractionary” monetary policy shocks. Our results suggest that the effects of forward guidance, specifically related to the release of Fed private information may be driving this counterintuitive finding in the literature. These results are consistent with the finding of [Miranda-Agrippino \(2016\)](#) that also emphasizes the role of information asymmetries.

Our results raise an important issue about the measurement of the effects of forward guidance. Should the Delphic component of forward guidance be considered a policy tool for the Federal Reserve? Or alternatively, should the focus just be on studying the effect of Fed communication (about future interest rate moves) that is unrelated to economic developments?<sup>6</sup> In addition to the work of [Campbell, Evans, Fisher, and Justiniano \(2012\)](#) and [Campbell, Fisher, Justiniano, and Melosi \(2016\)](#), there is recent evidence suggesting that the Delphic component is important. Using high-frequency data, [Nakamura and Steinsson \(2015\)](#) find what they call a “Fed information effect” where Fed communication has an effect on agents’ expectations about future economic fundamentals. In a structural DSGE framework [Melosi \(2016\)](#) emphasizes the importance of the “signalling” channel of monetary policy where the central bank reveals their information about macroeconomic fundamentals. Overall, we view our results as complementing this literature and highlighting the need for developing structural models where the Delphic component of forward guidance is explicitly modeled.

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<sup>5</sup>Furthermore, we show that using the common Cholesky identification scheme with two monetary policy tools results in forward guidance shocks having essentially no effect on output.

<sup>6</sup>This is the more traditional definition of a forward guidance shock and in the terminology of [Campbell, Evans, Fisher, and Justiniano \(2012\)](#) it is referred to as “Odyssean” forward guidance.

This paper is also related to a growing empirical literature that uses SVARs to estimate the effects of Federal Reserve communication. [D'Amico and King \(2015\)](#) use survey expectations and sign restrictions to identify the structural shocks. [Bundick and Smith \(2016\)](#) embed high-frequency futures market measures of expected policy rates in a SVAR but use a recursive identification scheme. [Ben Zeev, Gunn N, and Khan \(2015\)](#) use the maximum-forecast error variance framework to identify monetary shocks following the news shock literature. Finally, [Hansen and McMahon \(forthcoming\)](#) and [Lucca and Trebbi \(2009\)](#) study the effects of communication using different versions of computational linguistics to categorize the content of FOMC communication. There are three key features that differentiate our framework from this literature. First, we use the external instruments methodology to identify structural shocks. Second, we explicitly model two monetary policy tools simultaneously to capture the joint effects of monetary policy. Finally, we use forecast data to control for Federal Reserve private information.

The paper proceeds by first laying out the econometric framework in [section 2](#). This section also includes a discussion of the two alternative identification strategies. Next, in [section 3](#) we discuss how the high-frequency data is used to construct the instruments and how it fits into the external instruments framework. [Section 4](#) presents the results from the baseline specification and establishes their robustness, while various other checks are presented in [section 6](#) and in the online appendix. In [5](#) we investigate the role of Federal Reserve private information and a concluding discussion is provided in [section 7](#).

## 2 ECONOMETRIC METHODOLOGY AND IDENTIFICATION

The application in this paper investigates the transmission mechanism of monetary policy. The goal is to separately identify the effects of fed funds target rate changes from forward guidance. The VAR uses data on two monetary policy tools; a short term rate and a medium term interest rate. The identification strategy based on futures market data allows us to uncover the structural monetary policy shocks corresponding to the two policy tools. Further details about the macroeconomic and futures market data used in the VAR are provided in [section 3](#). First, we begin with a discussion of the econometric methodology underlying the identification strategy.

Consider the structural VAR where  $y_t$  is an  $n \times 1$  vector of macroeconomic variables and  $\alpha_i$  and  $A$

are  $n \times n$  parameter matrices

$$Ay_t = \alpha_1 y_{t-1} + \dots + \alpha_p y_{t-p} + \varepsilon_t \quad (2.1)$$

The components of the error terms  $\varepsilon_t$  are assumed to be uncorrelated with each other and interpreted as structural shocks. Pre-multiply by  $A^{-1}$  to get the reduced form VAR

$$y_t = \delta_1 y_{t-1} + \dots + \delta_p y_{t-p} + u_t \quad (2.2)$$

where

$$u_t = B\varepsilon_t \quad (2.3)$$

and  $A^{-1} = B$ . Also note that  $E[u_t u_t'] = BB' = \Sigma$ . This reduced form VAR can be estimated in a straightforward manner. However identification of the impulse responses to the structural shocks requires an estimate of the matrix  $B = A^{-1}$ . This requires further identifying restrictions. In this paper we will follow the external instruments procedure developed by [Stock and Watson \(2012\)](#) and [Mertens and Ravn \(2013\)](#).<sup>7</sup>

In the external instruments methodology, the key requirements are to find instruments that are i) correlated with the shocks of interest (monetary policy shocks here), and ii) uncorrelated with the other structural shocks (shocks to inflation and output). Denote the policy shocks as  $\varepsilon_t^p$  and the non-policy shocks as  $\varepsilon_t^q$ . For a given set of instruments  $Z_t$ , these two conditions can be formally stated as

$$E[Z_t \varepsilon_t^{p'}] = \phi \quad (2.4)$$

$$E[Z_t \varepsilon_t^{q'}] = 0 \quad (2.5)$$

The restrictions 2.3, 2.4 and 2.5 can be represented as

$$B_{21} = \left( E[Z_t u_t^{p'}]^{-1} E[Z_t u_t^{q'}] \right)' B_{11} \quad (2.6)$$

where the impact matrix  $B$  is given by

$$B = \begin{bmatrix} B_1 & B_2 \end{bmatrix}, B_1 = \begin{bmatrix} B'_{11} & B'_{21} \end{bmatrix}', B_2 = \begin{bmatrix} B'_{12} & B'_{22} \end{bmatrix}' \quad (2.7)$$

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<sup>7</sup>The idea of using exogenous shocks as instruments goes back to [Hamilton \(2003\)](#).

Intuitively, the estimation follows the following three steps. First, the reduced form VAR in equation 2.2 is estimated by ordinary least squares regression. Next, the residuals from the non-policy equations  $u_t^q$  are regressed on the residuals from the policy equations  $u_t^p$ , using  $Z_t$  as instruments. This gives an estimate of  $E[Z_t u_t^{p'}]^{-1} E[Z_t u_t^{q'}]$ . Finally, the restrictions in equation 2.6 are used to estimate the relevant columns of the impact matrix  $B$ .

If we are interested in identifying the effects of only one shock (i.e. the policy shock  $\varepsilon_t^p$  in equation 2.4 is a scalar), then the econometric framework identifies the impact coefficients up to a sign convention. However, if there is more than one policy shock of interest, additional restrictions are required. In this paper, we have two policy tools and two instruments. Next, we discuss how these additional restrictions can be obtained using two different identification strategies.

**2.1 IDENTIFICATION WITH TWO POLICY SHOCKS AND TWO INSTRUMENTS** The first strategy imposes restriction on the relationship between the reduced-form residuals in the policy equation and the structural policy shocks. The second strategy relies on imposing restrictions on how the instruments are related to the structural policy shocks. In the scalar case, these two strategies are equivalent, however this is not true in general for more than one policy shock.

**2.1.1 IDENTIFICATION STRATEGY I** The first strategy follows the approach taken in [Mertens and Ravn \(2013\)](#). To clearly see the identification issue we reproduce the key estimating equations from their approach.

$$B_{11}S_1^{-1} = (I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1})^{-1} \quad (2.8)$$

$$B_{21}S_1^{-1} = B_{21}B_{11}^{-1}(I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1})^{-1} \quad (2.9)$$

$$S_1S_1' = (I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1})(I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1})' \quad (2.10)$$

The estimation of the covariance matrix of the reduced-form VAR together with the instrumental variables regression provides estimates of  $B_{12}B_{22}^{-1}$ ,  $B_{11}B_{11}'$  and  $B_{21}B_{11}^{-1}$ .<sup>8</sup> For the scalar case, this is enough to identify  $S_1^2$  from equation 2.10 and thus  $S_1$  up to a sign convention. With  $S_1$  in hand, we can back out  $B_{11}$  and  $B_{21}$  which give us the column of the impact matrix required for identification. With more than one policy shock, we cannot obtain  $S_1$  from  $S_1S_1'$ .

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<sup>8</sup>For details see the appendix section 8.1.



The first approach involves putting restrictions on this  $S_1$  matrix. Specifically, in this paper we will impose a triangular structure on  $S_1$ , so that a simple Cholesky factorization of  $S_1 S_1'$  gives  $S_1$ . This triangular assumption imposes zero restrictions on elements of the  $S_1$  matrix. To understand what a restriction on  $S_1$  means, consider the following decomposition of the reduced-form residuals.<sup>9</sup>

$$u_t^p = \eta u_t^q + S_1 \varepsilon_t^p \quad (2.11)$$

with

$$B_1 = \begin{pmatrix} I + \eta(I - \zeta\eta)^{-1}\zeta \\ (I - \zeta\eta)^{-1}\zeta \end{pmatrix} S_1 \quad (2.12)$$

Recall that  $\varepsilon_t^p$  and  $u_t^p$  are the structural and reduced-form residuals of the two policy equations. Thus a zero restriction on the row  $i$  column  $j$  element in  $S_1$  implies no direct effect of the  $j^{\text{th}}$  policy shock in  $\varepsilon_t^p$  on the  $i^{\text{th}}$  reduced-form residual in  $u_t^p$ . For the application in this paper:  $\varepsilon_t^{p'} = \begin{bmatrix} \varepsilon_t^{ff} & \varepsilon_t^{fwd} \end{bmatrix}$  where the “ $ff$ ” superscript refers to the fed funds rate shock and the “ $fwd$ ” superscript refers to the forward guidance shock. Then equation 2.11 can be written as

$$\begin{pmatrix} u_t^{ff} \\ u_t^{fwd} \end{pmatrix} = \eta u_t^q + \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{ff} \\ \varepsilon_t^{fwd} \end{pmatrix}$$

Thus a lower triangular assumption implies that  $S_{12} = 0$ . This means that the structural forward guidance shock has no direct effect on the reduced form fed funds rate residual after controlling for the effect of structural shock that is captured through  $u_t^q$ .

**2.1.2 IDENTIFICATION STRATEGY II** The second identification strategy imposes zero restrictions on the relationship between the structural policy shocks and the instruments. We derive the estimating equations using an alternative approach (following [Lunsford \(2015\)](#)) to help understand this second strategy. Recall the relevance and validity conditions of the instrument,  $E[Z_t \varepsilon_t^{p'}] = \phi$  and  $E[Z_t \varepsilon_t^{q'}] = 0$  and that the covariance matrix of the residuals is given by  $E(u_t u_t') = B B'$ . From these equations we

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<sup>9</sup> $\eta$  and  $\zeta$  are parameters that govern the impact matrix  $B$ , see [Mertens and Ravn \(2013\)](#) for more details.

can show that<sup>10</sup>

$$E(Z_t u_t') = \phi B_1' \quad (2.13)$$

$$E(Z_t u_t') [E(u_t u_t')]^{-1} E(u_t Z_t') = \phi \phi' \quad (2.14)$$

If we have an estimate of  $\phi$ , we can back out the relevant columns of the impact matrix  $B$ , which is  $B_1$

$$B_1 = E(u_t Z_t') (\phi')^{-1} \quad (2.15)$$

Again, if there is only one shock then  $\phi$  is a scalar and we can estimate it from from equation 2.14 up to a sign convention. But if there are  $k > 1$  shocks (and instruments) then  $\phi$  has  $k^2$  unique elements, while  $E(Z_t u_t') [E(u_t u_t')]^{-1} E(u_t Z_t')$  is a symmetric matrix with only  $\frac{k(k+1)}{2}$  unique elements. The second strategy involves putting zero restrictions on  $\phi$ . We assume that  $\phi$  is triangular and thus a Cholesky factorization of  $\phi \phi'$  gives  $\phi$ . The interpretation of a zero restriction on  $\phi$  is straightforward from the relevance condition of the instruments. A zero restriction on the row  $i$  column  $j$  element in  $\phi$  implies that the  $j^{\text{th}}$  structural policy shock in  $\varepsilon_t^p$  is uncorrelated with the  $i^{\text{th}}$  instrument in  $Z_t$ . For the application in this paper we will use two instruments,  $Z_t = [Z_t^1 \quad Z_t^2]'$ . We can now re-write the relevance condition as

$$E \begin{pmatrix} Z_t^1 \varepsilon_t^{ff} & Z_t^1 \varepsilon_t^{fd} \\ Z_t^2 \varepsilon_t^{ff} & Z_t^2 \varepsilon_t^{fd} \end{pmatrix} = \begin{pmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{pmatrix}$$

Thus a triangular identifying assumption that imposes  $\phi_{21} = 0$  implies that  $E[Z_t^2 \varepsilon_t^{ff}] = 0$ . This assumption is justified by finding an instrument  $Z_2$  that is uncorrelated with the fed funds rate shock but correlated with the forward guidance shock. Specifically, we will use high frequency futures market data and apply the methodology of GSS. This involves performing a rotation of the principal components to construct a factor that satisfies the above requirement. This factor (labeled the path factor) captures shocks in longer term rates but is uncorrelated to fed funds rate shocks. The construction of the instruments is discussed in more detail in section 3.2.

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<sup>10</sup>The details are provided in the appendix section 8.1

### 3 DATA AND INSTRUMENTS

**3.1 MACRO DATA** The baseline VAR is a simple 4 variable monthly VAR with a measure of output, prices and the two monetary policy tools. Economic activity is measured using the Federal Reserve Board’s index of industrial production. Inflation is measured using the Consumer Price Index. For the monetary policy variables we use the fed funds rate as representing the current stance of monetary policy. To capture forward guidance, we use either the 1 year or 2 year Treasury yield. We use 12 lags in the estimation. In section 6, we discuss the robustness of the results to other specifications that include expanding the VAR by adding unemployment and other financial variables. Additionally, the online appendix contains more robustness checks where the VAR is estimated with different sample dates.

For the baseline estimates, we use a monthly data set spanning July 1979 to December 2011. The start date is chosen to correspond to the appointment of Fed chairman Paul Volcker. In monetary VAR analyses that use only the fed funds rate as the policy tool, it is typical to stop the sample in late 2008 when the fed funds rate hit the zero lower bound. In the baseline model, in addition to the fed funds rate we are using the 1 year rate to capture the effects of the unconventional policy tool of forward guidance. Forward guidance has been used by the Fed throughout the current zero lower bound episode. However, we stop the sample in late 2011 based on the analysis of [Swanson and Williams \(2014\)](#). They show that 1 year and 2 year bond rates were effectively restrained by the zero lower bound constraint starting in late 2011. We have also tried using a longer-term interest rate (10 year Treasury rate) as the monetary policy tool in the VAR to get around this problem. Unfortunately, this raises a serious issue about weak instruments, something that is not a major concern with the 1 or 2 year rate as discussed in more detail in section 4. In section 6 below we show results excluding the post-2008 sample and in the online appendix we provide more results for samples extending to 2015 and starting in 1984.

**3.2 INSTRUMENT CONSTRUCTION** The external instruments methodology requires instruments that are correlated with the monetary policy shocks but uncorrelated with the non-policy shocks. We follow the strategy of GK and use high-frequency data from financial markets to construct our instruments. Based on the work of [Kuttner \(2001\)](#), they use the change in federal funds futures and eurodollar futures contracts around FOMC meeting dates as the instrument. The idea is that in a small window around the FOMC announcement there are unlikely to be other events that significantly affect the market’s

expectations of future interest rates.

The crucial difference between this paper and GK is that they use only one policy tool (1 year rate) to capture the effect of both conventional and unconventional policy. In this paper the goal is to separate the effects of contemporaneous changes in the fed funds rate from changes in the 1 year rate due to forward guidance. To construct two instruments that can allow the separate identification of these two different policy tools, we follow the analysis in GSS to construct two factors from the response of futures prices.

Let  $X$  denote a  $T \times r$  matrix of the daily change in the futures price on FOMC days, where  $T$  is the number of time periods and  $r$  represents the number of futures price changes used. For the baseline specification, we will use data from both Fed Funds Futures and Eurodollar Futures contracts up to 4 quarters ahead. We can then perform a principal components analysis of the futures price changes

$$X = F\Lambda + \tilde{\eta}$$

where  $F$  is a  $T \times k$  matrix of principal components,  $\Lambda$  is a  $k \times 1$  vector of factor loadings and  $\tilde{\eta}$  is an error term. The idea is to increase the dimension of the principal components ( $k$ ) until a sufficiently large portion of the variation in the data  $X$  is explained by the factors  $F$ . A point to note is that for the baseline results we use end of day data. To check the robustness of the baseline results, in section 4 we discuss results using a narrower 30 minute window constructed with intraday data and also a broader 2 day window.

For the principal components estimation we use 5 futures contracts: current-month and 3-month-ahead federal funds futures contracts and the 2-, 3-, and 4-quarter-ahead Eurodollar futures contracts, following the analysis in GSS. We use all the FOMC meeting dates starting with January 1991, which includes both the scheduled and unscheduled meetings. In the online appendix, we provide a full list of the dates that are used in the construction of the instruments. For the baseline specification, we use all the dates except two. We drop two FOMC meeting observations following [Campbell, Evans, Fisher, and Justiniano \(2012\)](#). The first one is the unscheduled FOMC meeting on September 17, 2001 following the 9/11 attacks and the second one is the QE1 announcement at the FOMC meeting on March 18, 2009. In section 4, we re-do the estimation dropping all the unscheduled FOMC meeting dates and show that

the results are similar.<sup>11</sup>

GSS found that the first two principal components were sufficient to characterize changes in the five futures contracts mentioned above. Extending the GSS data to 2015, we find the same result. Table 1 shows that the first two principal components can explain more than 95% of the variation in the futures contracts.<sup>12</sup> This conclusion is consistent with the work of [Campbell, Evans, Fisher, and Justiniano \(2012\)](#) who also perform the target and path factor analysis of GSS using daily data.

For identification strategy I, we can directly use the two factors  $F_1$  and  $F_2$  as the two instruments in  $Z$  in equation 2.4, since the identification restrictions are put on  $S_1$ . In the reduced form VAR, if the fed funds rate is ordered before the long term interest rate, then the matrix  $S_1$  is lower triangular. Intuitively, this restriction implies that the response to a forward guidance shock is the response to an exogenous change that changes the long-rate by 1 percentage point but does not directly affect the fed funds rate (after taking into account the effect from  $u_t^q$ ).<sup>13</sup> On the other hand, in response to a fed funds rate shock, the long-rate is directly affected in addition to any change that occurs through  $u_t^q$ .

For identification strategy II, we cannot directly use  $F_1$  and  $F_2$  as instruments. This is because the changes in the futures contracts on FOMC days contain information about both changes in the current stance of monetary policy (i.e. the fed funds rate) and also the future stance of monetary policy (i.e. changes in long-term rates due to forward guidance). The two principal components will capture both these effects. But identification strategy II requires that one of the instruments be uncorrelated with one of the structural policy shocks. To tackle this issue we rotate the principal components in a way that one of the factors will be uncorrelated to changes in the current month's futures contract price. In other words, this factor will be uncorrelated to surprise changes in the fed funds rate but will contain information about changes in the longer term interest rate. GSS outline a way to perform this rotation that naturally fits the required restriction needed for identification strategy II. Label the two new factors that will be used as instruments in  $Z$  as the target factor ( $Z_1$ ) and the path factor ( $Z_2$ ). The rotation involves finding an orthogonal matrix  $U$  such that  $Z_1$  and  $Z_2$  explain the same amount of variation in  $X$  as  $F_1$  and  $F_2$ . More importantly,  $Z_2$  is uncorrelated to changes in the current month's

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<sup>11</sup>Furthermore, in the online appendix we show that the results are similar when we exclude the 1991-1993 FOMC meetings.

<sup>12</sup>The table actually shows the target and path factors which are rotations of the first two principal components. As discussed below, these rotated factors explain the exact same amount of the variation in the futures price changes as the first two principal components.

<sup>13</sup>In [Mertens and Ravn \(2013\)](#)'s terminology, a forward guidance shock leaves the fed funds rate unchanged in "cyclically adjusted" terms.

futures contract price. We can write the transformation in the following way.

$$[Z_1 \ Z_2] = [F_1 \ F_2]U$$

The details of the rotation computation are provided in the appendix in section 8.2. Figure 1 plots the target and path factors for the baseline sample. Going back to table 1 we see that by construction the path factor explains 0% of the variation in the current month's futures contract. As the horizon of the futures contract increases the amount of variation explained by the path factor increases. On the other hand the target factor has more explanatory power at shorter horizons.

Finally, we need to aggregate up the daily factor data series (either  $F_1$  and  $F_2$  or  $Z_1$  and  $Z_2$ ) to use them in a monthly VAR. We follow the procedure used in GK, which adjusts for the fact that FOMC meetings fall on different days in the month. Since we use interest rate data that are measured as monthly averages, a meeting that falls earlier in the month will have a bigger impact. We first create a daily series that cumulates the futures price changes for any FOMC meeting that has occurred in the past month. Next, we compute the monthly average of this daily series. An alternative methodology is to construct the monthly numbers by weighing the daily FOMC data based on the day of the month when the FOMC meeting occurred and then summing up any daily data points within a given month. In the online appendix we show that the results are similar when using this alternative methodology.

## 4 RESULTS

As mentioned above, the baseline specification has four variables: log Industrial production, log CPI, federal funds rate and the 1 year Treasury rate. The interest rates are used in levels, as is common in monetary VARs. The baseline sample for the reduced form VAR runs from July 1979 to December 2011, while the structural identification is carried out using futures data from January 1991 to December 2011.

One potential concern with using the external instruments identification strategy is the weak instruments problem. To explore the strength of the factors as instruments we present the results from the first stage regressions in table 2, with robust standard errors reported in parentheses. The table shows the regression of the reduced-form residual from the policy equations on the target and path factors. For

identification strategy I, we don't need to rotate the principal components to obtain the target and path factors. The only thing that matters in this case is the joint explanatory power of the two instruments. But note that the rotation of the principal components preserves the amount of variation explained by the factors. Thus the F-statistics for the first stage regressions are identical whether we use the two principal components ( $F_1$  and  $F_2$ ) or the rotated factors ( $Z_1$  and  $Z_2$ ). However for identification strategy II, we need to use the rotated factors and thus these are the ones reported in the first stage. The first two columns represent results from using the fed funds rate and 1 year rate as policy tools, while the second two columns use the fed funds rate and the 2 year rate as policy tools in the reduced-form VAR. From the first two columns, notice that the robust F-statistics are 18.91 and 14.73. These numbers are above 10, which is a number recommended by [Stock, Wright, and Yogo \(2002\)](#) and is commonly used as a benchmark in the applied literature. The table also reports the Cragg-Donald statistic for the joint test proposed by [Stock and Yogo \(2005\)](#) for multiple endogenous regressors. Comparing the statistic to the critical values from [Stock and Yogo \(2005\)](#) we can reject the null of weak instruments at a 10% significance level.<sup>14</sup> Yet another alternative is to use the multiple endogenous regressor test proposed in more recent work by [Sanderson and Windmeijer \(2016\)](#). They provide an individual F-statistic for each endogenous regressor. For the VAR with the 1 year rate, the corresponding p-values (reported in [table 2](#)) for the fed funds residual and 1 year residual are 0.033 and 0.025 respectively. For the VAR with the 2 year rate, the p-values are 0.008 and .023. Thus overall the first stage results show that the instruments are reasonably strong.<sup>15</sup> The robust F-statistics are a little lower for the 2 year rate and this motivates the use of the 1 year rate as the policy tool in the baseline results. In [section 6](#), we show that the results are similar using the 2 year rate.

We now turn our attention to the main results of the paper. We find that the results are quite similar for both the identification strategies discussed above, which is reassuring. In [this section](#) and [section 5](#) we will present the results using identification strategy I, while in [section 6](#) we provide a comparison of these results with identification strategy II. [Figure 2](#) shows the impulse responses to the two monetary policy shocks from the baseline SVAR, together with 90% confidence intervals. The confidence intervals

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<sup>14</sup>Note that the inference is dependent on the selected maximal IV size. See [table 16](#) in the online appendix for critical values for various different maximal IV sizes.

<sup>15</sup>Recent work by [Lunsford \(2015\)](#) derives critical values for the F-statistic depending on the level of asymptotic bias in the external instruments framework. However, this paper only considers the case of one policy shock and one instrument which is not directly applicable here.

are computed using the recursive wild bootstrap following [Gonçalves and Kilian \(2004\)](#).<sup>16</sup> The first column of figure 2 shows the response to a 100 basis point increase to the fed funds rate. This produces a persistent response with the fed funds rate falling to zero after a year and a half. The 1 year rate rises roughly 50 basis points on impact and falls gradually towards zero around the 2 year mark. Industrial production falls by .1% on impact and has a U-shaped response with a statistically significant trough close to  $-2\%$  being reached around two years. This result is consistent with the prototypical theoretical macro models and also with VAR analyses of monetary policy, see for example [Christiano, Eichenbaum, and Evans \(1999\)](#). Even though the CPI falls on impact, it actually rises for about a year, leading to the so-called price puzzle. While this positive response is not statistically significantly different from zero, it will be a recurring feature of the various specifications considered in this paper. This result is consistent with the findings of [Barakchian and Crowe \(2013\)](#) and [Ramey \(2016\)](#) who find price puzzles even after using futures based identification of monetary policy shocks. Thus in this paper we will restrict our attention to focusing on the response of output.

The second column of figure 2 shows the effect of a forward guidance shock that increases the 1 year rate by 100 basis points. After rising on impact, the 1 year rate stays high for about a year before decreasing. The fed funds rate is essentially unchanged on impact. Recall that the identification restriction does not impose the contemporaneous response of the fed funds rate to be zero in response to a forward guidance shock.<sup>17</sup> The rise in the contemporaneous 1 year rate captures the signal from the Federal Reserve to increase interest rates in the future and we see this in the response of the fed funds rate which rises slowly for about a year after the shock. Most notably, CPI and industrial production both *rise* on impact and continue rising for the next year. Moreover, this response is statistically significant for both, at least in the first few months. Some recent studies have also found expansionary effects of contractionary monetary policy shocks, see for example [Barakchian and Crowe \(2013\)](#) and [Ramey \(2016\)](#). However, in those studies and the overall monetary SVAR literature, monetary policy is modeled with only one policy tool. Thus one interpretation of the results from figure 2 is that the counterintuitive finding in the literature can potentially be narrowed down to the effects coming from forward guidance. However, this result is at odds with standard macro theory and also the SVAR based

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<sup>16</sup>Recent work by [Montiel-Olea, Stock, and Watson \(2016\)](#) and [Lunsford and Jentsch \(2016\)](#) propose alternative ways to construct confidence sets for impulse responses in the external instruments framework, but they only consider the case of one policy shock and one instrument.

<sup>17</sup>The fed funds rate can be indirectly affected by the forward guidance shock through output and prices but not directly by the forward guidance announcement.



forward guidance literature cited above.

Our explanation for the source of this effect is related to the so-called “Fed information” effect. More specifically we find an important role for the asymmetry in macroeconomic forecasts between the Federal Reserve and the market (which we label as Federal Reserve private information). In constructing the instruments used in the SVAR, if we control for this private information, the response of output to a forward guidance shock no longer displays the puzzling behavior. The details of these results and a discussion about the Fed information effect are presented in section 5. But first we establish the robustness of these findings and compare the results from this baseline SVAR to specifications that are widely used in the literature. From the various robustness checks that we consider, the most relevant ones are presented here in this section. Some other checks are presented towards the end in section 6 below and yet more checks are presented in the online appendix. First stage results from all the different specifications are provided in the online appendix.

**4.1 EXTENDED RESULTS** We start by confirming that the effect of forward guidance captured in the SVAR is indeed coming from Federal Reserve communication. While the FOMC first released a written statement in 1994, the statements were only sporadically released in the mid 1990s and did not become a regular feature until 1999.<sup>18</sup> The target and path factors plotted in figure 1 also highlight this distinction. The blue lines show the FOMC meetings when no statement was released while the red lines correspond to meetings when a statement was released. The path factor displays more variation when a statement is released consistent with the futures market reacting to FOMC communication. A simple way to check the robustness of the baseline results is to construct the futures based instruments by only using FOMC meetings with an accompanying statement. We follow this procedure and redo the instrument construction and SVAR estimation. The dashed black lines in figure 3 show the impulse responses using this approach together with the baseline results shown with the dashed blue lines. The same pattern that appears in the baseline results also appears with this approach. Output falls with a hump shaped pattern following a fed funds rate shock while output rises in response to a forward guidance shock. In fact, this pattern appears to be slightly stronger here. However, by excluding the FOMC dates when no statement was released we are losing out on useful information about surprise

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<sup>18</sup>In the online appendix we provide a list of FOMC meetings indicating which ones had an accompanying statement release.

fed funds target rate decisions which are captured in the target factor.<sup>19</sup>

In the online appendix we address another concern about including the FOMC meetings from the early 1990s as part of the futures based instruments sample. There we show that the results are similar even if we drop the FOMC meetings from 1991 to 1993. A related concern is that our result is driven by the inclusion of unscheduled FOMC meeting dates in the instrument sample. As noted in [Barakchian and Crowe \(2013\)](#) among others, the unscheduled FOMC meetings may represent actions by the Federal Reserve that correspond to simultaneous release of macroeconomic news. To check whether this explains our counterintuitive results, we redo the analysis leaving out the unscheduled FOMC meetings and find that the magnitude and the sign of the impulse responses are similar to the baseline case. These results are also presented in the online appendix.

In the baseline specification we did not use a direct measure of GDP due to the monthly frequency of the VAR. Since the unemployment rate is available at this frequency, we add it to the VAR to further confirm the response of economic activity. The dashed black line in figure 4 show the impulse responses from this specification, with the solid blue lines showing the baseline results. As we can see the responses with the unemployment rate added are very similar to the baseline case. Importantly, the response of the unemployment rate itself is consistent with the story that emerges from the baseline results, i.e. unemployment rises in response to a contractionary fed funds rate shock but falls in response to a forward guidance shock.

Another important concern is that the small VAR used for the baseline specification may be leaving out some information related to financial markets that is relevant for the Federal Reserve in making policy decisions. The excess bond premium of [Gilchrist and Zakrajšek \(2012\)](#) is an easy way to capture some of this missing information in the VAR.<sup>20</sup> The dashed black lines in figure 5 shows the impulse responses from this specification. For ease of comparison, the solid blue lines show the responses from the baseline specification. The excess bond premium rises in response to a contractionary funds rate shock but has essentially no contemporaneous response to a forward guidance shock. In response to a forward guidance shock, the rise in output on impact is identical to the baseline case, but it goes back to zero a little faster when the excess bond premium is included in the VAR. However, the overall

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<sup>19</sup>The first stage results for this specification are presented in the online appendix. The robust F-statistics in the first stage fall to 10.22 for the fed funds rate residual and 9.45 for the 1 year rate residual. Recall that they are 18.91 and 14.73 in the baseline case.

<sup>20</sup>This has been advocated in recent papers by GK and [Caldara and Herbst \(2016\)](#).

responses of economic activity are very similar.<sup>21</sup>

To further establish the robustness of the results, in section 6 below we present various other results, including using the 2 year rate as the policy tool and using a narrower (30 min) or broader (2 day) window to construct futures based instruments. For the remainder of this section we explore how our results depend on two main modeling features. First, how important is the fact that we separate conventional monetary policy from forward guidance? To evaluate this, we compare our results to a SVAR identified using external instruments but in a setting where only conventional policy is modeled (using only the fed funds rate) and a setting where both conventional and unconventional policies are captured by one policy tool. Second, how important is the external instruments identification methodology in driving the results? To evaluate this, we compare the results from the baseline SVAR with the commonly used recursive (Cholesky) identification strategy that puts zero restrictions on the matrix governing the contemporaneous relations between the endogenous variables.

**4.2 COMPARISON OF POLICY TOOLS** Here we compare our results with monetary SVARs that allow for only one monetary policy tool. The most common approach in the literature is to just use the fed funds rate as the policy tool. To do this comparison we estimate a SVAR similar to the baseline case, but remove the 1 year rate. We want to use the same identification strategy as the baseline case when making the comparison. Since the only policy tool is the fed funds rate, the instrument is constructed using just the current month’s fed funds futures contract (labeled MP1). This is the measure of monetary policy surprises first constructed in [Kuttner \(2001\)](#) and also used by GSS.<sup>22</sup> An alternative approach uses a SVAR to compute the “joint” effect of monetary policy. Here, a longer term interest rate is the only policy tool and is meant to capture the joint effect of both conventional monetary policy and forward guidance. To do this comparison we use the external instruments methodology to estimate the baseline SVAR specification but leave out the fed funds rate. This is essentially the specification of GK.<sup>23</sup> We follow their approach and use the 3 month ahead fed funds futures contract (labeled FF4) as an instrument for the shocks to the 1 year rate.

The impulse responses from both these approaches are presented in dashed black lines in figure 6.

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<sup>21</sup>The response of the excess bond premium here is a little muted relative to GK. Recall that the use of daily data and the use of two monetary policy tools are two main differences between GK and this paper. We found that the latter of the two is more important in driving the subdued response.

<sup>22</sup>As expected, this measure turns out to be very similar to the target factor and the correlation between them is 0.98.

<sup>23</sup>To make the model as comparable as possible to the baseline case, we leave out the excess bond premium from the GK specification. We have already shown in figure 5 that our results are robust to including this variable.

The first column shows the response to a one percentage point fed funds rate shock, while the second column shows the responses to a one percentage point shock to the 1 year rate. For both models, output rises slightly on impact, but then falls and is significantly lower at the two year mark. The solid blue lines in figure 6 are responses to a funds rate and forward guidance shock respectively from the baseline impulse responses (figure 2). For CPI, the responses from using the two individual policy tools is very similar to the decomposed effect of the two shocks from the baseline specification. For output the effect of the fed funds rate shock identified individually is very similar to the baseline fed funds rate shock. Where we do see a noticeable difference is in the response of output to a one year rate shock. When the 1 year rate shock is identified individually (and jointly captures the total effect of monetary policy) its effect on output displays a far lower “puzzling” response. More specifically, contrary to the baseline forward guidance shock, in this case output rises less on impact and is statistically significantly lower at the 2 year mark. This further highlights the importance of separating the effect of a fed funds rate shock from a forward guidance shock to avoid misrepresenting the overall effects of monetary policy.

**4.3 COMPARISON OF IDENTIFICATION STRATEGY** Next we want to explore whether using a simpler alternative identification strategy would give similar results. To this end we compare our results to the recursive Cholesky identification scheme that is frequently used in the literature. For this identification scheme, the order of the VAR is potentially crucial as it determines which elements of the contemporaneous relationship matrix are set to zero. In the monetary SVAR literature, the convention is to have output and prices ordered before the monetary policy instrument, see for example [Christiano, Eichenbaum, and Evans \(1999\)](#). In the case with two policy instruments we have to also order the fed funds rate and the 1 year rate. From the asset pricing literature there is a clear expectations channel through which movements in the short rate contemporaneously affect longer rates, while the reverse contemporaneous effect is not entirely obvious. Thus we use the following ordering: i) Industrial Production, ii) CPI, iii) fed funds rate and iv) 1 year rate.<sup>24</sup> This ordering implies that output and prices do not respond contemporaneously to either the fed funds rate shock or the 1 year rate shock. Additionally, the fed funds rate does not respond contemporaneously to the 1 year rate shock but the 1 year rate can respond contemporaneously to all variables. The impulse responses to a fed funds rate shock and a shock to the 1 year rate are plotted in figure 7. The dashed black lines show the recursive Cholesky

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<sup>24</sup>Swapping the order of output with prices does not affect the results.

identification with the baseline responses in solid blue lines. For the Cholesky identified fed funds rate shock (first column), we notice that the responses are extremely similar to the baseline responses identified using external instruments. However for the shock to the 1 year rate, we see that the response of both prices and output is quite different. The Cholesky identified shock has essentially a zero impact on output after a couple of months. the shape of the response of output is somewhat similar to the external instruments case but the differential impact effects result in substantial differences. Overall, this exercise suggests that the external instruments methodology produces qualitatively and quantitatively different results from the Cholesky identification. We conclude that the restrictions imposed from the external instruments methodology imply effects of forward guidance that are quite different from the recursive identification. Next we turn to a potential explanation of the counterintuitive forward guidance response from the baseline specification.

## 5 FORWARD GUIDANCE AND FEDERAL RESERVE PRIVATE INFORMATION

What explains the counterintuitive response of output to a forward guidance shock? In two recent papers [Campbell, Evans, Fisher, and Justiniano \(2012\)](#) and [Campbell, Fisher, Justiniano, and Melosi \(2016\)](#) argue that forward guidance actions can be categorized into Delphic and Odyssean forward guidance. Odyssean forward guidance fits the conventional definition of forward guidance; a signal from the Federal Reserve about what it will do to short-term rates in the future. On the other hand, Delphic forward guidance is a signal that is tied to the release of Federal Reserve information about the future state of the economy. Importantly, the observed response of the economy to forward guidance shocks depends crucially on whether these shocks are Odyssean or Delphic in nature. An Odyssean forward guidance shock that indicates the Fed's intentions to make short-term rates higher in the future is unrelated to economic developments and should result in a fall in output and prices. Now consider a Delphic forward guidance shock that signals the intention of the Fed to raise rates based on revised forecasts that future economic activity is going to be stronger than expected. In this case, even though the Fed is going to raise rates, it is a response to an expected pickup in economic activity. Thus it might be possible to observe output and prices rise after a Delphic forward guidance announcement is made. Note that in this case the information revealed by the Fed has to be different from the market's expectation to have any meaningful effects.

To shed light on this distinction of forward guidance shocks, we redo the VAR analysis using a “cleansed” measure of the instruments that controls for the Delphic part of forward guidance. The idea is to remove any component from the factors that is capturing the release of private information by the Federal Reserve about the future state of the economy. To do so we first construct a measure of Federal Reserve private information following [Barakchian and Crowe \(2013\)](#) and [Campbell, Evans, Fisher, and Justiniano \(2012\)](#) among others. Next we regress our target and path factors on this measure of Fed private information. Finally, we use the residuals from the regressions as instruments in the SVAR. The underlying assumption in this framework is that futures market reaction depends on how the market interprets FOMC communication as revealing Fed private information.<sup>25</sup>

The measure of private information is constructed using two datasets on forecasts. The Greenbook dataset is used to capture the Fed’s forecasts. This is produced by the Fed’s staff and made available to FOMC participants a week before the scheduled FOMC meetings. The Greenbook forecasts are made publicly available after a five year lag and thus represent information that is not contemporaneously available to the public. Second, we use the consensus forecasts from the Blue Chip survey as an indicator of the market’s expectations. The difference between the Greenbook forecasts and the Bluechip forecasts is used as a measure of Federal Reserve private information. Both the Greenbook and Blue Chip datasets contain forecasts for macro variables several quarters into the future. We will use forecasts from 1 quarter ahead up to 4 quarters ahead, since the policy tool for forward guidance in our baseline VAR is the 1 year rate.

Table 3 shows the regressions of the target and path factors on measures of private information for GDP and CPI and the lagged value of these private information measures. We use forecasts from one quarter ahead to four quarters ahead denoted  $t1$  through  $t4$ . The sample ends in December 2010, as that is the latest available data for the Greenbook forecasts. Columns (a) and (b) show the regression coefficients with robust standard errors. The R-squared from both columns is low, suggesting that Federal Reserve private information only accounts for a small component of the variation in the futures contracts. Notice that the R-squared is bigger for the path factor regression and that the adjusted R-squared is actually negative for the target factor regression. Moreover, as can be seen from column (c), the p-value for the Wald test implies that we fail to reject the null hypothesis that all the coefficients

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<sup>25</sup>For a further theoretical motivation for this regression, see [Miranda-Agrippino \(2016\)](#) and [Lakdawala and Schaffer \(2016\)](#).

in the target factor regression are zero. On the other hand, the path factor Wald tests show that the null hypothesis of all coefficients being zero can be rejected even at the 1% level. Additionally, testing different groups of parameters for the path factor regression leads to a similar conclusion. We have also added forecasts of unemployment to this regression and the results stay the same, these are available in the online appendix. Thus these regressions suggest that Fed private information is primarily related to future policy actions as captured through the path factor.<sup>26</sup> In the light of these results we re-estimate the baseline SVAR using as instruments i) the target factor and ii) the residual from the path factor regression.<sup>27</sup>

We now use the target factor and the cleansed path factor (labeled “Path Factor (Pvt Res)”) as instruments in the estimation of the SVAR.<sup>28</sup> The first column of figure 8 shows the response to a forward guidance shock using the cleansed instruments, while the second column shows the responses using the baseline (or unmodified) instruments. In each column the solid blue line represents the specification with all available data, while the dashed black lines represents the specification where only the FOMC meetings with accompanying statements are used. The striking result is that now the contemporaneous response of output to a forward guidance shock is very close to zero and the response at the 2 and 3 year mark is negative (around  $-1\%$  for the full sample case). This is in sharp contrast to the results obtained with the baseline path factor shown in the second column. In this case, output rises on impact in response to a contractionary forward guidance shock and the response stays positive for over 3 years. The difference in the results between using the cleansed and baseline path factor is slightly larger when we restrict the sample to FOMC meetings with statements as seen by the dashed black lines.

To summarize, the overall effect of a “contractionary” forward guidance shock is to increase output while the first column of figure 8 suggests that a contractionary shock controlling for Fed private information has a small negative impact on output. One interpretation is that the total measured effect is being dominated by the Delphic component (which is captured by the Fed’s private information). This reasoning has the underlying assumption that a shock of Delphic type that increases interest rates is followed by an increase in output. There is a way to check this interpretation in our framework.

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<sup>26</sup>The methodology of using forecast differences is a particular to capture the information content of monetary policy surprises. Thus we cannot rule out that there is an information effect for target rate changes as well that may be working through other channels.

<sup>27</sup>Using the residual from the target factor does not change the results. The correlation between the target factor and the residual from private information regression is 0.96.

<sup>28</sup>In the online appendix we plot this cleansed path factor along with the path factor for comparison and provide the first stage results which are quite similar to the baseline case.

To capture the pure Delphic effect, we can use the fitted value from the private information path factor regression and use it as an instrument in the SVAR. The response of output to this type of forward guidance shock is shown with the dashed red line in figure 9. For comparison, we plot the response from the baseline specification using the dotted black line and from the Path Factor (Pvt Res) specification using the dashed blue line. These responses match up well with the interpretation discussed above. A “contractionary” Delphic forward guidance shock raises output, while an Odyssean one results in a fall in output. The Delphic component dominates to result in an increase in output in response to a forward guidance shock. Here we must mention an important caveat regarding the results using the fitted value from the private information regressions. The 1 year residual’s first stage coefficient on the path factor is much smaller in magnitude and the standard error is quite large, full results are presented in the online appendix. This results in confidence intervals for the impulse responses that are much larger for the Path Factor (Pvt Fit) results. Thus we view the results from figure 9 as only suggestive and recommend interpreting them with a high degree of caution.

## 6 ADDITIONAL ROBUSTNESS CHECKS

In this section we present a few more robustness checks. Due to space constraints, we present the impulse responses only for output, with the full set of impulse responses and first stage results relegated to the online appendix. The left column of figure 11 shows the response of industrial production to a fed funds rate shock while the right column shows responses to a forward guidance shock. Each of the subplots shows the responses from the baseline specification in solid blue lines (from figure 2 and the alternative specification responses in dashed black lines.)

A potential issue involves the size of the window used to construct the instruments. In the baseline results we use the end of day data to measure the change in the futures prices on FOMC days. An alternative is to use a narrower window to measure this change. Notably, GSS and GK both use a 30 minute window around the FOMC announcement. This is motivated by the notion that the narrower the window the less likely it is that an event other than the FOMC announcement is driving the change in the futures price. On the flip side, some authors have argued that it may take financial markets more time to digest the FOMC announcement, see for example [Hanson and Stein \(2015\)](#) who use a two day change. To check the robustness of our results, we estimate our model using both the 30 minute and 2



day window to construct the instruments. Figure 10 plots the target and path factors from these two alternative approaches and compares it with the baseline case. We can see the high amount of overlap between these measures. As a result, the impulse responses from both approaches (first row labeled “a) 30 min window” and second row labeled “b) 2 day window”) show the standard response to a fed funds rate shock but the expansionary effect of a “contractionary” forward guidance shock. The narrow window results are larger in magnitude than the baseline case whereas the broader window results are quite similar in magnitude to the baseline case.

In the baseline specification we presented the results with identification strategy I. In the third row (labeled “c) ID II”) we show the responses from using identification strategy II. The overall effects are strikingly similar to identification strategy I with two small differences. First, the response of output to a fed funds rate shock takes a few extra months to turn negative. Second, in response to a forward guidance shock, output stays a little higher in the medium run relative to strategy I. Next, we estimate the SVAR replacing the 1 year rate with the 2 year rate as the monetary policy tool. These responses are shown in the fourth row (labeled “d) 2 year rate”). It is clear that the response of output is extremely similar as compared to the 1 year rate case. Finally, we re-estimate the SVAR stopping the sample in December 2008. While the 2009-2011 period is an important one for the Federal Reserve’s forward guidance policy, this period is also characterized by the Federal Reserve’s large scale asset purchases (see for example [Rogers, Scotti, and Wright \(2014\)](#)). As discussed above in the introduction, there is a debate in the literature about whether the main channel through which the asset purchases worked was through forward guidance or not. Rather than getting caught up in this debate, for the purposes of this paper we want to confirm that our results are not driven exclusively by this small subsample. Thus we perform the estimation excluding the ZLB period. These results are presented in the last row (labeled “e) Pre-ZLB”). Again we notice that the response of output is very similar to the baseline case.

Overall, we conclude that output falls in a hump shaped manner after a fed funds rate shock but has a persistent rise after a forward guidance shock. Thus the overall effect of a contractionary forward guidance shock appears to create an expansionary effect on the economy which we have shown in section 5 above to be tied to the asymmetric information between the market and the Federal Reserve.

## 7 DISCUSSION AND CONCLUDING REMARKS

What have we learned about the effects of forward guidance in light of the private information analysis from section 5. One line of thinking is that we should purge out any effect of Federal Reserve private information when measuring forward guidance. In other words, only the Odyssean component of forward guidance should matter when studying the effects of central bank communication. From this perspective, the results shown in figure 8 suggest that the effects of forward guidance are small in magnitude and qualitatively in line with conventional theory. However, we would like to raise two important issues that should be kept in mind when interpreting these results.

First, it is possible that central bank announcements of even the Delphic kind can have direct effects on the economy. The forecast data used in the previous section highlights the importance of information asymmetries and there is new evidence in the literature that suggests this can have important effects on agents' expectations and the economy. [Nakamura and Steinsson \(2015\)](#) find a "Fed information effect" where Fed communication affects agents' expectation of future economic activity. [Melosi \(2016\)](#) sets up a DSGE model with an explicit signalling channel of monetary policy and finds that it has empirically relevant effects. Finally, [Tang \(2015\)](#) also finds that the empirical patterns in the U.S. inflation data are consistent with the existence of a signalling channel. While this a nascent literature, it does seem to suggest that the "signalling/information" channel is important and that the Delphic component of forward guidance should not be ignored.

Second, it is important to note that the estimates in this paper are based on using data only on FOMC dates. While it is true that FOMC meeting days are the most important dates on the monetary policy calendar, there are other occasions on which the Federal Reserve communicates to the public. The publicly announced events include speeches made by FOMC members, media interviews and testimony to Congress. Additionally, some information from the Federal Reserve may filter through to the markets through other sources. A recent paper by [Cieslak, Morse, and Vissing-Jorgensen \(2015\)](#) suggests that this may even be happening at a bi-weekly frequency. Thus we view our results as measuring only the partial effect of FOMC communication. An important concern with expanding the instrument sample to include these days is maintaining the credibility of the exogeneity assumption, i.e. can we still reasonably assume that the primary source of movements in the futures price changes is due to FOMC communication? A careful analysis that addresses this concern appears to be a promising area

for future research.

To summarize, in this paper we separately identify the effects of conventional monetary policy from the more unconventional policy of forward guidance. This is done in a SVAR framework where the identification of the monetary transmission mechanism is achieved using the external instruments methodology. Within this framework of multiple policy tools we show that there are two alternative identification strategies that can be used with two instruments constructed from futures data. While the effects of fed funds rate shock is consistent with standard macro theory, the effect of forward guidance shocks on output appears to be a “puzzle”. We show that this puzzle can be explained once the discrepancies in the forecast of the Federal Reserve and the general public is accounted for. Overall, our results highlight the need for developing structural models of central bank communication which incorporate an additional channel through which the release of central bank information can potentially affect agents’ expectations about future economic activity.

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## 8 APPENDIX

### 8.1 IDENTIFICATION WITH EXTERNAL INSTRUMENTS

SETUP FOR IDENTIFICATION STRATEGY I The reduced-form covariance matrix in equation 2.2 is given by

$$\Sigma = \begin{pmatrix} \Sigma_{11} & \Sigma_{12} \\ \Sigma_{21} & \Sigma_{22} \end{pmatrix}$$

The instrumental variables estimation gives

$$B_{21}B_{11}^{-1} = E[Z_t u_t^{p'}]^{-1} E[Z_t u_t^{q'}]$$

With these two, we can calculate the following matrices

$$\begin{aligned} B_{12}B_{22}^{-1} &= \left[ (B_{12}B'_{12}(B_{21}B_{11}^{-1})') + (\Sigma_{21} - B_{21}B_{11}^{-1}\Sigma_{11})' \right] (B_{22}B_{22}^{-1}') \\ B_{12}B'_{12} &= (\Sigma_{21} - B_{21}B_{11}^{-1}\Sigma_{11})' Z^{-1} (\Sigma_{21} - B_{21}B_{11}^{-1}\Sigma_{11}) \\ B_{22}B'_{22} &= \Sigma_{22} + B_{21}B_{11}^{-1} (B_{12}B'_{12} - \Sigma_{11}) (B_{21}B_{11}^{-1})' \\ B_{11}B'_{11} &= \Sigma_{11} - B_{12}B'_{12} \\ Z &= B_{21}B_{11}^{-1}\Sigma_{11} (B_{21}B_{11}^{-1})' - \left( \Sigma_{21} (B_{21}B_{11}^{-1})' + B_{21}B_{11}^{-1}\Sigma'_{21} \right) + \Sigma_{22} \end{aligned}$$

The approach in [Mertens and Ravn \(2013\)](#) relies on estimating the matrix  $S_1$  which is related to the above estimable matrices in the following manner

$$S_1 S'_1 = (I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1}) B_{11}B'_{11} (I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1})'$$

In the case of 1 shock and 1 instrument, we can identify  $S_1$  up to a sign convention from the above equation. With more than 1 shock,  $S_1$  is not identified without further restrictions. As explained in section 2.1, identification strategy I involves imposing a triangular structure on  $S_1$ , such that a Cholesky factorization of the above equation gives  $S_1$ . With  $S_1$  in hand, we can get the relevant column of the

impact matrix  $B_1 = \begin{bmatrix} B'_{11} & B'_{21} \end{bmatrix}$  from the following two equations

$$\begin{aligned} B_{11}S_1^{-1} &= (I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1})^{-1} \\ B_{21}S_1^{-1} &= B_{21}B_{11}^{-1}(I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1})^{-1} \end{aligned}$$

**SETUP FOR IDENTIFICATION STRATEGY II** Given relevance and validity conditions of the instrument,  $E[Z_t\varepsilon_t^p] = \phi$  and  $E[Z_t\varepsilon_t^q] = 0$  and that the covariance matrix of the residuals  $E(u_tu_t') = BB'$ , we can derive equations 2.13 and 2.14 in a straightforward manner.

$$\begin{aligned} E(Z_tu_t') &= E(Z_t[B\varepsilon_t]') \\ &= E\left(Z_t \left[ (B_1 \ B_2) \begin{pmatrix} \varepsilon_t^p \\ \varepsilon_t^q \end{pmatrix} \right]'\right) \\ &= E\left[\begin{pmatrix} Z_t\varepsilon_t^p \\ Z_t\varepsilon_t^q \end{pmatrix} (B_1 \ B_2)'\right] \\ &= E\left[\begin{pmatrix} \phi \\ 0 \end{pmatrix} (B_1 \ B_2)'\right] \\ &= \phi B'_1 \end{aligned}$$

$$\begin{aligned} E(Z_tu_t') [E(u_tu_t')]^{-1} E(u_tZ_t') &= \phi B'_1 (BB')^{-1} B_1 \phi' \\ &= \phi B'_1 (B')^{-1} B^{-1} B_1 \phi' \\ &= \phi \phi' \end{aligned}$$

In the case of 1 shock and 1 instrument, now we can identify  $\phi$  up to a sign convention from the above equation. With more than 1 shock,  $\phi$  is not identified without further restrictions. As explained in section 2.1, identification strategy II involves imposing a triangular structure on  $\phi$ , such that a Cholesky factorization of the above equation gives  $\phi$ . With  $\phi$  in hand, we can get the relevant column of the



impact matrix  $B_1$  from

$$B_1 = E(u_t Z_t' (\phi')^{-1}) \quad (8.1)$$

**8.2 TARGET AND PATH FACTOR CONSTRUCTION** The goal is to construct two new factors  $Z_1$  and  $Z_2$  from the first two principal components  $F_1$  and  $F_2$  by finding an orthogonal matrix  $U$

$$[Z_1 \ Z_2] = [F_1 \ F_2]U \quad (8.2)$$

$U$  matrix has 4 unique elements and requires 4 restrictions for identification

$$U = \begin{pmatrix} \alpha_1 & \beta_1 \\ \alpha_2 & \beta_2 \end{pmatrix}$$

The first two come from a simple normalization that imposes the columns of  $U$  to have unit length, i.e.  $\alpha_1^2 + \alpha_2^2 = 1$  and  $\beta_1^2 + \beta_2^2 = 1$ . Next, we maintain the orthogonality of the two factors  $E(Z_1 Z_2) = 0$ , which gives  $\alpha_1 \beta_1 + \alpha_2 \beta_2 = 0$ . Finally we impose the condition required for identification strategy II, that the second factor  $Z_2$  is not related to the current month's futures price change. This condition is given by  $\gamma_2 \alpha_1 - \gamma_1 \alpha_2 = 0$ . To see this last condition, let  $\gamma_1$  and  $\gamma_2$  be the factor loadings on  $F_1$  and  $F_2$  for change in current month's futures contract (given by  $X(1)$ )

$$X(1) = \gamma_1 F_1 + \gamma_2 F_2 \quad (8.3)$$

From equation 8.2 we can write

$$\begin{aligned} F_1 &= \frac{1}{\alpha_1 \beta_2 - \alpha_2 \beta_1} [\beta_2 Z_1 - \alpha_2 Z_2] \\ F_2 &= \frac{1}{\alpha_1 \beta_2 - \alpha_2 \beta_1} [-\beta_1 Z_1 + \alpha_1 Z_2] \end{aligned}$$

Now plug these into equation 8.3 and impose the condition that the loading of  $Z_2$  on  $X(1)$  is zero to get the restriction  $\gamma_2 \alpha_1 - \gamma_1 \alpha_2 = 0$ .

| Share of variance     |               |             |             |
|-----------------------|---------------|-------------|-------------|
| Futures Contract      | Target factor | Path factor | Unexplained |
| Current (FF)          | 0.980         | 0.000       | 0.020       |
| 1 quarter ahead (FF)  | 0.833         | 0.130       | 0.037       |
| 2 quarters ahead (ED) | 0.526         | 0.443       | 0.031       |
| 3 quarters ahead (ED) | 0.374         | 0.621       | 0.005       |
| 4 quarters ahead (ED) | 0.241         | 0.739       | 0.020       |

Table 1: Contribution of the first two principal components towards the variance of the futures contracts. The target and path factors are rotations of the first two principal components, computed following [Gürkaynak, Sack, and Swanson \(2005\)](#). Sample is January 1991 to December 2011.

| VARIABLES                     | (a)                 |                     | (b)                 |                     |
|-------------------------------|---------------------|---------------------|---------------------|---------------------|
|                               | FFR residual        | 1 year residual     | FFR residual        | 2 year residual     |
| Target Factor                 | 0.796***<br>(0.132) | 0.902***<br>(0.168) |                     |                     |
| Path Factor                   | -0.134<br>(0.177)   | 0.347<br>(0.233)    |                     |                     |
| Target Factor                 |                     |                     | 0.878***<br>(0.136) | 0.756***<br>(0.203) |
| Path Factor                   |                     |                     | -0.164<br>(0.276)   | 0.695*<br>(0.365)   |
| Constant                      | -0.006<br>(0.010)   | -0.000<br>(0.012)   | -0.006<br>(0.010)   | 0.003<br>(0.014)    |
| Observations                  | 252                 | 252                 | 252                 | 252                 |
| R-squared                     | 0.111               | 0.101               | 0.120               | 0.064               |
| Adjusted R-squared            | 0.104               | 0.0942              | 0.113               | 0.0565              |
| Robust F-statistic            | 18.91               | 14.73               | 22.56               | 7.695               |
| Cragg-Donald Statistic        |                     | 2.92                |                     | 2.86                |
| Sanderson-Windmeijer p-values | 0.033               | 0.025               | 0.008               | 0.023               |

Table 2: First stage regression of residuals from the reduced form VAR on the target and path factors. Sample is January 1991 to December 2011. Panel (a) is the baseline model with the 1 year rate as the forward guidance tool while panel (b) is the same specification with the 2 year rate replacing the 1 year rate. Robust standard errors in parentheses, \*\*\*  $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ .

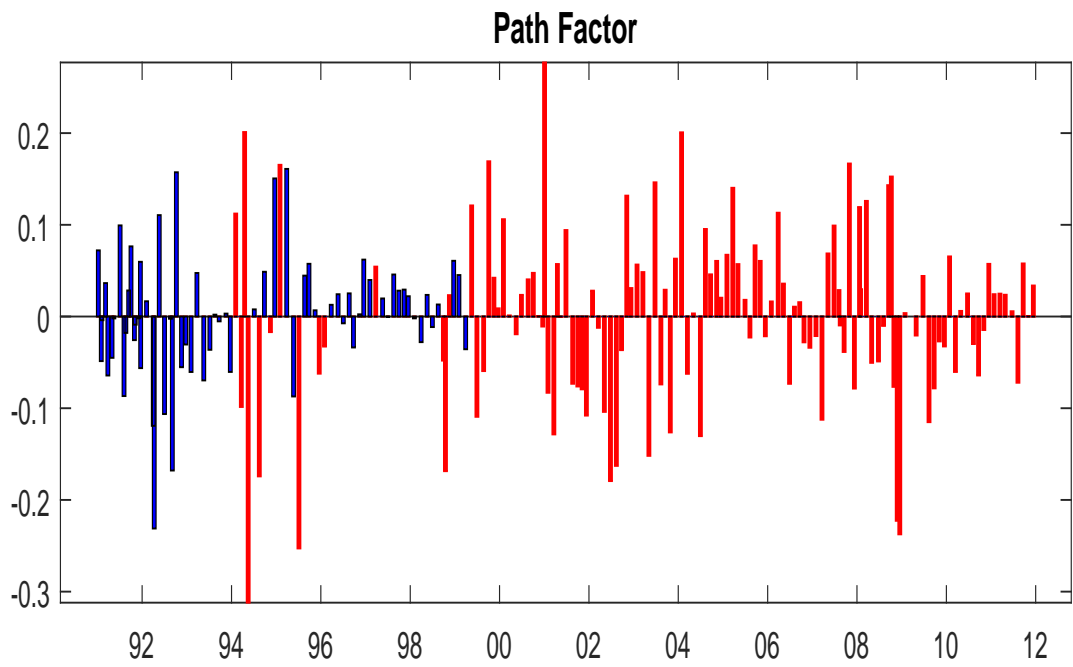
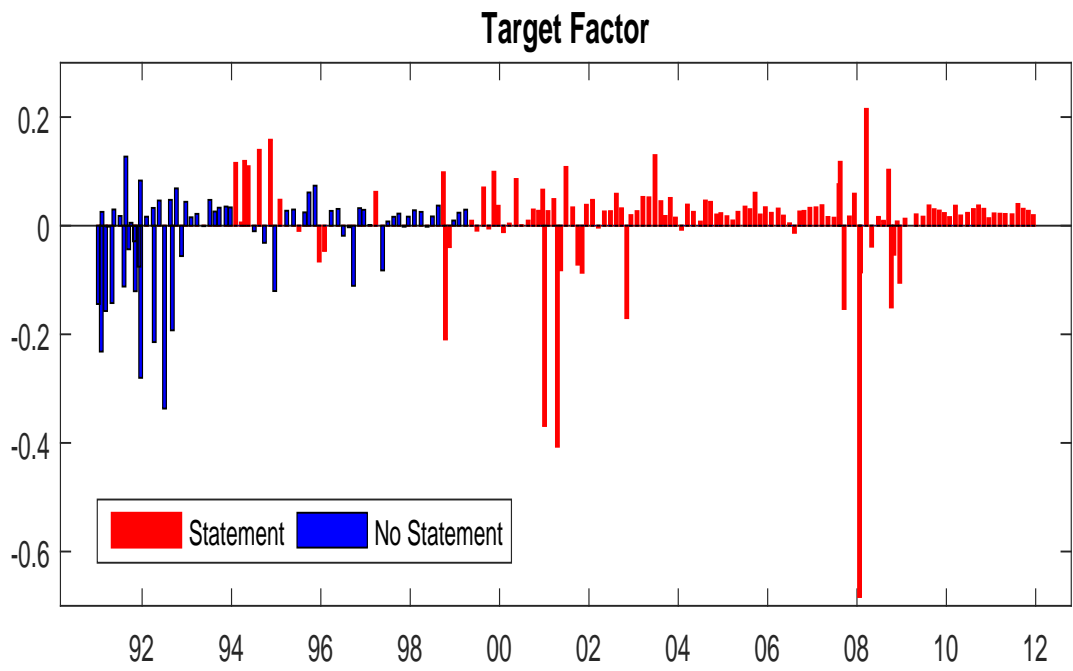


Figure 1: Target and path factors constructed from futures data.

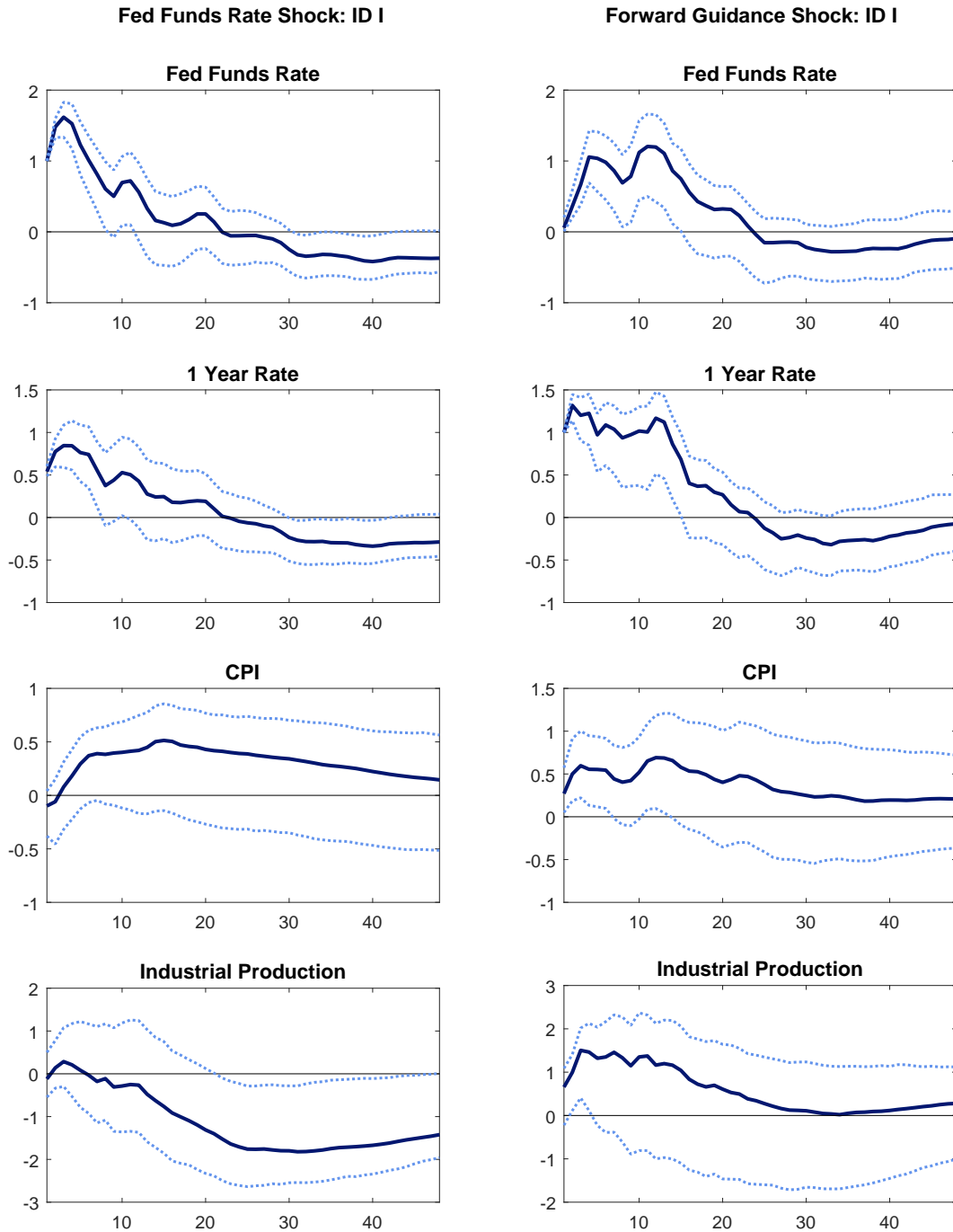


Figure 2: The impulse responses to a unit monetary policy shock identified using the external instruments identification strategy I outlined in the text, with 90% confidence intervals. The first column shows the response to a conventional monetary policy shock (i.e. shock to the federal funds rate equation), while the second column shows the response to a forward guidance shock (i.e. shock to the 1 year rate equation). Reduced form VAR sample: July 1979 to December 2011, futures market identification sample: January 1991 to December 2011

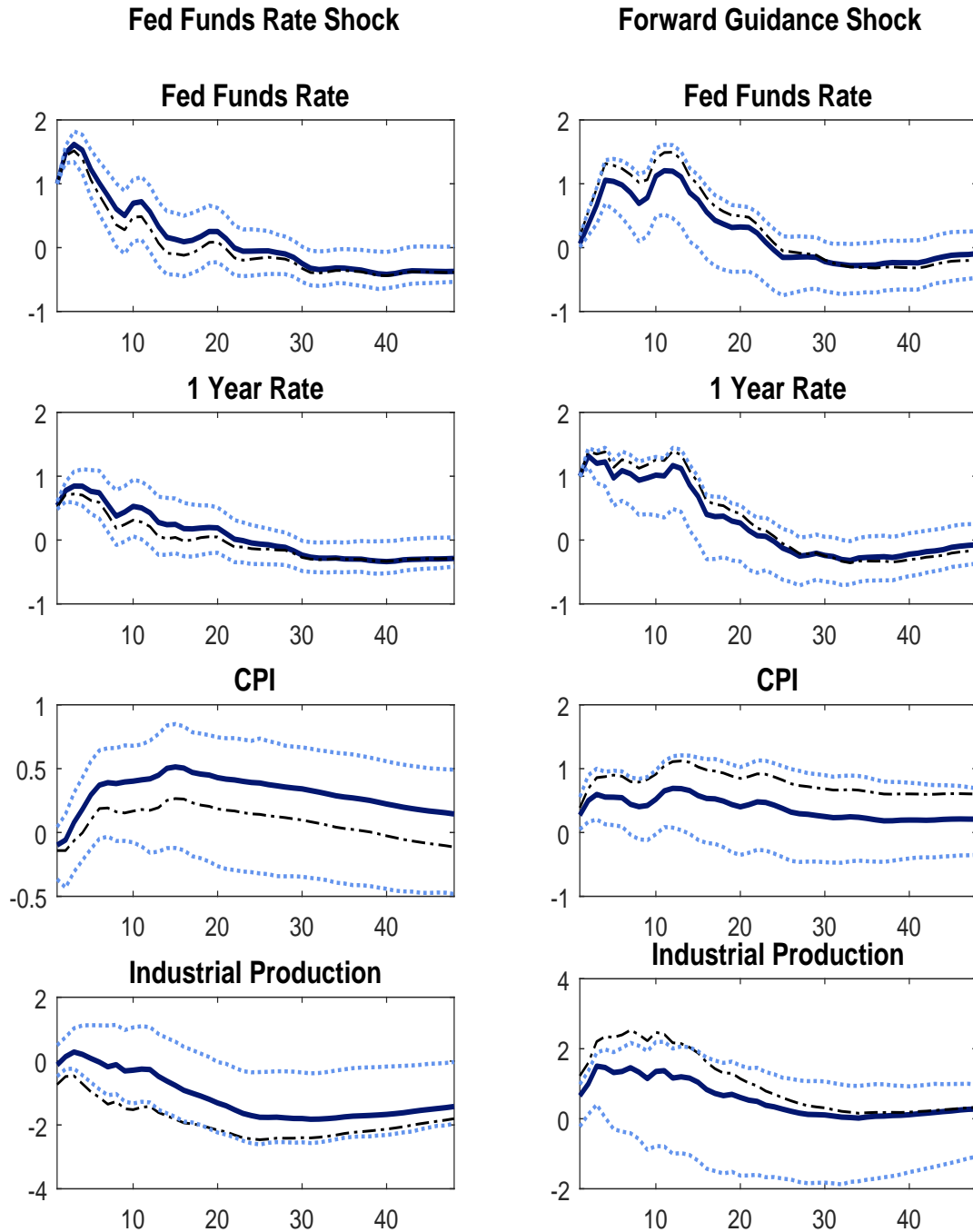


Figure 3: The impulse responses to a unit monetary policy shock with 90% confidence intervals. The solid blue line shows results with the baseline specification. The dashed black line shows results where only those FOMC meetings that were accompanied by a statement are included in the instrument construction. Reduced form VAR sample: July 1979 to December 2011, futures market identification sample: January 1991 to December 2011.

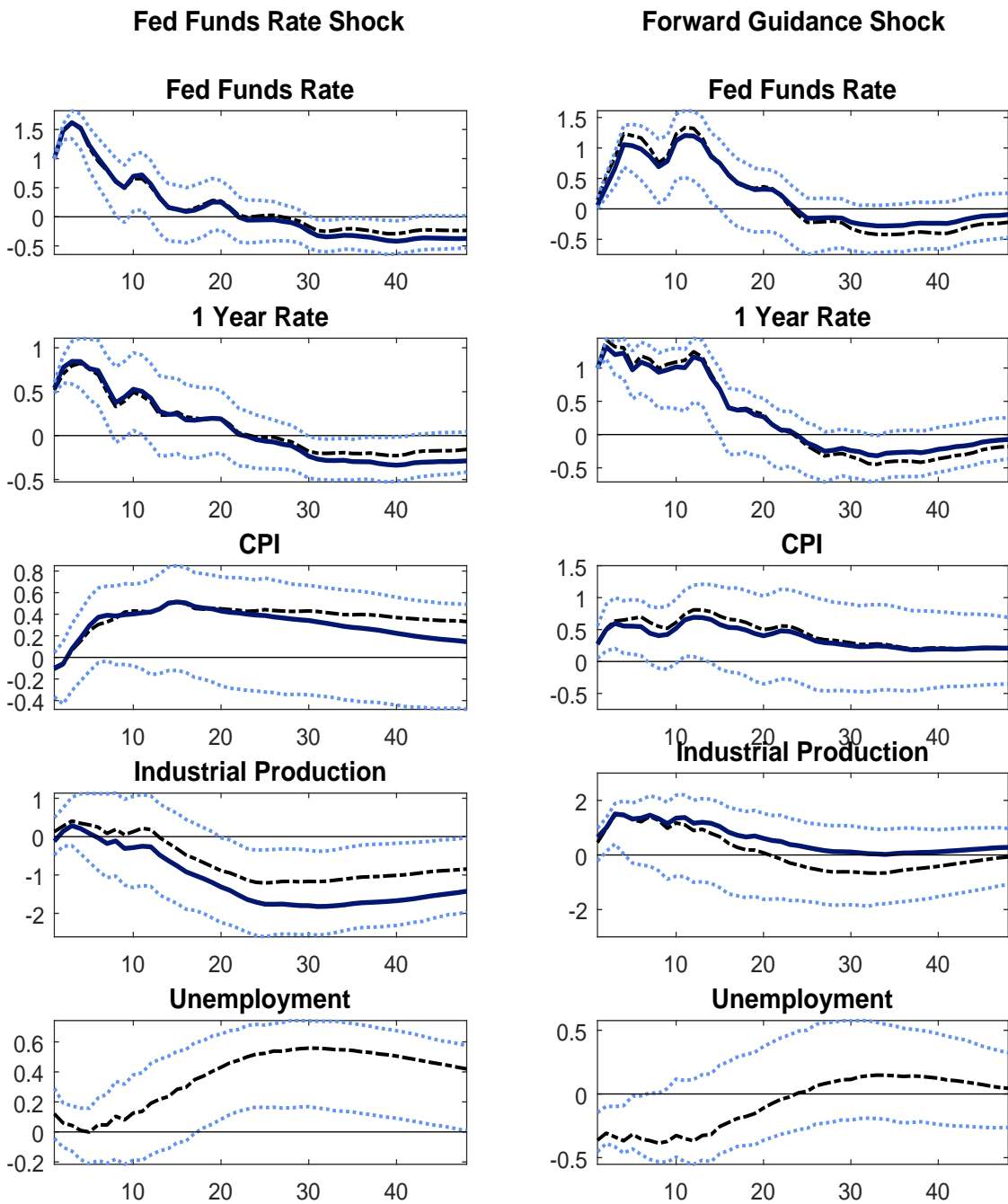


Figure 4: The impulse responses to a unit monetary policy shock with 90% confidence intervals. The dashed black lines show the impulse responses for the VAR with unemployment added to the baseline specification. The solid blue lines show the responses from the baseline specification. Reduced form VAR sample: July 1979 to December 2011, futures market identification sample: January 1991 to December 2011.

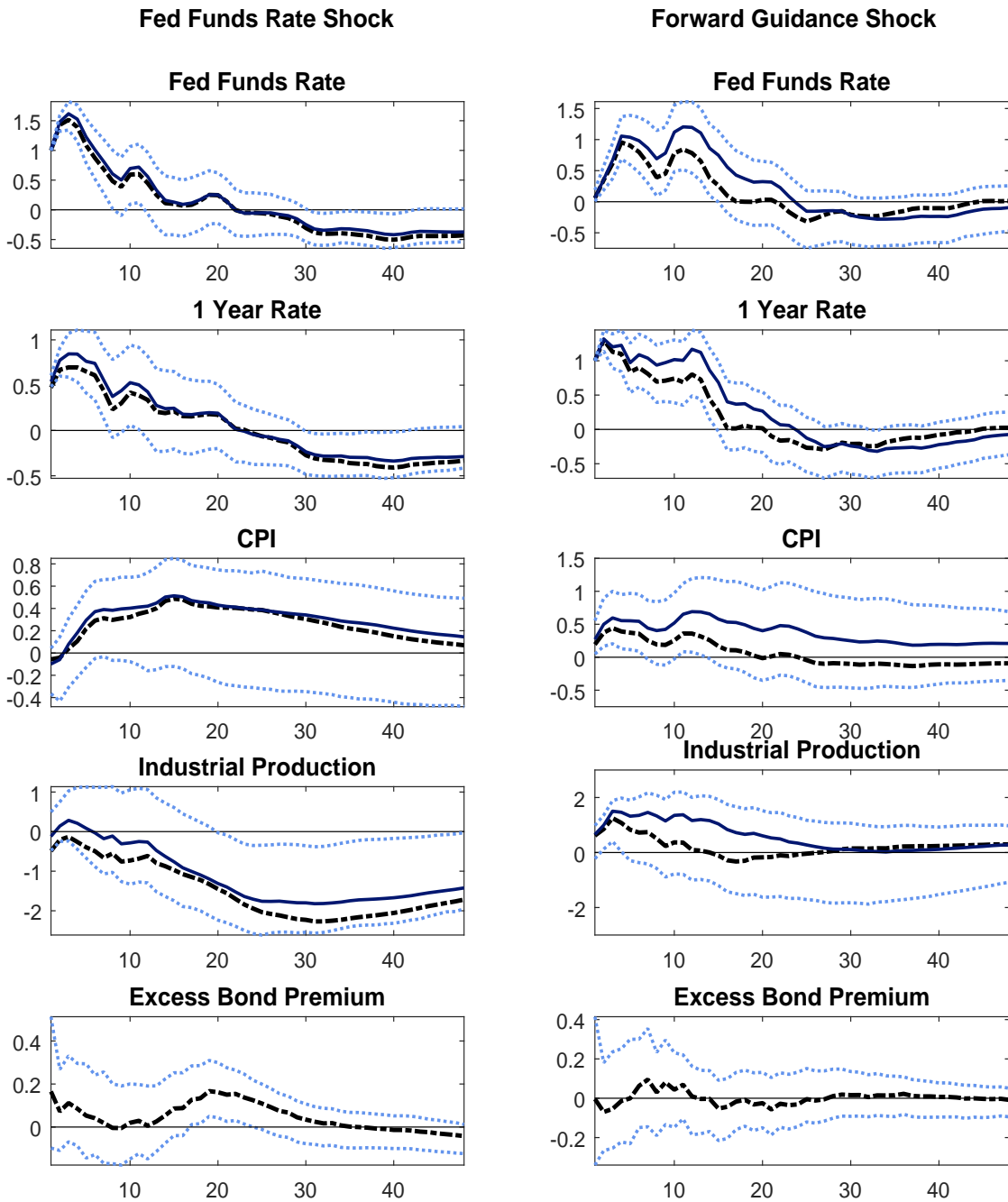


Figure 5: The impulse responses to a unit monetary policy shock with 90% confidence intervals. The dashed black lines lines show the impulse responses for the VAR with Excess Bond Premium added to the baseline specification. The solid blue show the responses from the baseline specification. Reduced form VAR sample: July 1979 to December 2011, futures market identification sample: January 1991 to December 2011.



## Only 1 policy tool

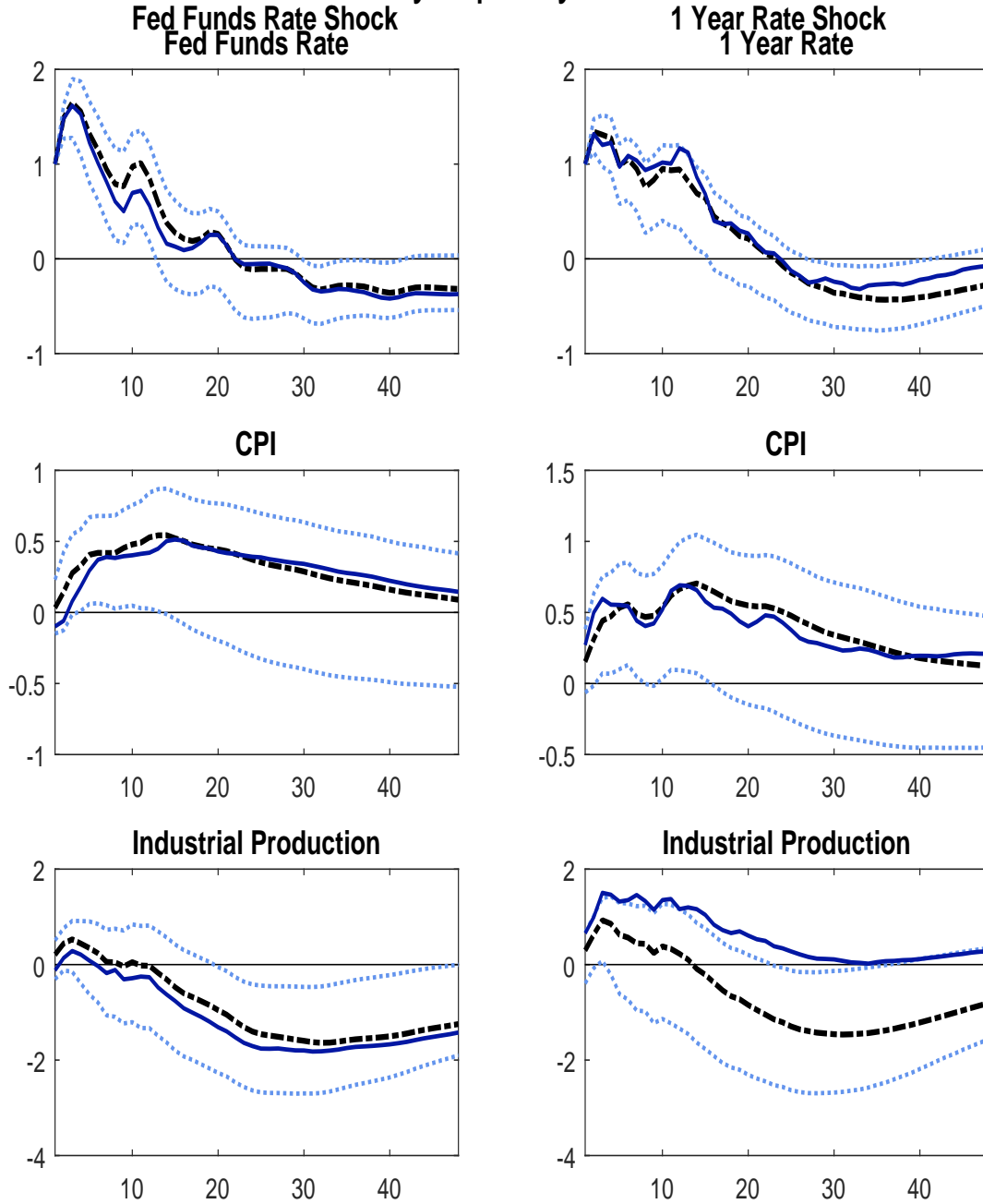


Figure 6: The impulse responses to a unit monetary policy shock with 90% confidence intervals. The dashed black lines show impulse responses from two VARs each with only one policy tool. The first column uses the fed funds rate as the monetary policy tool while the second column uses the 1 year rate as the policy tool. The solid blue line shows the responses from the baseline specification. Reduced form VAR sample: July 1979 to December 2011, futures market identification sample: January 1991 to December 2011.

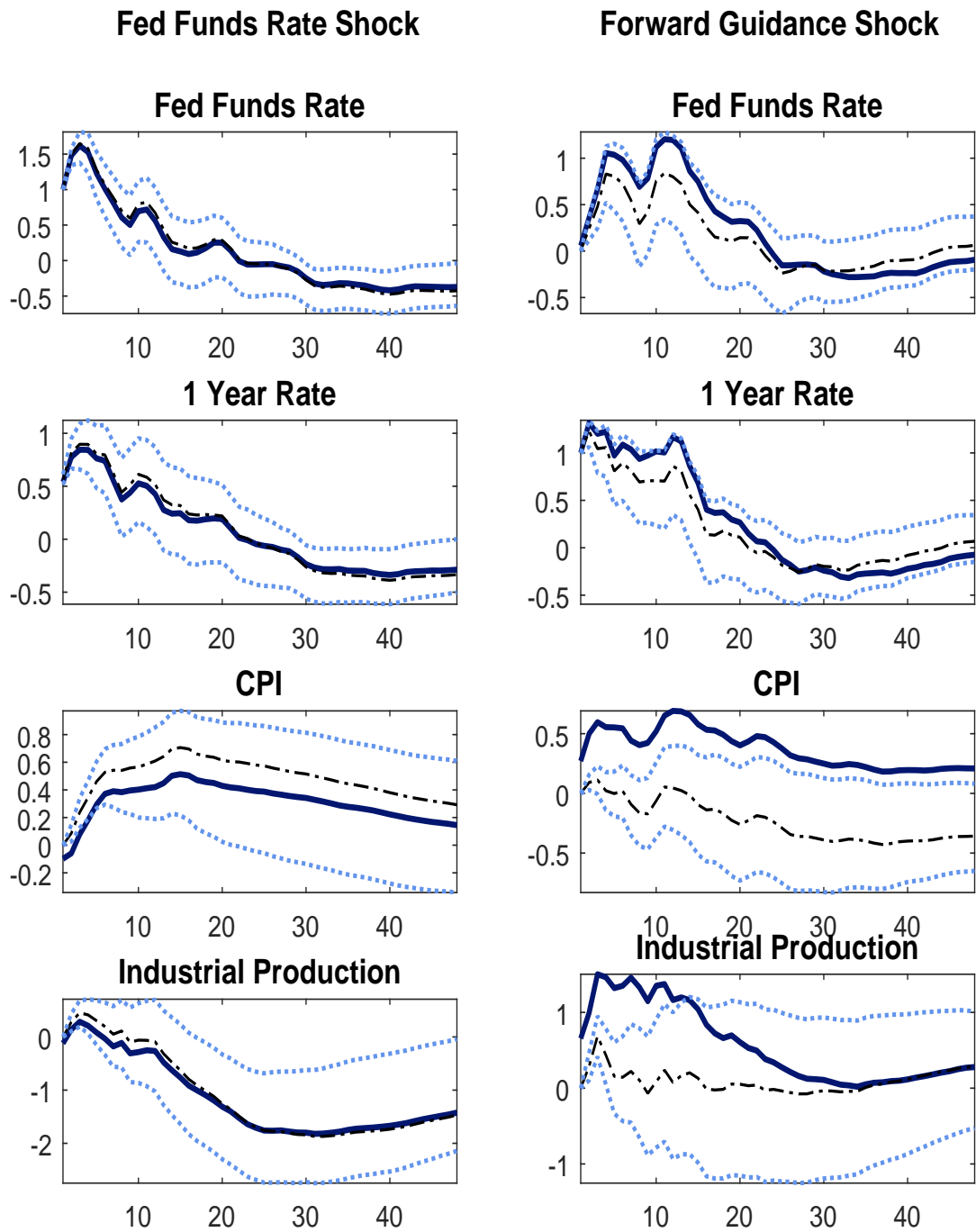


Figure 7: The impulse responses to a unit monetary policy shock with 90% confidence intervals. The dashed black lines show responses identified using the Cholesky restrictions. The solid blue lines show the responses from the baseline specification. Reduced form VAR sample: July 1979 to December 2011, futures market identification sample: January 1991 to December 2011.

| VARIABLES          | (a)                  | (b)                  | VARIABLES | (c)           | (d)         |
|--------------------|----------------------|----------------------|-----------|---------------|-------------|
|                    | Target Factor        | Path Factor          |           | Target Factor | Path Factor |
| GDPt1              | 0.006<br>(0.014)     | 0.004<br>(0.013)     | All       | 0.2812        | 0.0016      |
| GDPt2              | -0.006<br>(0.016)    | -0.002<br>(0.012)    | GDP       | 0.5847        | 0.0049      |
| GDPt3              | -0.020<br>(0.016)    | 0.009<br>(0.013)     | CPI       | 0.2733        | 0.055       |
| GDPt4              | 0.016<br>(0.018)     | 0.029*<br>(0.017)    | Current   | 0.9164        | 0.0194      |
| CPIt1              | 0.001<br>(0.009)     | 0.010<br>(0.008)     | Lagged    | 0.1226        | 0.0216      |
| CPIt2              | -0.012<br>(0.018)    | -0.060***<br>(0.019) |           |               |             |
| CPIt3              | 0.044<br>(0.037)     | 0.007<br>(0.035)     |           |               |             |
| CPIt4              | -0.035<br>(0.046)    | 0.070<br>(0.052)     |           |               |             |
| GDPt1lag           | 0.013<br>(0.013)     | 0.004<br>(0.010)     |           |               |             |
| GDPt2lag           | -0.018<br>(0.014)    | -0.004<br>(0.011)    |           |               |             |
| GDPt3lag           | 0.028*<br>(0.017)    | 0.024*<br>(0.013)    |           |               |             |
| GDPt4lag           | 0.006<br>(0.020)     | -0.047***<br>(0.018) |           |               |             |
| CPIt1lag           | 0.003<br>(0.006)     | -0.000<br>(0.007)    |           |               |             |
| CPIt2lag           | 0.025<br>(0.017)     | -0.018<br>(0.021)    |           |               |             |
| CPIt3lag           | -0.097***<br>(0.035) | 0.077**<br>(0.038)   |           |               |             |
| CPIt4lag           | 0.060<br>(0.042)     | -0.078<br>(0.055)    |           |               |             |
| Constant           | -0.002<br>(0.010)    | 0.009<br>(0.010)     |           |               |             |
| Observations       | 177                  | 177                  |           |               |             |
| R-squared          | 0.076                | 0.151                |           |               |             |
| Adjusted R-squared | -0.0169              | 0.0656               |           |               |             |

Table 3: Regression results of target and path factor on measure of Federal Reserve private information. Sample is January 1991 to December 2010. Columns (a) and (b) show the regression coefficients with robust standard errors in parentheses, \*\*\*  $p < 0.01$ , \*\* $p < 0.05$ , \* $p < 0.1$ , Columns (c) and (d) show the p-values from Wald tests. See the main text for more details.

### Forward Guidance Shock

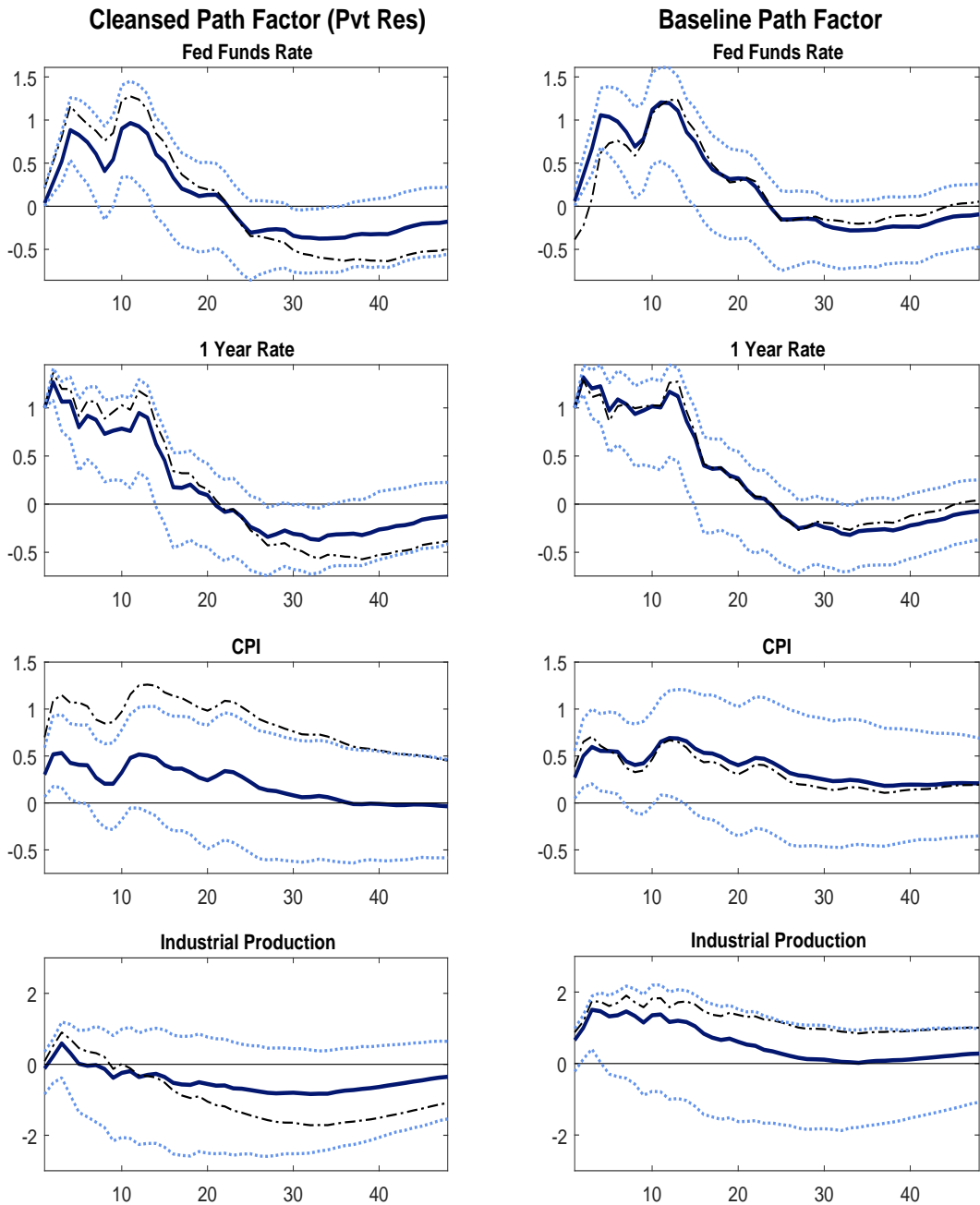


Figure 8: The impulse responses to a unit forward guidance shock with 90% confidence intervals. The first column shows the responses using the residual from the private information regressions discussed in section 5, see the main text for more details. The second column shows the responses from the baseline specification using the full path factor as an instrument. For both columns the solid blue line shows the responses using all FOMC meetings, while the dashed black line show responses where only those FOMC meetings that accompanied a statement are included in the instrument construction. Reduced form VAR sample: July 1979 to December 2011, futures market identification sample: January 1991 to December 2010.

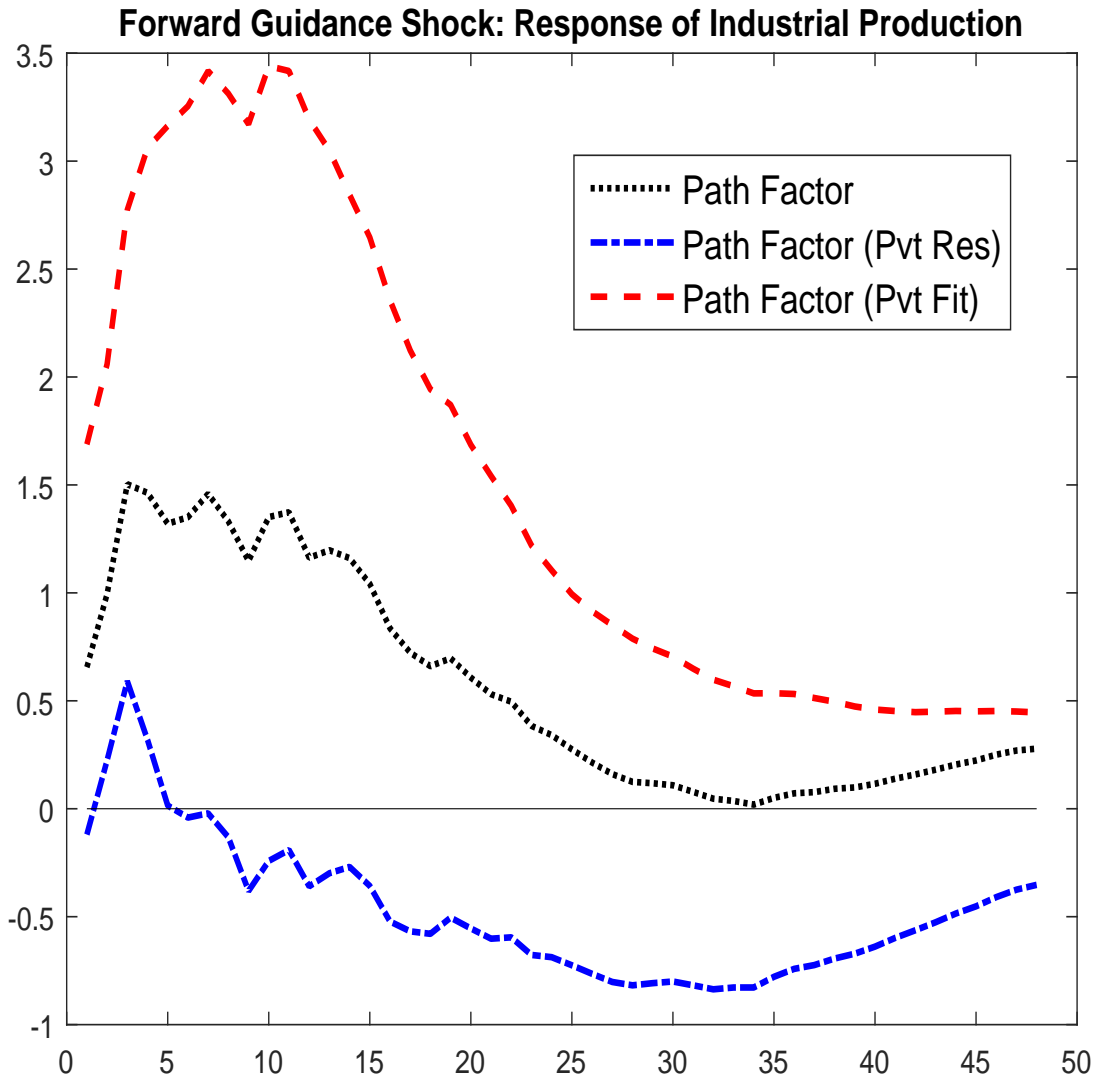


Figure 9: The impulse response of industrial production to a one unit forward guidance shock. The difference in the lines is the specific measure of the path factor used as an instrument. The dotted black line is the baseline specification using the unmodified path factor. The red and the blue line show the response using the fitted value and the residual respectively from the information regressions discussed in section 5, see the main text for more details. Reduced form VAR sample: July 1979 to December 2011, futures market identification sample: January 1991 to December 2010.

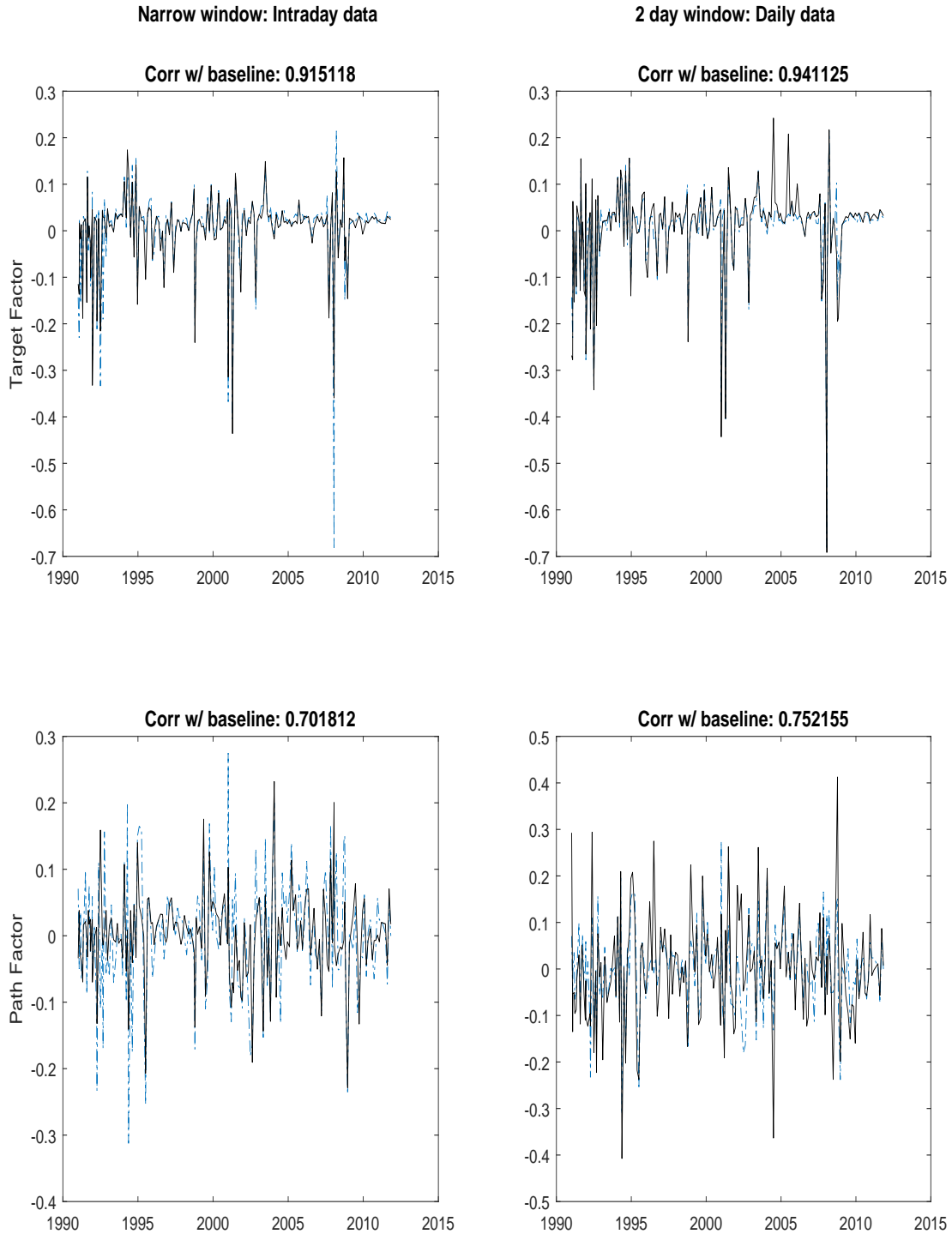


Figure 10: Target and path factors constructed from futures data. The dashed blue line in all the figures shows the baseline calculations using daily data. The solid lines in the left column show the factors constructed using a 30 minute window around FOMC announcements, while the right column uses the 2 day change.

### Response of Industrial Production

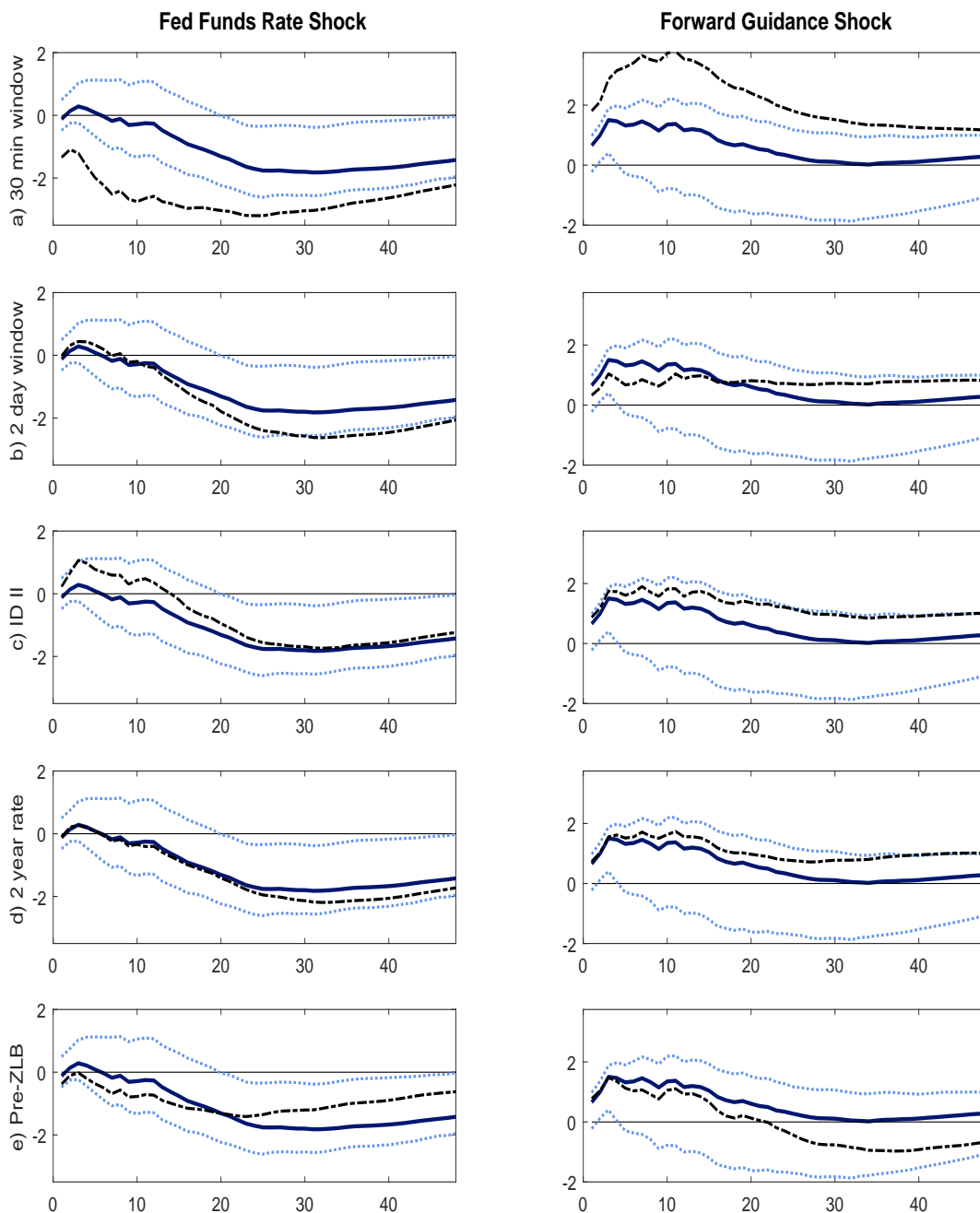


Figure 11: The impulse response of industrial production to a unit monetary policy shock with 90% confidence intervals. The solid blue line shows the baseline specification with the alternative specifications shown with the dashed black line. Reduced form VAR sample: July 1979 to December 2011, futures market identification sample: January 1991 to December 2011, except for panel e) where both samples end in December 2008.