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

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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.[1] While there is theoretical motivation for its use,[2] 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. Using the external instruments framework we can separately identify the two monetary policy shocks while still allowing both policy variables to respond to the current state of the economy.

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

[1] 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.

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

restriction for exact identification. We impose this restriction using the intuitive idea that a pure forward guidance shock should have no contemporaneous effect on the fed funds rate. Our baseline identification strategy involves a 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. We also consider an alternative identification strategy that instead puts a restriction on the relationship between the structural shocks and the instruments.

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 output to a contractionary federal funds rate shock has a delayed negative response and is consistent with both conventional macroeconomic theory (see for example Galí (2008)) and standard results from SVAR analyses of monetary policy (see for example Christiano, Eichenbaum, and Evans (1999)). However, the response 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 holds for a variety of robustness checks that include using narrower or broader windows to construct the instruments, excluding FOMC meetings that were not accompanied by an explicit statement, excluding unscheduled meetings, using different samples and expanding the information set of the VAR to include financial variables.

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 Blue Chip 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 no longer rises in response to a contractionary forward guidance shock.[3] 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.

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?[4] In addition to the work of Campbell, Evans, Fisher, and Justiniano (2012) and Campbell, Fisher, Justiniano, and Melosi (2016), there is a growing literature that emphasizes the role of information frictions in the monetary transmission mechanism. Miranda-Agrippino and Ricco (2018) and Jarocinski and Karadi (2018) use a SVAR framework while Nakamura and Steinsson (2018), Cieslak and Schrimpf (2019), Lunsford (2018) and Andrade and Ferroni (2018) use a high frequency analysis to shed light on the importance of this information channel. Finally, Melosi (2016) and Tang (2015) provide some structural evidence. Overall, we view our results as complementing this literature and highlighting the need for developing structural models where the information component of forward guidance is explicitly modeled.

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, and Khan (2015) use the maximum-forecast error variance framework to identify monetary shocks following the news shock literature. Finally, Hansen and McMahon (2016) and Lucca and Trebbi (2009)

[3]Output actually falls but the fall is not statistically significant.

[4]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.

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.

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 x 1 vector of macroeconomic variables and α_i and A are n x n parameter matrices

$$Ay_t = \alpha_1 y_{t-1} + \ldots + \alpha_p y_{t-p} + \varepsilon_t \tag{2.1}$$

The components of the error terms ε_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

$$y_t = \delta_1 y_{t-1} + \ldots + \delta_p y_{t-p} + u_t \tag{2.2}$$

where

$$u_t = B\varepsilon_t \tag{2.3}$$

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).[5]

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 structural policy shocks as ε_t^p and the structural non-policy shocks as ε_t^q. The reduced-form residuals from the corresponding policy and non-policy equations are denoted u_t^p and u_t^q respectively. For a given set of instruments Z_t, these two conditions can be formally stated as

$$E[Z_t \varepsilon_t^{p'}] = \phi \tag{2.4}$$

$$E[Z_t \varepsilon_t^{q'}] = 0 \tag{2.5}$$

where ϕ is assumed to be invertible. The impact matrix B can be partitioned in the following way

$$B = \begin{bmatrix} B_1 & B_2 \end{bmatrix}, B_1 = \begin{bmatrix} B_{11}' & B_{21}' \end{bmatrix}', B_2 = \begin{bmatrix} B_{12}' & B_{22}' \end{bmatrix}' \tag{2.6}$$

where B_{11} and B_{22} are also assumed to be invertible. This means that (for example for B_{11}) linear combinations of the policy shocks will have different and non-zero effects on the different policy variables. These different effects are necessary for separate identification of the policy shocks. The restrictions 2.3, 2.4 and 2.5 can then be represented as

$$B_{21} = \left(E[Z_t u_t^{p'}]^{-1} E[Z_t u_t^{q'}]\right)' B_{11} \tag{2.7}$$

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 2.7 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 ε_t^p in equation 2.4 is a scalar), then the econometric framework identifies the impact coefficients up to a sign convention.

[5]The idea of using exogenous shocks as instruments goes back to Hamilton (2003). For a recent alternative way to identify monetary policy shocks, see Arias, Caldara, and Rubio-Ramirez (2019).

However, if there is more than one policy shock of interest, additional restrictions are required for exact identification. In this paper, we have two policy tools and two instruments. Next, we discuss how these additional restrictions can be obtained.

2.1 Identification with Two Policy Shocks and Two Instruments

The baseline strategy imposes restriction on the relationship between the reduced-form residuals in the policy equation and the structural policy shocks. We also use an alternative strategy that 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. Here we layout the baseline identification strategy and briefly mention the alternative strategy while relegating the detailed derivation of both strategies to the online appendix.

To clearly see the identification issue, the relationship between the reduced form VAR residuals and the structural shocks $u_t = B\varepsilon_t$ can be re-written as

$$u_t^p = \eta u_t^q + S_1 \varepsilon_t^p \tag{2.8}$$

$$u_t^q = \zeta u_t^p + S_2 \varepsilon_t^q \tag{2.9}$$

where $\eta = B_{12}B_{22}^{-1}$, $\zeta = B_{21}B_{11}^{-1}$, $S_1 = \left(B_{11} - B_{12}B_{22}^{-1}B_{21}\right)$ and $S_2 = \left(B_{22} - B_{21}B_{11}^{-1}B_{12}\right)$ are parameters that govern the impact matrix B. Since these equations are derived from $u_t = B\varepsilon_t$, it is the case that the pairs u_t^q, ε_t^p and u_t^p, ε_t^q are correlated. This motivates the use of instrumental variable estimation rather than just OLS. The baseline strategy follows the approach taken in Mertens and Ravn (2013). We reproduce the key estimating equations from their approach below.

$$B_{11}S_1^{-1} = \left(I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1}\right)^{-1} \tag{2.10}$$

$$B_{21}S_1^{-1} = B_{21}B_{11}^{-1}\left(I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1}\right)^{-1} \tag{2.11}$$

$$S_1S_1' = \left(I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1}\right) B_{11}B_{11}' \left(I - B_{12}B_{22}^{-1}B_{21}B_{11}^{-1}\right)' \tag{2.12}$$

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 $B_{21}B_{11}^{-1}$. For the scalar case, this is enough to identify $S_1S_1' = S_1^2$ from equation 2.12 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 $S_1 S_1'$.

Our approach involves putting restrictions on this S_1 matrix. Specifically, 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, recall from equation 2.8 that u_t^p represent the reduced-form residuals from the two policy equations while ε_t^p represent the two monetary policy shocks. Thus a zero restriction on the row i column j element in S_1 implies no direct effect of the j^{th} policy shock in ε_t^p on the i^{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 2.8 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 the structural shock that is captured through u_t^q.

There is an alternative identification strategy available based on a different approach taken to derive the estimating equations (see Lunsford (2015)). Re-write the relevance condition as

$$\begin{aligned} E[Z_t \varepsilon_t^{p'}] &= \phi \\ E\begin{pmatrix} Z_t^1 \varepsilon_t^{ff} & Z_t^1 \varepsilon_t^{fwd} \\ Z_t^2 \varepsilon_t^{ff} & Z_t^2 \varepsilon_t^{fwd} \end{pmatrix} &= \begin{pmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{pmatrix} \end{aligned}$$

This identification strategy imposes zero restrictions on ϕ, the relationship between the structural policy shocks and the instruments. In the online appendix we show how this restriction allows the identification of the relevant column of the impact matrix. Specifically, we impose that $\phi_{21} = 0$, which implies that $E[Z_t^2 \varepsilon_t^{ff}] = 0$. This assumption is justified by finding an instrument that is uncorrelated with the fed funds rate shock but correlated with the forward guidance shock. In the online appendix we also show that the methodology of GSS which involves performing a rotation of futures market data satisfies this requirement. In section 6 we show that the impulse responses from this alternative strategy are very similar to the baseline results.

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 or 2 year Treasury yield. We use 12 lags in the estimation.

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 SVAR 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 to 2 year bond rates were effectively restrained by the zero lower bound constraint starting in late 2011.

3.2 Instrument Construction 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 x 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. We can then perform a principal components analysis of the futures price changes, denoted by $X = F\Lambda + \widetilde{\eta}$, where F is a T x k matrix of principal components, Λ is a k x 1 vector of factor loadings and $\widetilde{\eta}$ is an error term. 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-which includes both the scheduled and unscheduled meetings-starting with January 1991, except the two observations as recommended by 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.

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 2011, we find that the first two principal components can explain more than 95% of the variation in the futures contracts (table shown in online appendix). This 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 the baseline identification strategy, we can directly use the two factors F_1 and F_2 or the rotated factors Z_1 and Z_2 (discussed below) 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).[6] 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 the alternative identification strategy, 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

[6] In Mertens and Ravn (2013)'s terminology, a forward guidance shock leaves the fed funds rate unchanged in "cyclically adjusted" terms.

policy (i.e. changes in long-term rates due to forward guidance). But the alternative identification strategy 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. GSS outline a way to perform this rotation that naturally fits the required restriction needed for the alternative identification strategy. 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 ensures 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 futures contract price. The details of the rotation computation are provided in the online appendix. Figure 1 plots the target and path factors for the baseline sample.

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.[7] 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.

4 Results

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 1, with robust standard errors reported in parentheses. The table shows the regression of the reduced-from residual from the policy equations on the target and path factors.[8] The first two columns represent results from using the fed funds rate and 1 year rate as policy

[7]See Gazzani and Vicondoa (2016) for a detailed discussion.

[8]For the baseline identification strategy, 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

tools, while the second two columns use the fed funds rate and the 2 year rate as policy tools in the reduced-from 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. An 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 1) 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.[9] 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. Figure 2 shows the impulse responses to the two monetary policy shocks from the baseline SVAR, together with 68% confidence intervals. The confidence intervals are computed following the bootstrap methodology of Jentsch and Lunsford (2016).[10] Similar to GK, our reduced form VAR begins in 1979 while the instrument sample begins in 1991. In the online appendix we outline how we account for this in the bootstrap algorithm by doing two separate resamplings.

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 does not move much on impact but has a delayed negative 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

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 the alternative identification strategy, we need to use the rotated factors and thus these are the ones reported in the first stage.

[9] 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.

[10] Using the parametric bootstrap or the Delta method of Montiel Olea, Stock, and Watson (2018) gives similar results.

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.[11] 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 forward guidance literature cited above.

One concern with the SVAR framework is whether it satisfies the invertibility assumption, as highlighted by Stock and Watson (2018). This issue is sometimes thought to be more pressing for the forward guidance shock that embodies news about future policy actions and which may not be part of the SVAR's information set.[12] However, the forward guidance shock in our framework is better thought of as a contemporaneous shock to the long (1 year here) rate and where the path factor used for identification is constructed from information about how markets react to the FOMC announcement on the same day. In other words, the setup is one where the forward guidance "news" (as measured by futures changes around FOMC meetings) is completely captured by contemporaneous movements in

[11] 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.

[12] This issue is raised in the recent work of Plagborg-Møller and Wolf (2018). In the online appendix we discuss that there is a key difference in their specification relative to the framework here.

the long-rate (which is a variable that is included in the VAR). To confirm this intuition, we perform a Granger causality test for invertibility as suggested by Stock and Watson (2018), also see Giannone and Reichlin (2006), Forni and Gambetti (2014) and Plagborg-Møller and Wolf (2018). Specifically to focus on the forward guidance shock, we apply the Granger causality test for the forward guidance shock with the path factor as the instrument.[13]

Table 2 shows the p-values for the test that the path factor does not Granger cause the endogenous variables in the VAR. Each row shows the results for using a different number of lags of the instrument, from 2 to 8. As we can see there is no clear evidence that invertibility is rejected. SW also similarly find that invertibility cannot be rejected for the Gertler and Karadi (2015) VAR. Another option to deal with potential invertibility concerns is to add more information to the VAR. In Section 6 we show that adding financial information as captured by the excess bond premium does not qualitatively change the main result.

4.1 Comparison of Policy Tools To better understand our results, we compare them with monetary SVARs that allow for only one monetary policy tool. First we follow the common approach in the literature which just uses 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. Since the only policy tool is the fed funds rate, the instrument is constructed using just the current month's fed funds futures contract. This is the measure of monetary policy surprises first constructed in Kuttner (2001) and also used by GSS. Second, we consider a SVAR to evaluate 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.[14] We follow their approach and use the 3 month ahead fed funds futures contract as an instrument for the shocks to the 1 year rate.

The impulse responses from both these approaches are presented in dashed red lines in Figure 3. The first column shows the response to a unit fed funds rate shock, while the second column shows the responses to a unit shock to the 1 year rate. For both these specifications with one policy tool, output

[13]Note that since the path factor has been rotated appropriately, it satisfies the exogeneity and relevance condition required for identification of the forward guidance shock.

[14]To make the model as comparable as possible to the baseline case, we leave out the excess bond premium from the GK specification.

rises slightly on impact, but then falls and is significantly lower at the three year mark. The solid blue lines in Figure 3 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 attenuates the "puzzling" response we found earlier. More specifically, contrary to the baseline forward guidance shock, in this case output rises less on impact and is statistically significantly lower at the 3 year mark. This further highlights the importance of separating the effect of a fed funds rate shock from a forward guidance shock to avoid mischaracterizing the overall effects of monetary policy.

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.[15]

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 Blue Chip 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 $t4$. 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

[15] 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. Thus these regressions suggest that Fed private information is primarily related to future policy actions as captured through the path factor. 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.

We now use the target factor and the cleansed path factor (labeled "Path Factor (Pvt Res)") as instruments in the estimation of the SVAR. The first column of Figure 4 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. The interesting 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, showing an almost 1% fall. While this effect is not statistically significant it does show that once we control for the private information, we no longer find a significant but positive response of output to an increase in the 1 year rate. To summarize, the overall effect of a "contractionary" forward guidance shock is to increase output while the first column of Figure 4 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.

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 5. 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. 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 5 as only suggestive and recommend interpreting them with a high degree of caution.

6 Robustness Checks

In this section we present a variety of robustness checks. Due to space constraints, we present results that show only the response of output to a forward guidance shock (that raises the 1 year rate), with the full set of impulse responses relegated to the online appendix. These impulse responses are shown with dashed red lines in Figure 6 together with the baseline result shown with blue lines.

We start by confirming that the effect of forward guidance captured in the SVAR is indeed coming from Federal Reserve communication. The FOMC first released a written statement in 1994, while our instrument sample starts in 1991. Panel labeled "h) post-94" shows that excluding the 1991-1993 from our instrument sample does not affect the results. Moreover, even after 1994 the FOMC decision was only sporadically accompanied by a statement until 1999 after which it became a regular feature.[16] 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. These results shown in the panel labeled "f) Stat only" confirm that the results are not affected by leaving these meetings.

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

[16] In the online appendix we provide a list of FOMC meetings indicating which ones had an accompanying statement release.

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. The impulse responses from both approaches (first panel labeled "a) 30 min window" and second panel labeled 'b) 2 day window") confirm 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. Moreover, GSS point out that there are a few FOMC meetings in the 1990s that overlap with the release of the employment report that could create issues for daily futures measures. The panel labeled "i)No emp" shows that the results are similar to the baseline case when we drop the FOMC meetings that overlap with employment reports.

Yet another concern is that the small SVAR 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 SVAR. This has been advocated in recent papers by GK and Caldara and Herbst (2019). We re-estimate the SVAR adding the excess bond premium as a fifth variable. The panel labeled "g)EBP" shows that 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.

In the results presented so far we used the baseline identification strategy. In the third row (labeled "c) ID II") we show the responses from using the alternative identification strategy. The response of output on impact is similar to the baseline identification strategy but remains a little higher in the medium run for this alternative strategy. 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 panel labeled "d)2 year rate". It is clear that the response of output is extremely similar as compared to the 1 year rate case. We also 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) and Wright (2012)). 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 panel (labeled "e) Pre-ZLB"). Again we notice that the response of output is very similar to the baseline case. Finally, the panel labeled "j)No unsched" shows that the results are unchanged when we drop unscheduled meetings from our instrument sample.

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 4 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 growing evidence in the literature (cited in the introduction) that suggests this can have important effects on agents' expectations and the economy. 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. 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 effect of a 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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	(a)		(b)	
VARIABLES	FFR residual	1 year residual	FFR residual	2 year residual
Target Factor	0.796***	0.902***		
	(0.132)	(0.168)		
Path Factor	-0.134	0.347		
	(0.177)	(0.233)		
Target Factor			0.878***	0.756***
			(0.136)	(0.203)
Path Factor			-0.164	0.695*
			(0.276)	(0.365)
Constant	-0.006	-0.000	-0.006	0.003
	(0.010)	(0.012)	(0.010)	(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
Sanderson-Windmeijer p-values	0.033	0.025	0.008	0.023

Table 1: 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, *** $p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Lags	1 Year Rate	ln(IP)	ln(CPI)	FFR
2	0.59	0.55	0.09	0.09
4	0.55	0.64	0.01	0.35
6	0.73	0.58	0.06	0.54
8	0.74	0.67	0.01	0.06

Table 2: P-values for F-statistic testing the null that the coefficients on the lags of the instrument (path factor) are jointly equal to zero in each of the equations of the SVAR. This is a test of invertibility for forward guidance shock following the methodology in Stock and Watson (2018).

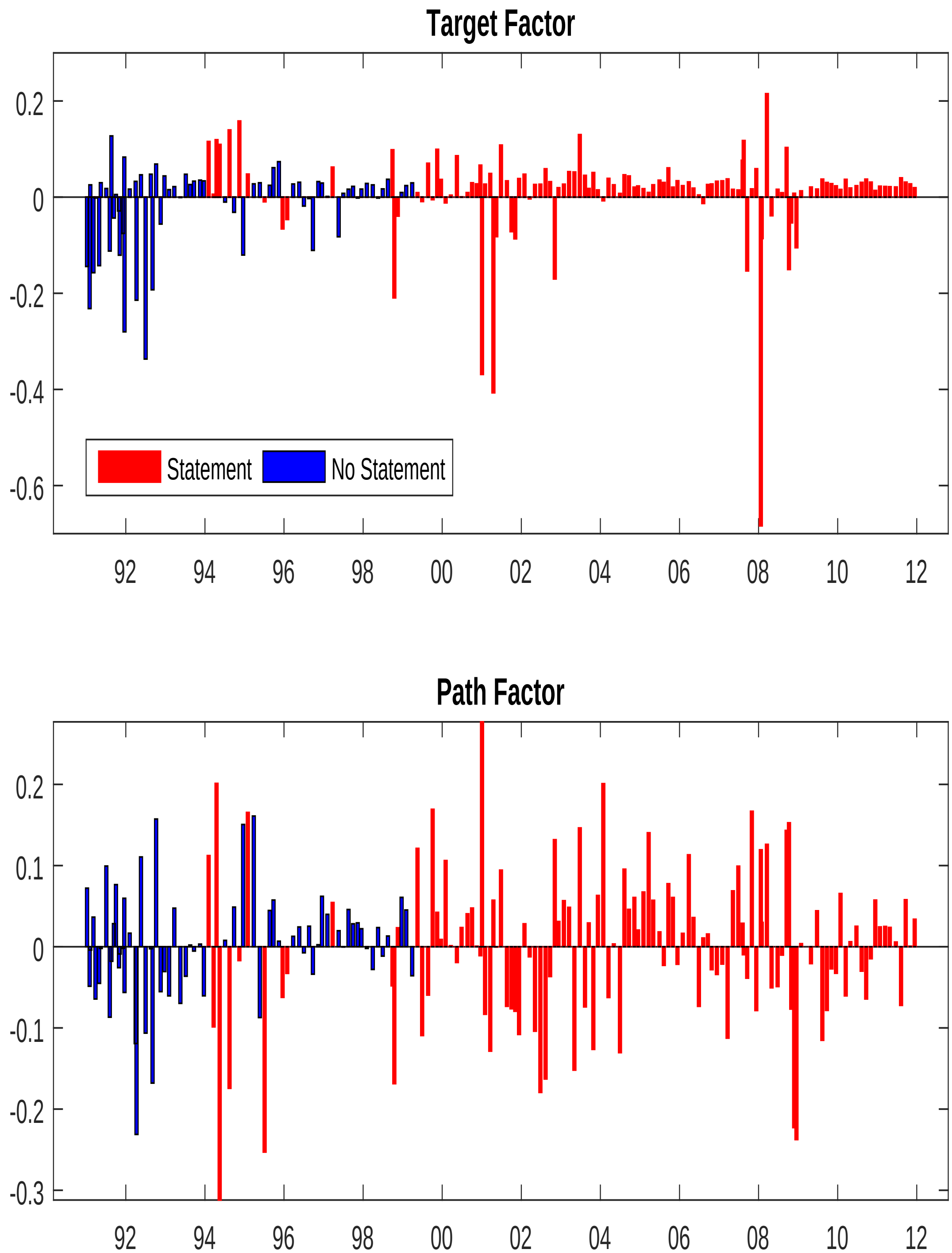

Figure 1: Target and path factors constructed from futures data.

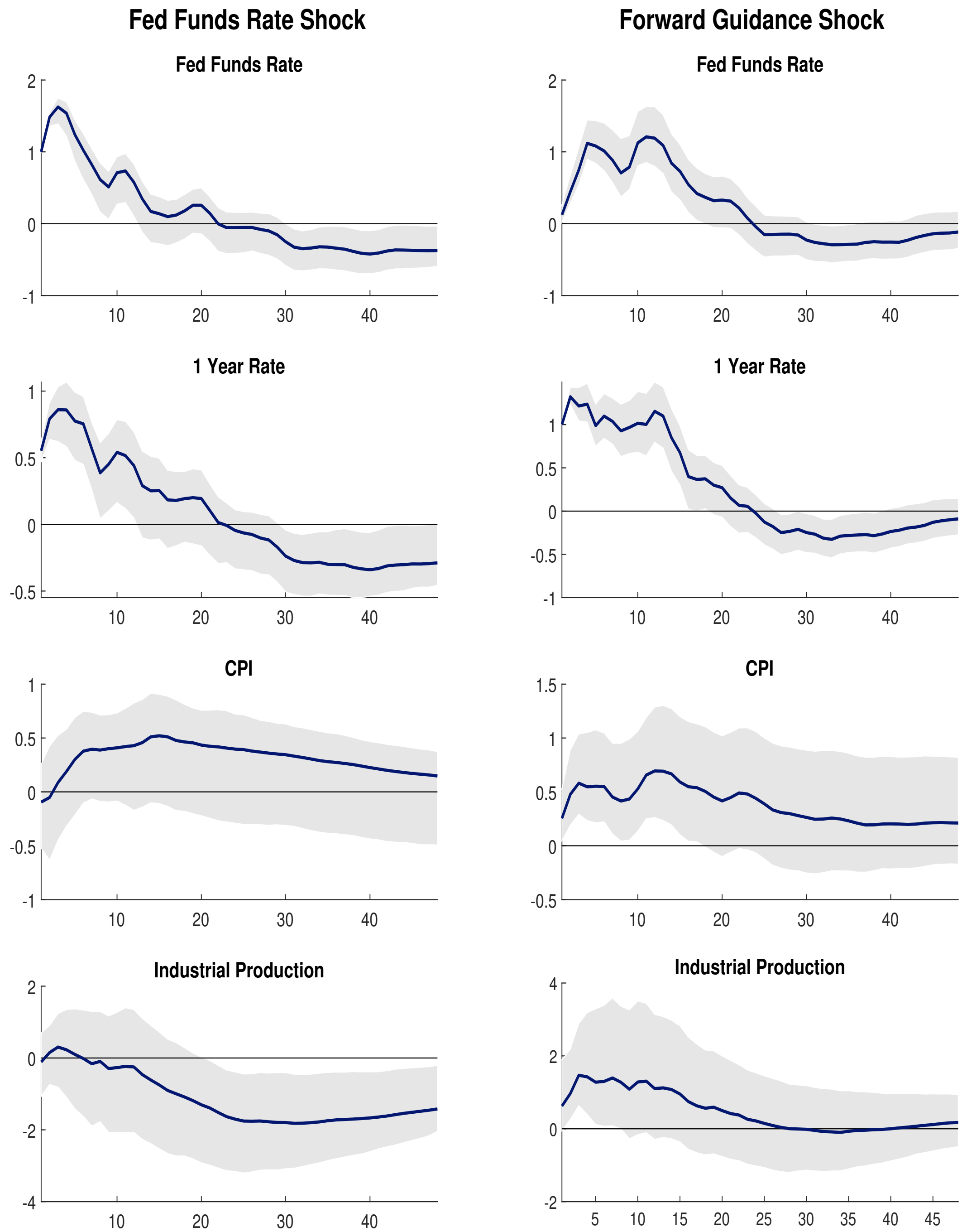

Figure 2: The impulse responses to a unit monetary policy shock identified using the external instruments identification strategy outlined in the text, with 68% confidence intervals. The first column shows the response to a conventional monetary policy shock (i.e shock to the federal funds rate equation), 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

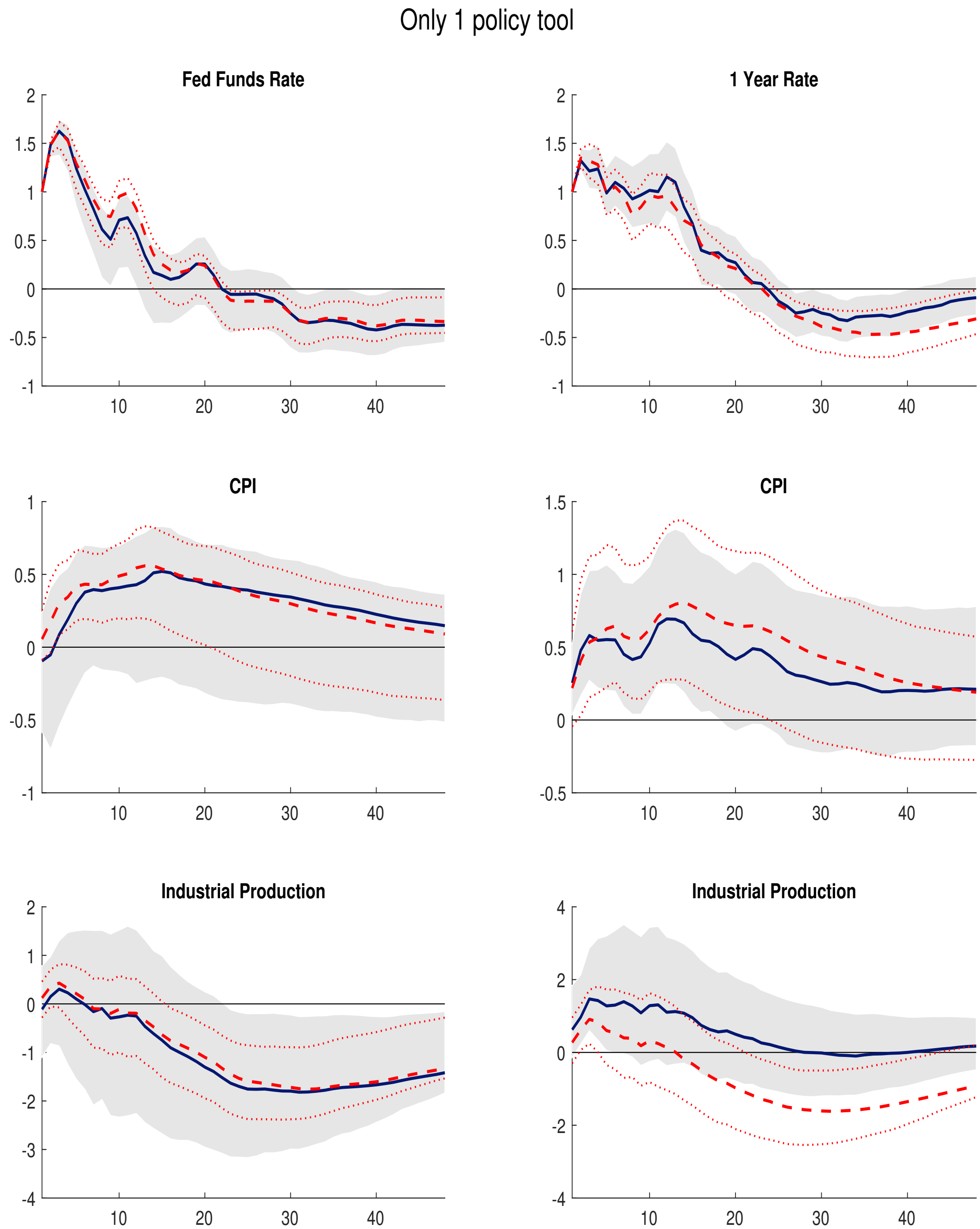

Figure 3: The impulse responses to a unit monetary policy shock with 68% bootstrapped confidence intervals. The dashed red lines show impulse responses from two VARs each with only one policy tool. The first column uses the fed funds rate as the monetary policy tool while the second column uses the 1 year rate as the policy tool, see section 4.1 for details. The solid blue line and the shaded grey area 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.

	(1) Target Factor	(2) Path Factor		(c) Target Factor	(d) Path Factor
GDPt1	0.006	0.005	All	0.289	0.001
	(0.013)	(0.012)	GDP	0.698	0.063
GDPt2	0.012	0.003	CPI	0.205	0.007
	(0.012)	(0.009)	Current	0.596	0.005
GDPt3	-0.005	-0.003	Lagged	0.332	0.032
	(0.016)	(0.012)			
GDPt4	-0.019	-0.003			
	(0.014)	(0.011)			
CPIt1	-0.019	0.008			
	(0.015)	(0.013)			
CPIt2	0.027	0.025**			
	(0.017)	(0.012)			
CPIt3	0.016	0.029*			
	(0.018)	(0.017)			
CPIt4	0.005	-0.047***			
	(0.019)	(0.017)			
GDPt1lag	0.002	0.009			
	(0.008)	(0.007)			
GDPt2lag	0.003	0.000			
	(0.006)	(0.006)			
GDPt3lag	-0.012	-0.060***			
	(0.017)	(0.018)			
GDPt4lag	0.021	-0.016			
	(0.016)	(0.019)			
CPIt1lag	0.042	0.006			
	(0.037)	(0.034)			
CPIt2lag	-0.091***	0.076**			
	(0.034)	(0.036)			
CPIt3lag	-0.035	0.072			
	(0.043)	(0.049)			
CPIt4lag	0.060	-0.081			
	(0.041)	(0.053)			
Constant	-0.003	0.008			
	(0.010)	(0.010)			
Observations	184	184			
R-squared	0.075	0.153			
Adjusted R-squared	-0.0140	0.0722			

Table 3: Regression results of target and path factor on measure of Federal Reserve private information. Sample is January 1991 to December 2011. 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.

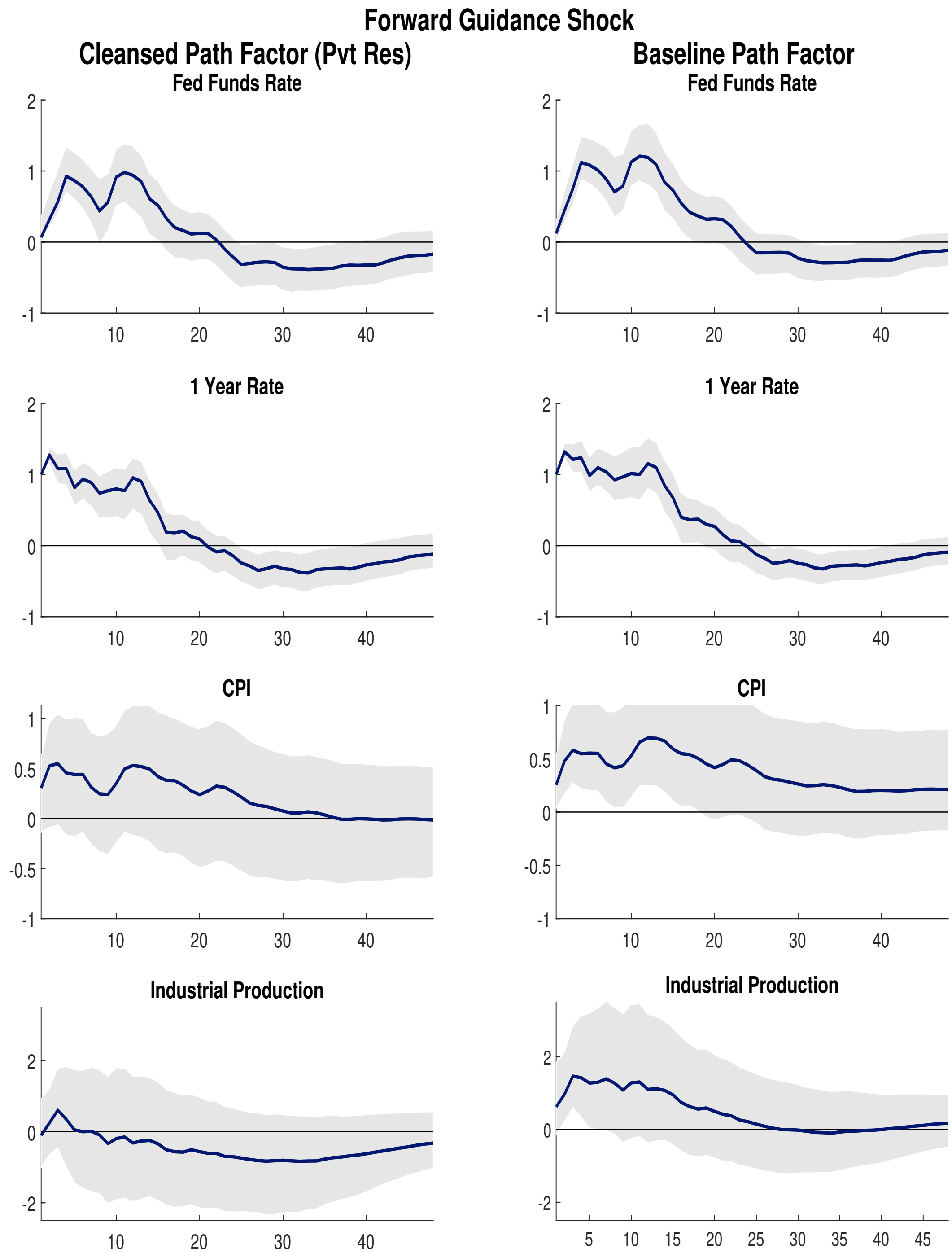

Figure 4: The impulse responses to a unit forward guidance shock with 68% confidence intervals. The first column shows the responses using the residual from the private information regressions discussed in section 5, see the main text for more details. The second column shows the responses from the baseline specification using the full path factor as an instrument. Reduced form VAR sample: July 1979 to December 2011, futures market identification sample: January 1991 to December 2011.

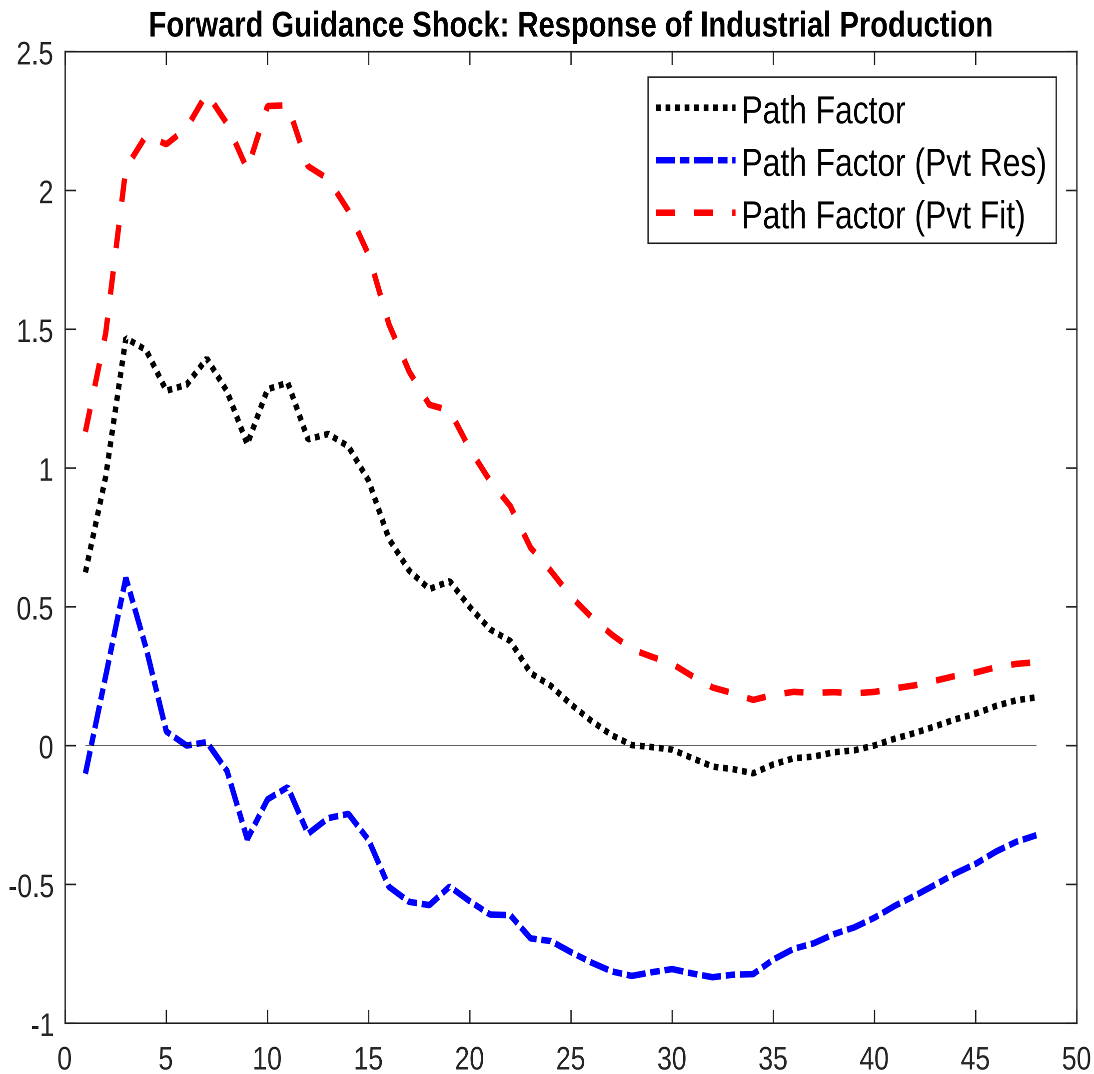

Figure 5: The impulse response of industrial production to a one unit forward guidance shock. The difference in the lines is the specific measure of the path factor used as an instrument. The dotted black line is the baseline specification using the unmodified path factor. The red and the blue line show 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 2011.

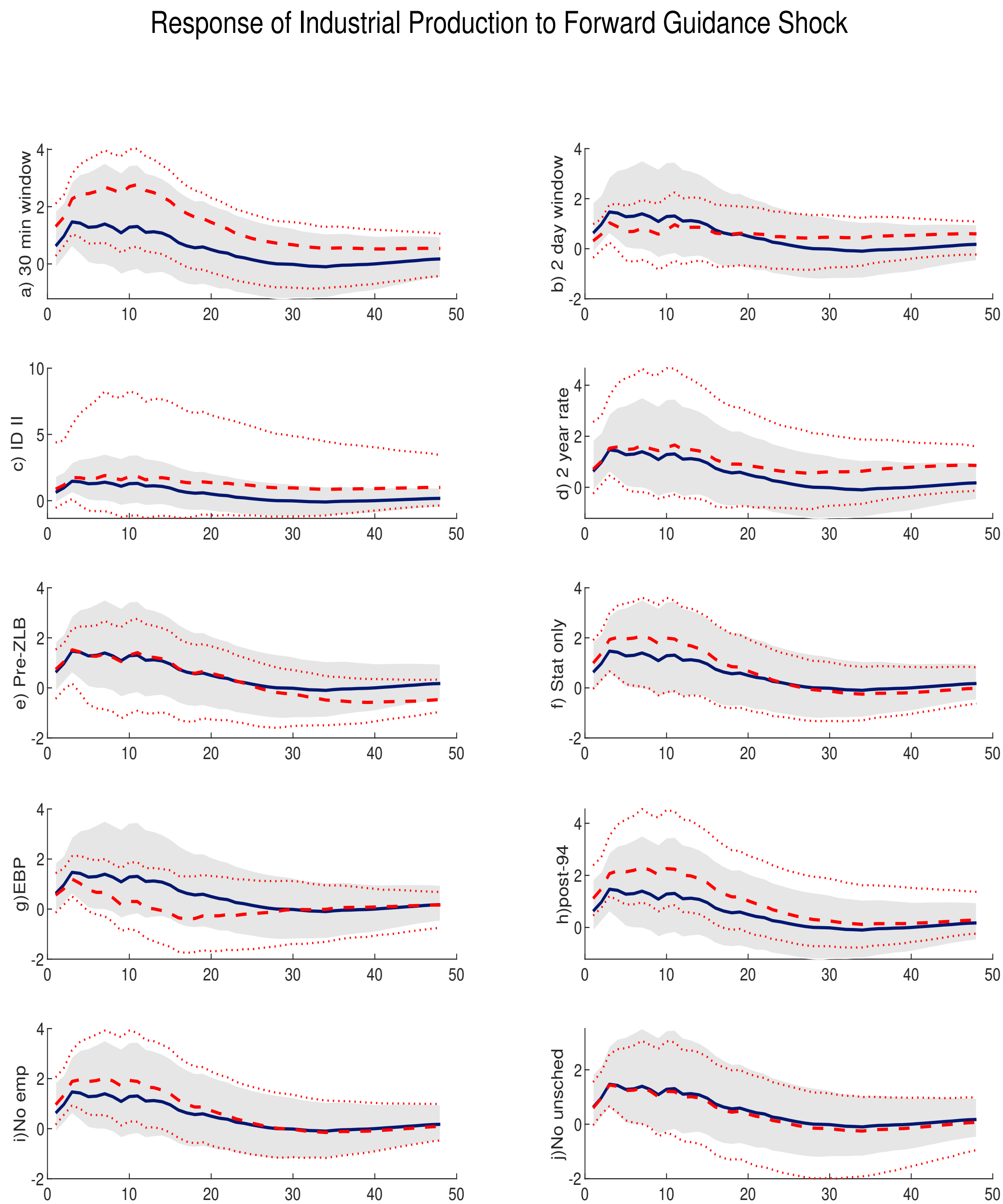

Figure 6: The impulse response of industrial production to a unit forward guidance shock with 68% bootstrapped confidence intervals. The dashed red line shows the various different specifications with confidence intervals marked with dotted red lines. The solid blue line and grey area show the baseline results. 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 and panel h) where the futures sample starts in 1994.