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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.[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. 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

[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).

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.[3]

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. It is important to note that this framework does not explicitly separate out announcements about large scale asset purchases (i.e. quantitative easing) as is done for example in Swanson (2016).

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)).[4] 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 unscheduled FOMC meetings from the sample, use narrower or broader windows to construct the instruments, and when we expand the information set of the VAR to include financial variables.[5]

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.

[3] Reassuringly, we find that the results are similar for both identification strategies.

[4] 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.

[5] 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.

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?[6] 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 (2015) 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.

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 in 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

[6] 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.

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. Sections 4 presents the results from the baseline specification with extended results presented in section 5. In 6 we investigate the role of Federal Reserve private information and a concluding discussion is provided in section 7.

2 Econometric Methodology and Identification

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).[7]

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 ε_t^p and the non-policy shocks as ε_t^q. For a given set of instruments Z_t, these two conditions can be formally stated as

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

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

The restrictions 2.3, 2.4 and 2.5 can be represented as

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

where the impact matrix B is given by

$$B = \begin{bmatrix} B_1 & B_2 \end{bmatrix}, B_1 = \begin{bmatrix} B_{11}' & B_{21}' \end{bmatrix}', B_2 = \begin{bmatrix} B_{12}' & B_{22}' \end{bmatrix}' \tag{2.7}$$

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 2.6 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 ε_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

[7] The idea of using exogenous shocks as instruments goes back to Hamilton (2003).

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.

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

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

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

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 $B_{21}B_{11}^{-1}$.[8] 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'.

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_1S_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.

$$u_t^p = \eta u_t^q + S_1\varepsilon_t^p \tag{2.11}$$

with

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

Recall that ε_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^{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

[8] For details see the appendix section 8.1.

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 $E(u_t u_t') = BB'$. From these equations we can show that[9]

$$E(Z_t u_t') = \phi B_1' \tag{2.13}$$

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

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

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

Again, if there is only one shock then ϕ 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 ϕ has k^2 unique elements, while $E(Z_t u_t') \left[E(u_t u_t')\right]^{-1} E(u_t Z_t')$ is a symmetric matrix with only $\frac{k(k+1)}{2}$ unique elements. The second strategy involves putting zero restrictions on ϕ. We assume that ϕ is triangular and thus a Cholesky factorization of $\phi\phi'$ gives ϕ. The interpretation of a zero restriction on ϕ is straightforward from the relevance condition of the instruments. A zero restriction on the row i column j element in ϕ implies that

[9] The details are provided in the appendix section 8.1

the j^{th} structural policy shock in ε_t^p is uncorrelated with the i^{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

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

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.

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 5, 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. In the online appendix we asses the robustness of the results to using alternative samples.

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 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. 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

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

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. 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, including labeling the scheduled and unscheduled meetings. 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.[10]

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.[11] 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).[12] 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

[10]Furthermore, in the online appendix we show that the results are similar when we exclude the 1991-1993 FOMC meetings.

[11]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.

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

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 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. 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-from 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 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-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.[13] The 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 5, we show that the results are similar using the 2 year rate.

Figure 1 shows the impulse responses from the baseline SVAR using the external instruments identification strategy I, together with 90% confidence intervals. The confidence intervals are computed using the recursive wild bootstrap following Gonçalves and Kilian (2004).[14] The first column of figure

[13]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. We are not aware of any work that calculates the critical values for more than one policy shock.

[14]Recent work by Montiel-Olea, Stock, and Watson (2016) and Lunsford and Jentsch (2016) propose alternative ways

1 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.[15] Thus in this paper we will mostly restrict our attention to focusing on the response of output.

Next we turn our attention to the second column of figure 1 which 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. Note that identification strategy I (or II for that matter) does not restrict the contemporaneous response of the fed funds rate to be zero in response to a forward guidance shock.[16] 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. In figure 2 we show the impulse responses from using identification strategy II. The overall effects are strikingly similar to identification strategy I with two minor differences. First, the 1 year rate rises more on impact in response to a fed funds rate shock under strategy II. Second, in response to a forward guidance shock, output rises on impact and stays a little higher in the medium run relative to strategy I. Overall, for both identification strategies we conclude that output falls in a hump shaped manner after a

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.

[15]Additionally, in a recent paper using external instruments that focuses on credit spreads, Caldara and Herbst (2016) exclude prices from their baseline VAR specification.

[16]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.

fed funds rate shock but rises persistently after a forward guidance shock. Thus a contractionary forward guidance shock appears to have an expansionary effect on the economy. 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 figures 1 and 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 might be concerned 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.[17] Table 3 shows the first stage results from this specification. Overall, the magnitude and the sign of the coefficients are similar to the baseline case. The robust F-statistics are lower than the commonly used threshold of 10. While this is potentially concerning, we find that the impulse responses from this specification are extremely similar to the baseline specification. These impulse responses are plotted in figure 3 in solid blue lines, with the dashed black lines showing the baseline case with all the FOMC meetings. After a fed funds rate shock, the lines in blue show that the response of output is a little lower and that of prices is a little higher relative to the baseline case. But this difference is small and importantly the responses to a forward guidance shock are essentially indistinguishable from the baseline case. In the online appendix we address a related 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.

Another 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

[17] In the online appendix we provide a list of both scheduled and unscheduled FOMC meeting dates.

in the futures price. On the flip side, some authors have argued that it may take financial markets more than a couple of hours 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 4 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 for both specifications confirm the findings from the baseline case.[18] Output falls after a positive shock to the fed funds rate but rises after a positive shock to the 1 year rate.[19] Thus we conclude that the expansionary effect of a "contractionary" forward guidance shock holds even if we use a narrower or broader window to construct the instruments or if we exclude unscheduled FOMC meeting dates.

To better understand the source of this effect, we perform various other exercises. The most important one turns out to be related to Federal Reserve private information. We find that when we control for a measure of private information when estimating the VAR, the response of output to a forward guidance shock no longer displays the puzzling behavior. These results are presented in detail in section 6. But first, we compare the results from this baseline SVAR to specifications that are widely used in the literature. We would like to understand 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.

4.1 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 VAR similar to the baseline case, but

[18] For space constraints, the first stage regressions (robust F-statistics remain at or above 10 for both these specifications) and the impulse responses are presented in the online appendix.

[19] There is a difference between the response of prices when using the narrower or broader window but as mentioned above, the focus of this paper is on studying the response of output.

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. As exepected, this measure turns out to be very similar to the target factor and the correlation between them is 0.98. The first-stage regression is presented in column (a) of table 4. The robust F-statistic from the first stage is sufficiently high at 78.58.

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.[20] 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 first-stage regression is presented in column (b) of table 4. The robust F-statistic from the first stage is 23.11, again implying no concern of a weak instrument.

The impulse responses from both these approaches are presented in figure 5. 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. Importantly, the qualitative response of output here is very similar to the response of output to a fed funds rate shock in the baseline specification of this paper, shown in figures 1 and 2. This suggests that studies using only one policy tool will tend to find effects of monetary policy that mainly capture the effects of conventional monetary policy. This is not surprising, given that for the majority of our sample period from 1979 to 2011, the fed funds rate is considered to have been the primary tool of monetary policy.

To better understand the result of decomposing monetary policy actions, we plot the response of output and prices from our baseline model with the corresponding responses from the model where only the 1 year rate is used as the policy instrument. The dashed black and solid blue lines in figure 6 are responses of output and prices to a funds rate and forward guidance shock respectively from the baseline

[20] To make the model as comparable as possible to the baseline case, we leave out the excess bond premium from the GK specification. In section 5 we show results with the excess bond premium added to the VAR.

impulse responses plotted in figure 1. The dotted red line shows the responses to a 1 year rate shock from figure 5. For the CPI, we notice that there are small differences on impact but after a few months the responses are essentially indistinguishable from one another. On the other hand, there are persistent differences in the output response. The fed funds rate shock creates a hump-shaped fall in output, while the forward guidance shock raises output. The combined effect, captured by the red line, creates a fall in output that lies in between the responses to the individual shocks. Thus an important point is that studies that do not separately model the effects of the two policy tools may end up misrepresenting the overall effects of monetary policy.

4.2 Comparison of Identification Strategy Having discussed the results using the external instruments identification, 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. In figure 7 we plot the impulse responses using this recursive Cholesky identification. 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.[21] 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. For the Cholesky identified fed funds rate shock, we notice that the responses are extremely similar to the baseline responses identified using external instruments, with only small differences on impact. 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

[21]Swapping the order of output with prices does not affect the results.

a couple of months. the shapes of the response of output and prices are 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.

5 Extended Results

In this section we estimate the baseline VAR by adding macroeconomic and financial variables that are commonly used in the literature. For all the specifications, we find that the main results still hold, i.e. that effects of a funds rate shock on output are as expected while that of a forward guidance shock are counter to standard theory. In the next section, we will provide an explanation of this finding based on information asymmetries, but first we establish the robustness of these findings. For all the specifications presented in this section, the first stage results are available in the online appendix. In the same online appendix, we also present the results for different sample periods, i)July 1979 to November 2015, ii)July 1979 to December 2008 and iii)July 1984 to December 2011, all of which are broadly consistent with the baseline results. Here we focus on results that expand the variables included in the VAR. We conduct the analysis by adding each variable one at a time to the baseline VAR. This is done to prevent the number of parameters estimated in the VAR from becoming too large.

First, we estimate the VAR using the 2 year rate as the monetary policy tool. The first stage regressions for this specification are provided in table 2. While the F-statistic on the 2 year rate residual is slightly below 10, the coefficients on both the target and path factor are significant. Figure 8 shows the impulse responses using both identification strategy I (solid blue line) and II (dashed black line). While there are some minor differences among the two identification strategies, the responses show the same pattern as the baseline results with the 1 year rate.

Next, we add the excess bond premium of Gilchrist and Zakrajšek (2012) to the baseline specification, following GK. One important concern is that the small VAR used for the baseline specification may be leaving out a lot of information that is actually used by the Federal Reserve in making policy decisions. The excess bond premium is an easy way to capture some of this missing information in the VAR. The first stage results (shown in the online appendix) give robust F-statistics above 10 for both residuals. The solid blue lines in figure 9 shows the impulse responses from this specification using identification strategy I. For ease of comparison, the dashed black 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 responses of economic activity are very similar. 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.

Next, we add a measure of commodity prices to the baseline specification. In the baseline results we noted that the response of the CPI displays the well known price puzzle. One common approach in the literature to account for this price puzzle is to include a measure of commodity prices in the VAR. The solid blue lines in figure 10 shows the impulse responses from this specification using identification strategy I, with the dashed black line showing the baseline results. Again, the responses of economic activity are similar with the main difference that the price puzzle is somewhat weakened when we add commodity prices. The response of commodity prices follows a similar pattern to that of economic activity, i.e. commodity prices fall in response to a contractionary fed funds rate shock but rise in response to a forward guidance shock.

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 solid blue lines in figure 11 show the impulse responses from this specification using identification strategy I, with the dashed black line 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. Next we turn to a potential explanation of this counterintuitive finding.

6 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 target and path factors 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 regression as instruments in the SVAR.

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 5 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. 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 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. Thus these regressions suggest that the release of private information by the Fed is informative only about the monetary policy actions at future FOMC meetings as captured in the statement. 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.[22]

Table 6 shows the first stage regressions using the cleansed path factor, which involves replacing the path factor with the residual from the private information regression discussed above. This cleansed path factor is labeled "Path Factor (Pvt Res)". The results in the first two columns in table 5 are remarkably similar to the first stage regressions of the baseline specification shown in table 2. The Robust F-statistic is above 15 for both the ffr and 1 year residuals. Note that while the coefficient on the path factor is not significant at the 10% level, it is very close with a p-value of 0.11.

We now use the target factor and the cleansed path factor ("Path Factor (Pvt Res)") as instruments

[22]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.

to identify the two monetary policy shocks.[23] The response of the economy to a fed funds rate shock for both identification schemes is similar to the baseline case and is omitted due to space constraints. The first column of Figure 12 shows the response to a forward guidance shock under the two identification strategies using this cleansed path factor. The solid blue line shows the responses from identification strategy I, while the dashed black line shows those under identification strategy II. The dotted blue lines show the confidence intervals from identification strategy I. 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 (a little lower in magnitude than -1%). Notice however that the responses are smaller in magnitude and statistically insignificant for all periods. This is in sharp contrast to the baseline specification whose results are reproduced in the second column of figure 12 for comparison. In this case, output rises on impact in response to a contractionary forward guidance shock and the response stays positive for over 3 years.

To summarize, the overall effect of a "contractionary" forward guidance shock is to increase output while the first column of figure 12 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. We can estimate the SVAR using the fitted component in the private information regression, rather than the residual component used in figure 12. This fitted component is labeled Path Factor (Pvt Fit). The response of output to this type of forward guidance shock is shown with the dashed red line in figure 13. 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. In table 6, columns (3) and (4) show the first stage regression when using Path Factor (Pvt Fit) as the instrument. While the F-statistics remain high, the coefficient on the Path Factor (Pvt Fit) is

[23] In the online appendix we plot this cleansed path factor along with the path factor for comparison.

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, especially for the identification strategy II. Thus we view the results from figure 13 as only suggestive and recommend interpreting them with a high degree of caution.

Finally, we redo the private information analysis for the case where the unscheduled FOMC meetings are excluded. The private information regression used to construct the residual and the corresponding first stage regressions are relegated to the online appendix. The overall results from these two tables are similar to tables 5 and 6. Again, the response to the fed funds rate shock is similar to the case where only the scheduled meetings are used and is not included here. Figure 14 plots the impulse responses to a forward guidance shock. The first column shows the response under the two identification strategies using the cleansed path factor ("Path Factor (Pvt Res)") as instruments to identify the two monetary policy shocks. The solid blue line shows the responses from identification strategy I, while the dashed black line shows those under identification strategy II. The dotted blue lines show the confidence intervals from identification strategy I. The bottom left column shows that output now falls after a contractionary forward guidance shock, although by less than 1% . Overall, this figure paints the same picture as figure 12. Once the asymmetric information of the Federal Reserve has been stripped out, the effects of forward guidance no longer generate the counterintuitive response of output.

7 Discussion and Concluding Remarks

What have we learned about the effects of forward guidance in light of the private information analysis from the previous section? 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 12 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 (2015) 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.

To summarize, in this paper we try to separately identify the effects of conventional monetary policy from the newer 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 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

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

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

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

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

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

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 $E(u_t u_t') = BB'$, we can derive equations 2.13 and 2.14 in a straightforward manner.

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

$$\begin{aligned} E(Z_t u_t')\left[E(u_t u_t')\right]^{-1}E(u_t Z_t') &= \phi B_1'(BB')^{-1}B_1\phi' \\ &= \phi B_1'(B')^{-1}B^{-1}B_1\phi' \\ &= \phi\phi' \end{aligned}$$

In the case of 1 shock and 1 instrument, now we can identify ϕ up to a sign convention from the above equation. With more than 1 shock, ϕ is not identified without further restrictions. As explained in section 2.1, identification strategy II involves imposing a triangular structure on ϕ, such that a Cholesky factorization of the above equation gives ϕ. With ϕ in hand, we can get the relevant column of the impact matrix B_1 from

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

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

$$[Z_1\ Z_2] = [F_1\ F_2]U \tag{8.2}$$

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 γ_1 and γ_2 be the factor loadings on F_1 and F_2 for change in current month's futures contract (given by X(1))

$$X(1) = \gamma_1 F_1 + \gamma_2 F_2 \tag{8.3}$$

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)

	(a)		(b)	
Variables	FFR residual	1 year residual	FFR residual	2 year residual
Target Factor	0.796***	0.902***	0.878***	0.756***
	(0.132)	(0.168)	(0.136)	(0.203)
Path Factor	-0.134	0.347	-0.164	0.695*
	(0.177)	(0.233)	(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

Table 2: First stage regression of residuals from the reduced form VAR on the target and path factors. 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, *** $p < 0.01$, **$p < 0.05$, *$p < 0.1$.

	(a)	(b)
Variables	FFR residual	1 year residual
Target Factor	0.896***	0.810**
	(0.287)	(0.340)
Path Factor	-0.237	0.234
	(0.192)	(0.263)
Constant	-0.006	0.000
	(0.010)	(0.013)
Observations	252	252
R-squared	0.048	0.027
Adjusted R-squared	0.0401	0.0191
Robust F-statistic	5.081	3.458

Table 3: First stage regression of residuals from the reduced form VAR on the target and path factors with only the scheduled FOMC meeting dates. Robust standard errors in parentheses, *** $p < 0.01$, **$p < 0.05$, *$p < 0.1$.

	(a)	(b)
Variables	FFR residual	1 year residual
MP1	1.090***	
	(0.123)	
FF4		1.138***
		(0.237)
Constant	0.014	0.018
	(0.011)	(0.013)
Observations	252	252
R-squared	0.188	0.102
Adjusted R-squared	0.185	0.0980
Robust F-statistic	78.58	23.11

Table 4: First stage regression of residuals from the reduced form VAR with only one policy tool. Panel (a) is the model with only fed funds rate as policy tool and MP1 as the instrument. Panel (b) is the model with only the 1 year rate as the policy tool with FF4 as the instrument. Robust standard errors in parentheses, *** $p < 0.01$, **$p < 0.05$, *$p < 0.1$.

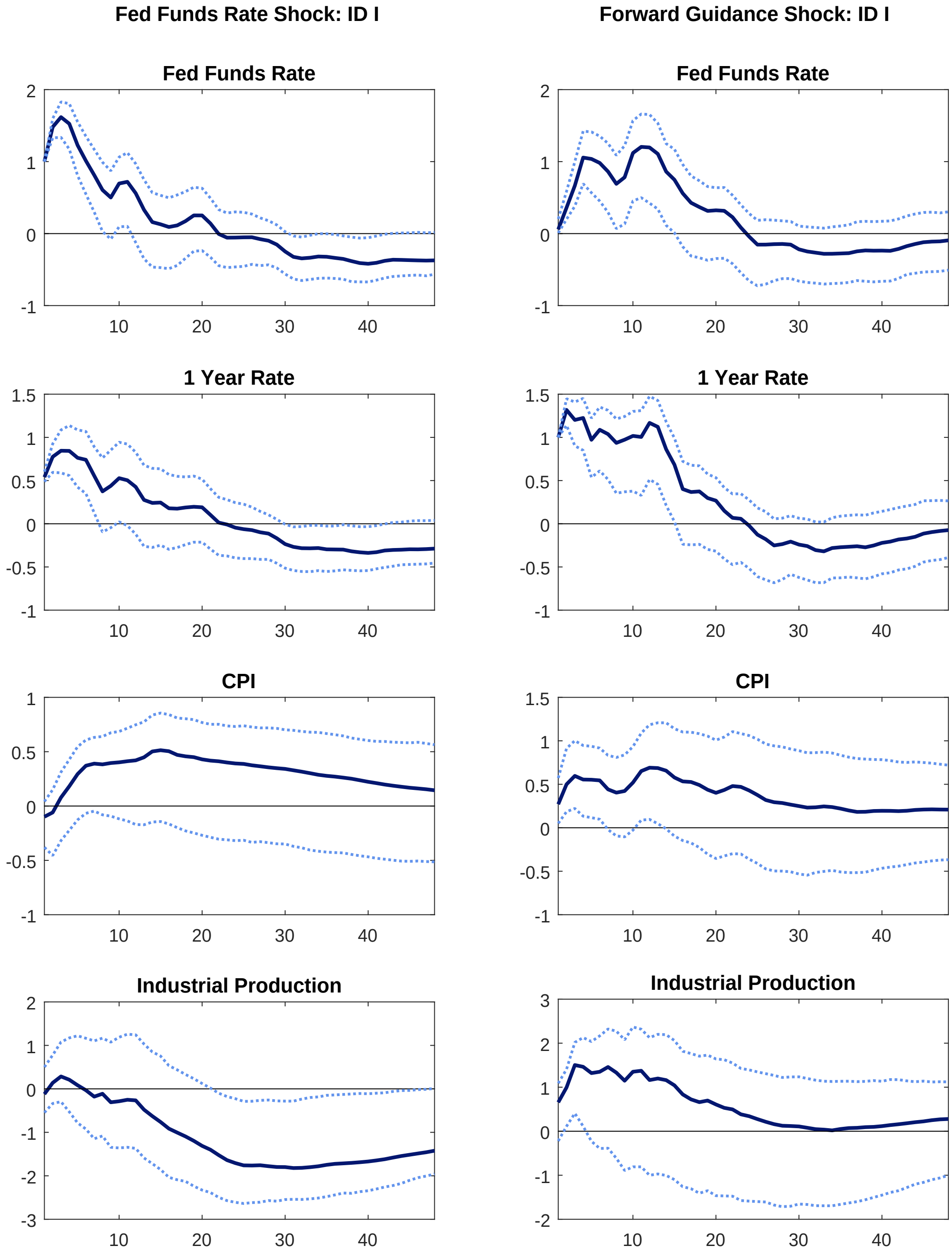

Figure 1: The impulse responses to a unit monetary policy shock identified using the external instruments identification strategy I outlined in the text, with 90% confidence intervals. The first column shows the response to a conventional monetary policy shock (i.e shock to the federal funds rate equation), while the second column shows the response to a forward guidance shock (i.e. shock to the 1 year rate equation)

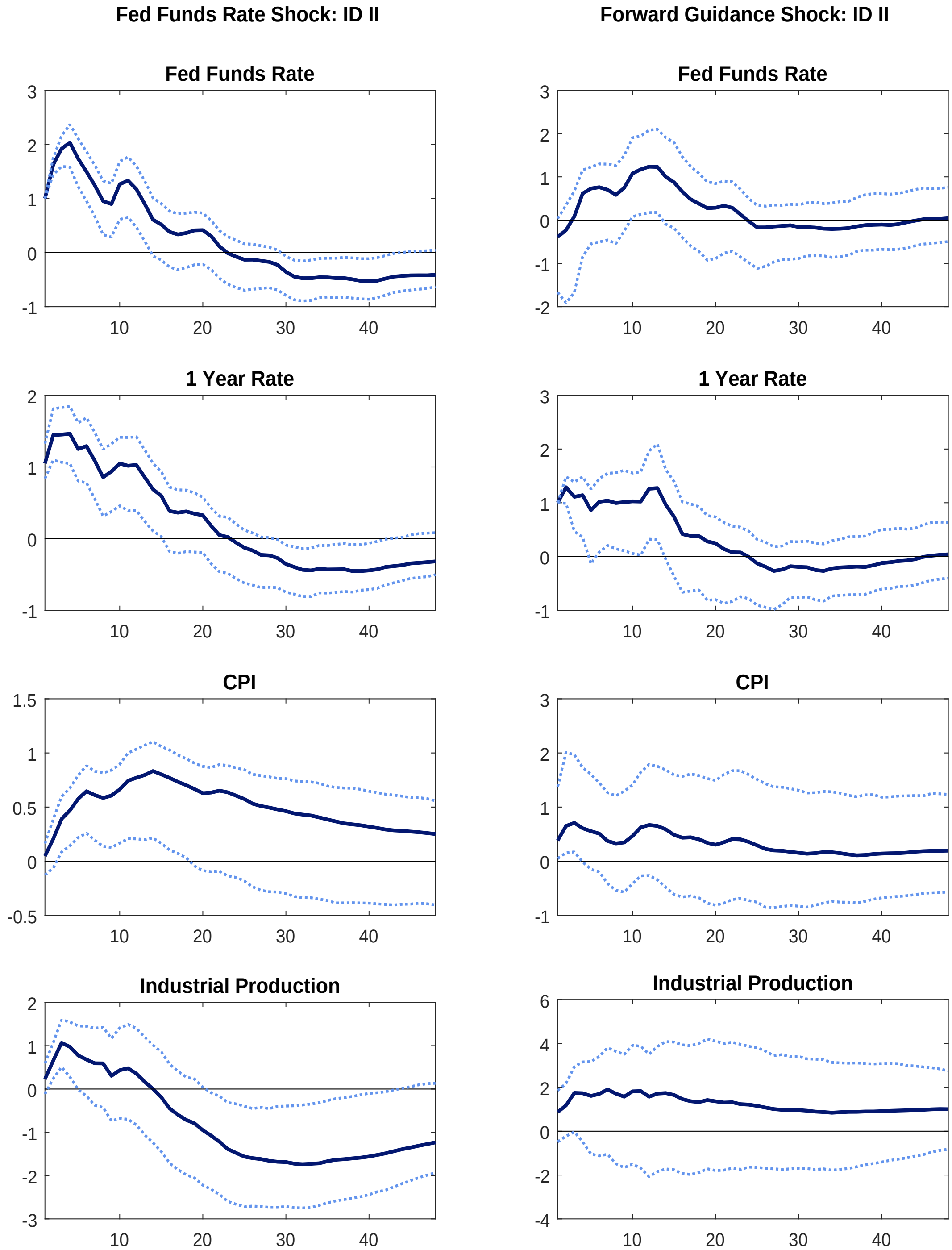

Figure 2: The impulse responses to a unit monetary policy shock identified using the external instruments identification strategy II outlined in the text, with 90% confidence intervals. The first column shows the response to a conventional monetary policy shock (i.e shock to the federal funds rate equation), while the second column shows the response to a forward guidance shock (i.e. shock to the 1 year rate equation)

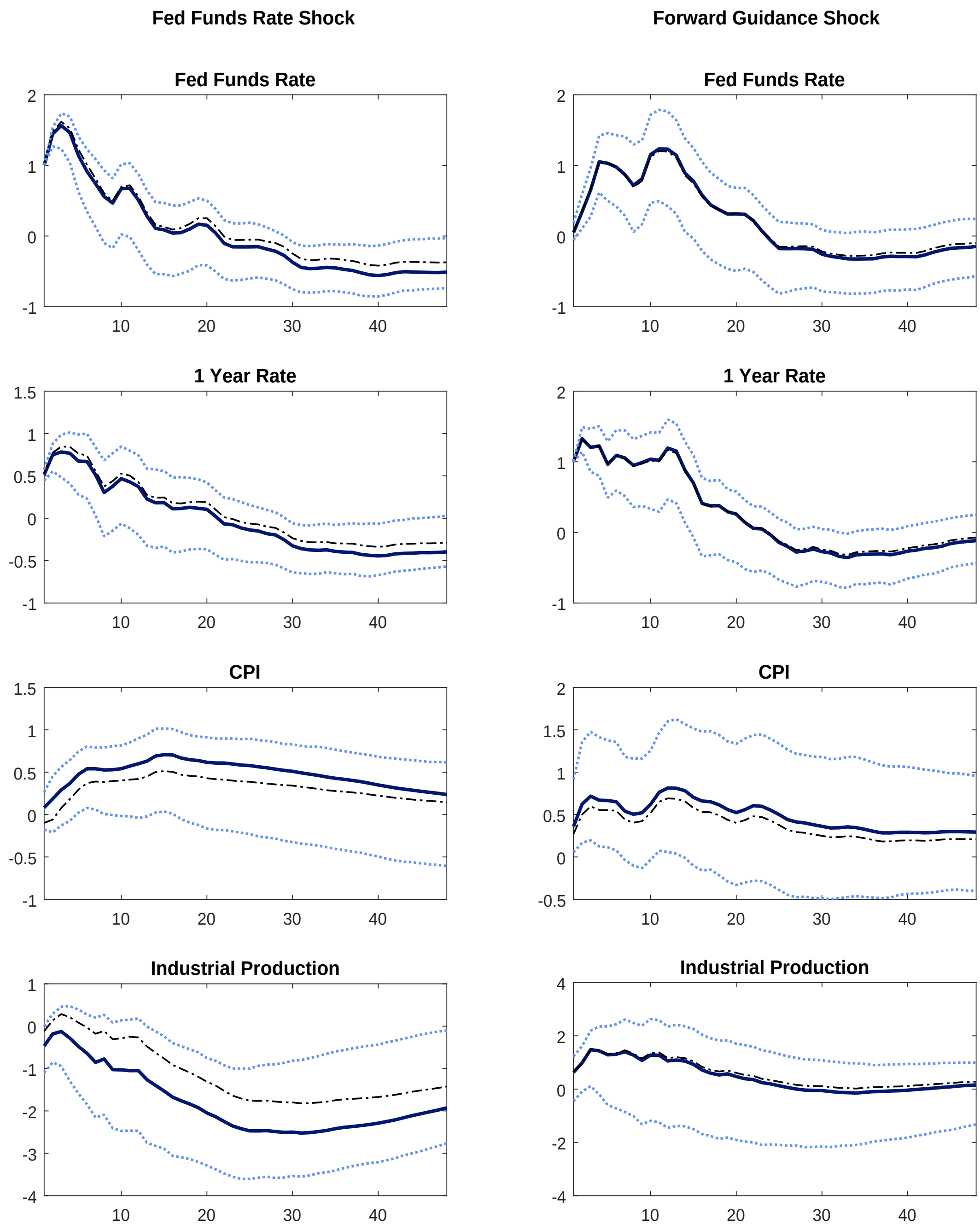

Figure 3: The impulse responses to a unit monetary policy shock identified using the external instruments identification strategy I outlined in the text, with 90% confidence intervals. The solid blue lines show the responses where only the scheduled FOMC meetings are used, while the dashed black line shows the baseline specification with both scheduled and unscheduled meetings. 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).

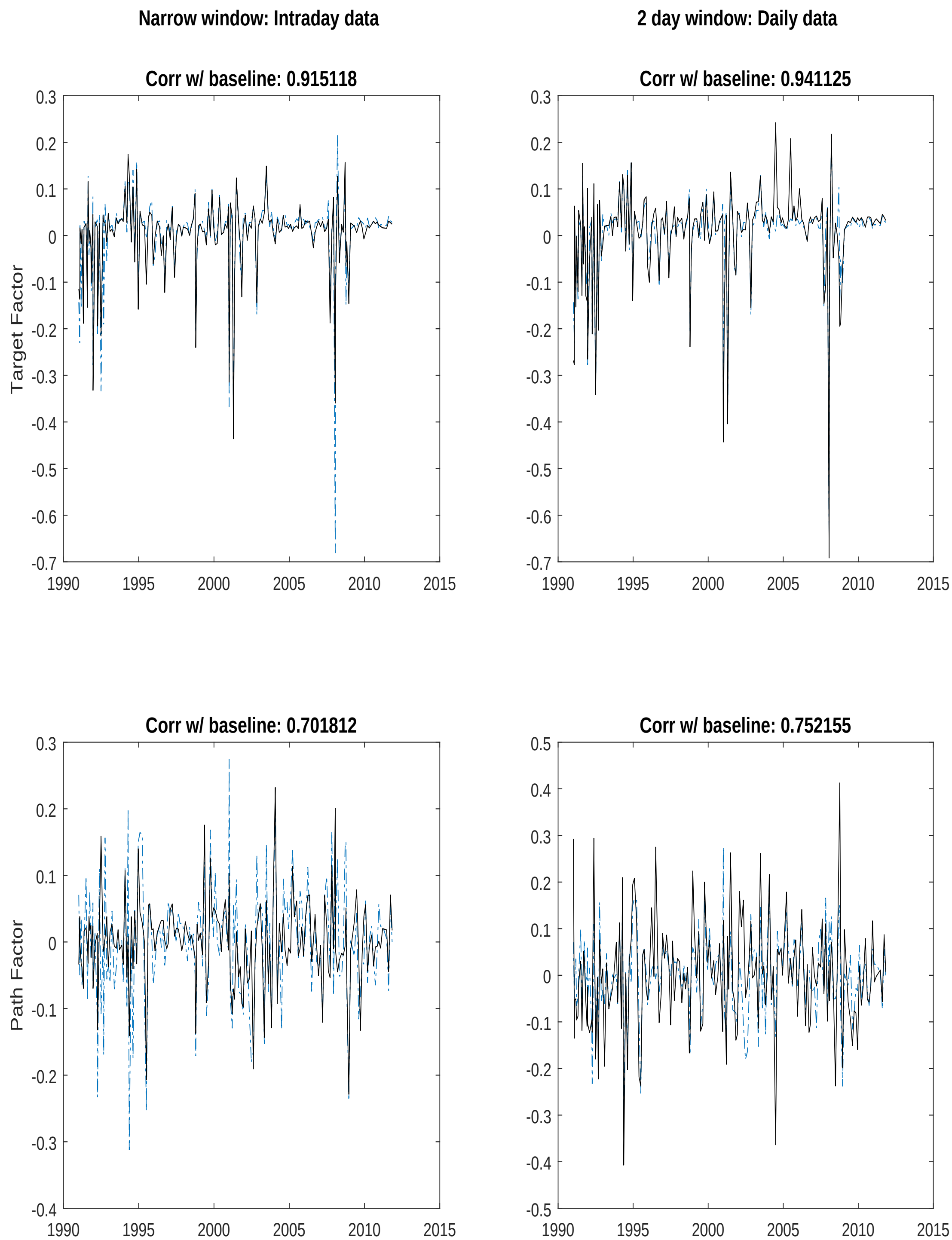

Figure 4: Target and path factors constructed from futures data. The dashed blue line in all the figures shows the baseline calculations using daily data. The solid lines in the left column show the factors constructed using a 30 minute window around FOMC announcements, while the right column uses the 2 day change.

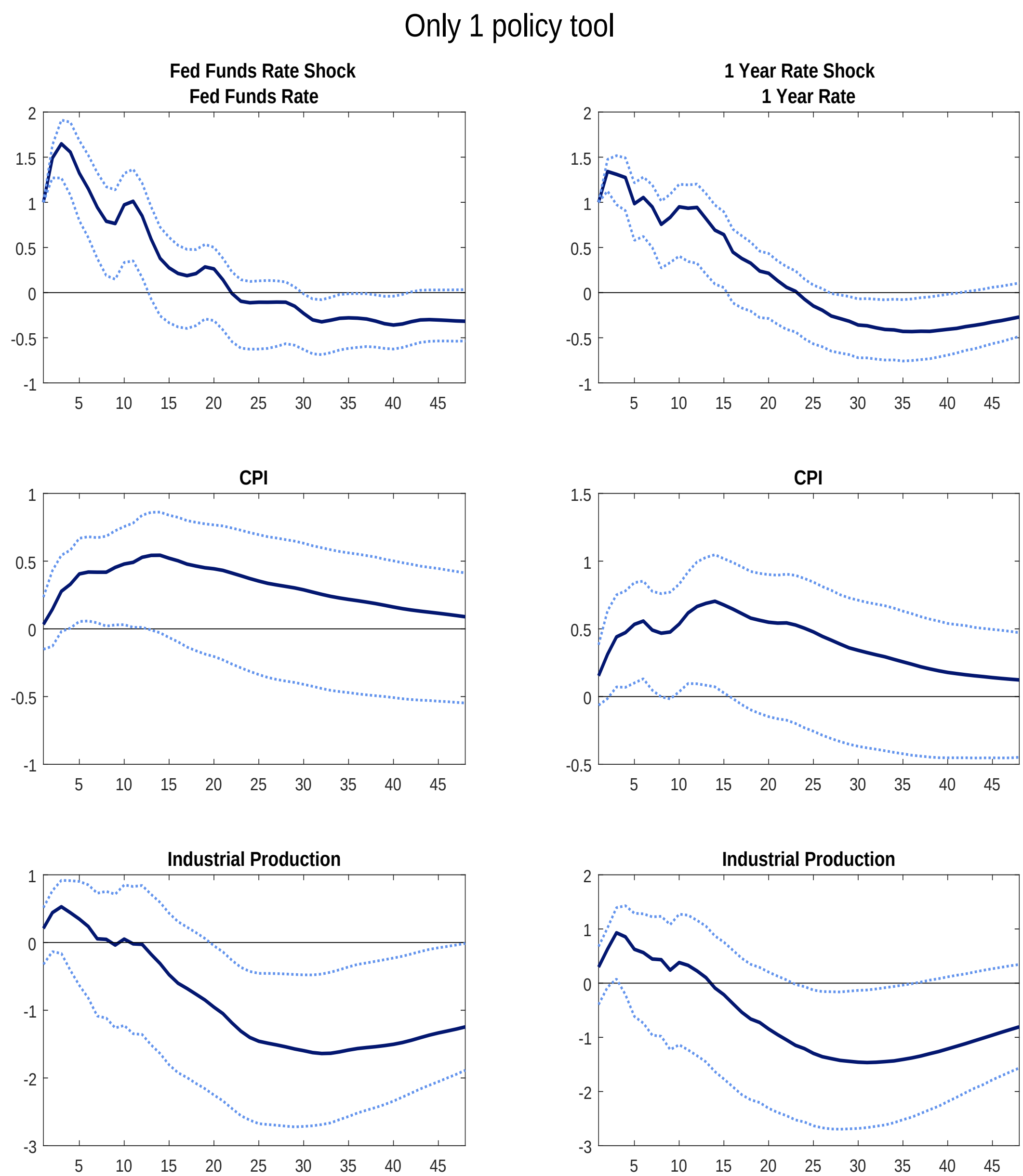

Figure 5: The impulse responses to a one unit monetary policy shock from VARs with only one policy tool, identified using external instruments methodology with 90% confidence intervals. The first column uses the fed funds rate as the monetary policy tool while the second column uses the 1 year rate as the policy tool.

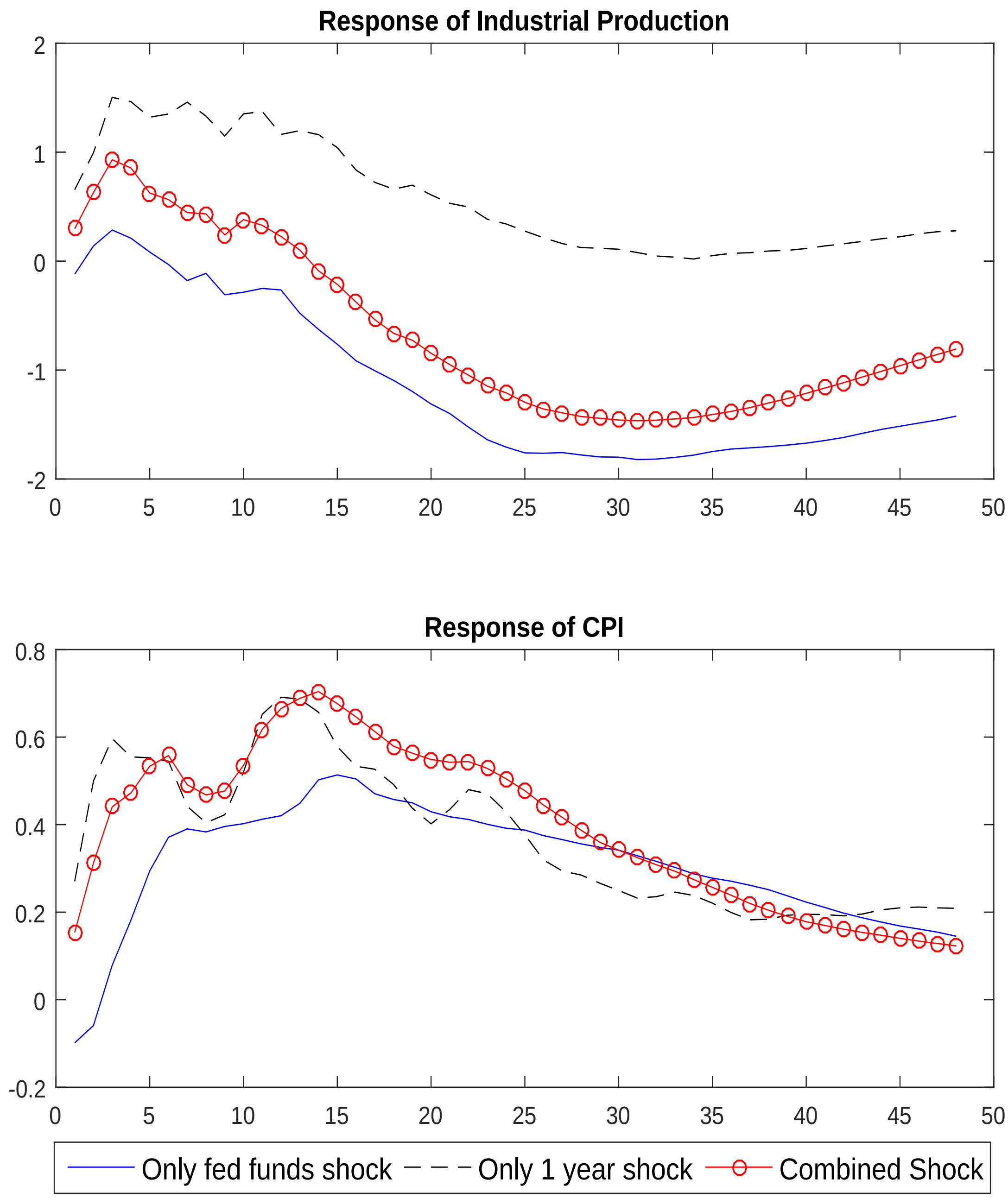

Figure 6: The impulse responses to a one unit monetary policy shock from VARs identified using external instruments methodology. The dashed black and solid blue lines show the responses to a funds rate and forward guidance shock respectively from the baseline specification (i.e. with 2 policy tools). The dotted red line shows the responses to a 1 year rate shock from the VAR with only the 1 year rate as the policy tool.

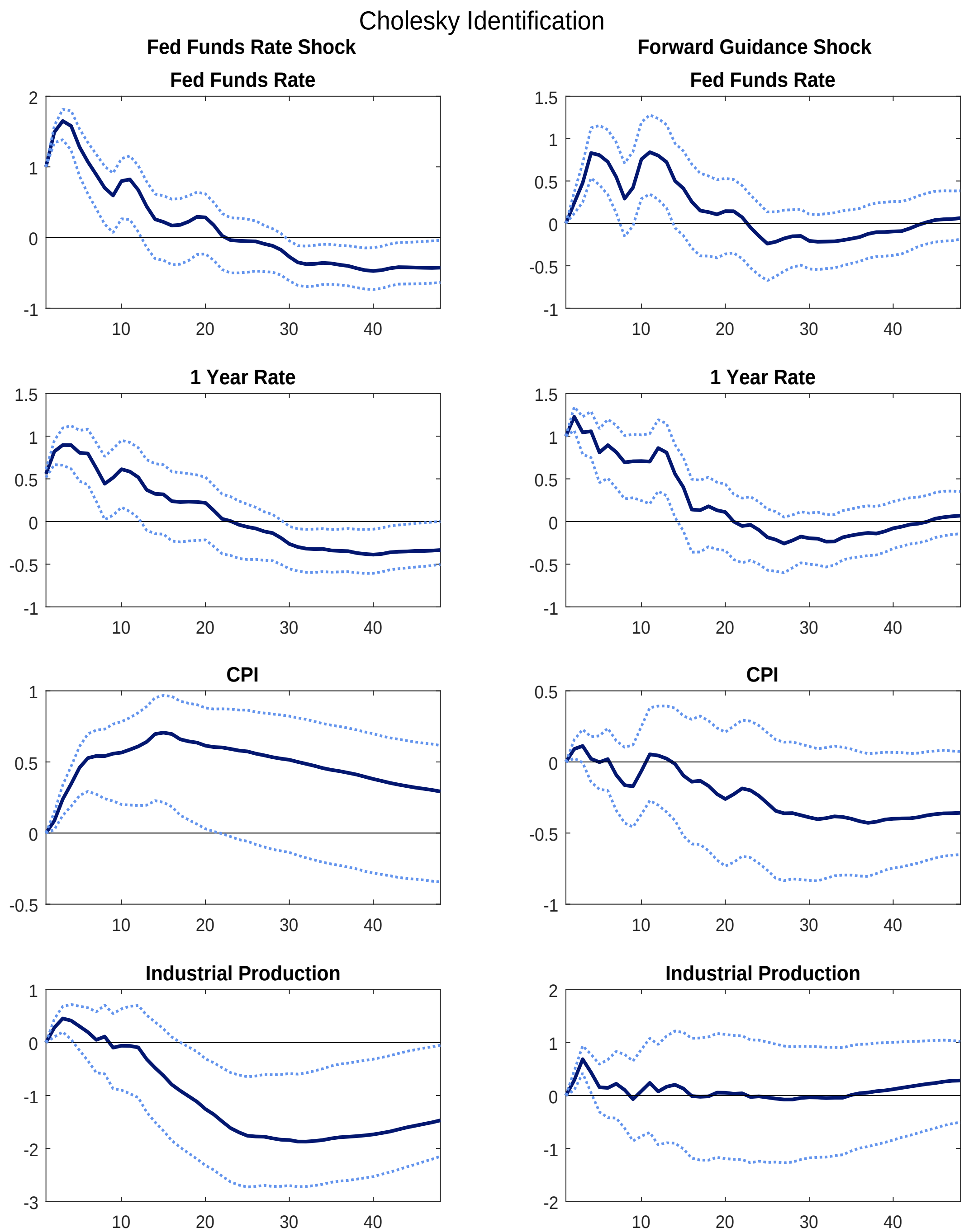

Figure 7: The impulse responses to a unit monetary policy shock identified using the Cholesky restrictions, with 90% confidence intervals. The first column shows the response to a conventional monetary policy shock (i.e shock to the federal funds rate equation), while the second column shows the response to a forward guidance shock (i.e. shock to the 1 year rate equation)

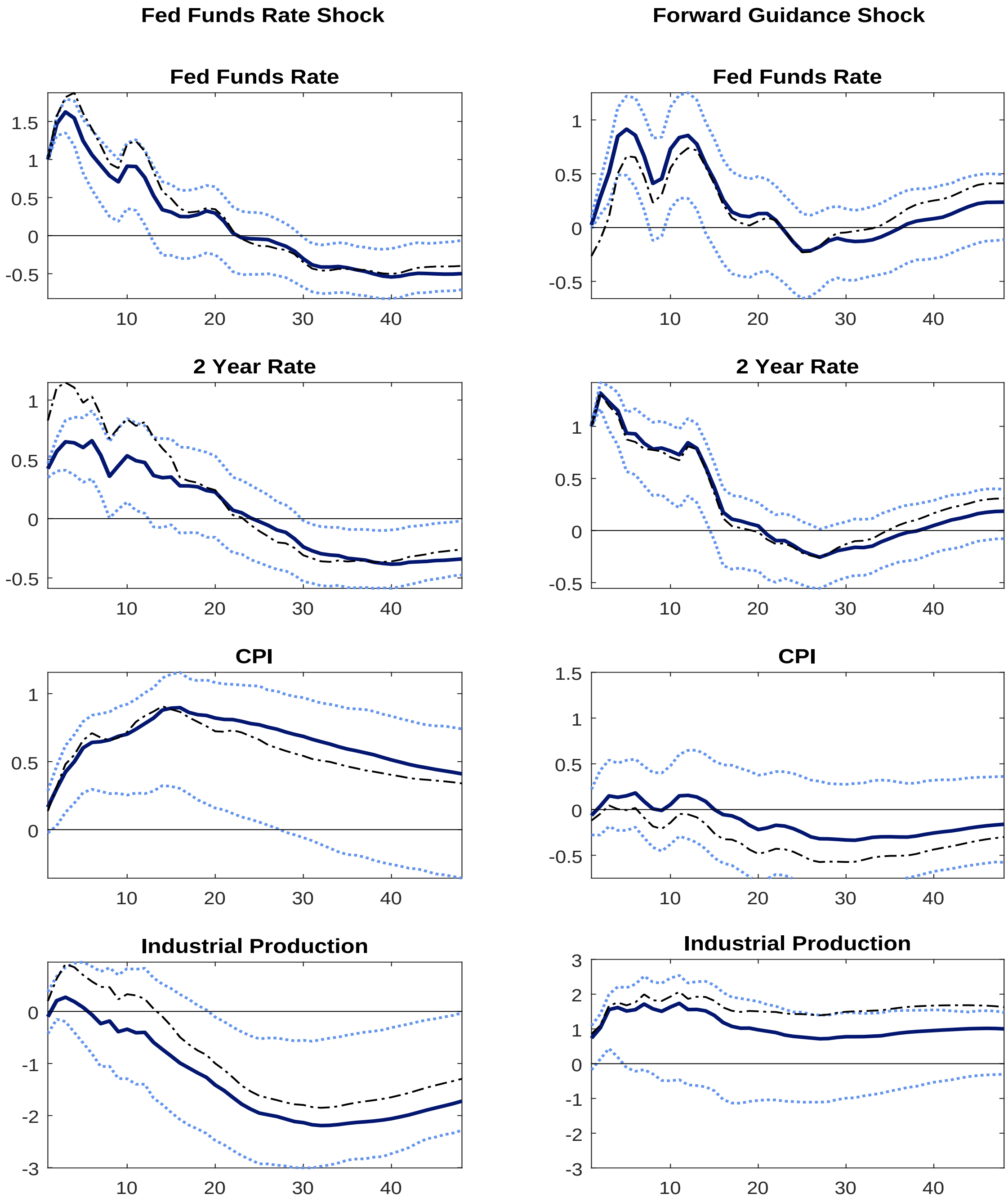

Figure 8: Impulse responses to a unit monetary policy shock with the 2 year rate as the forward guidance policy tool. The solid blue lines show responses using identification strategy I, with the dashed blue lines showing the 90% confidence intervals. The dashed black lines show the responses using identification strategy II. 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)

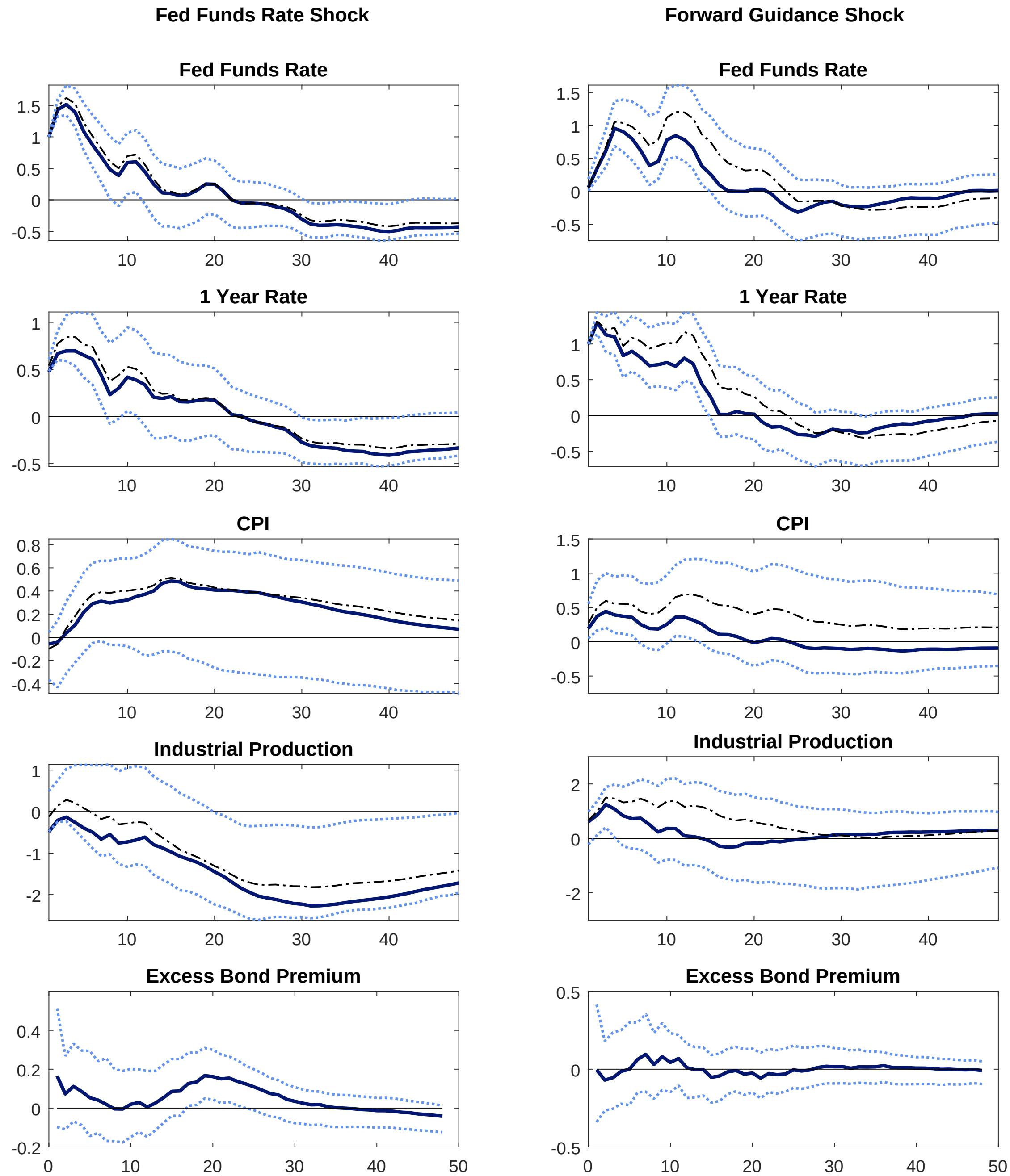

Figure 9: The solid blue lines show the impulse responses to a unit monetary policy shock for the VAR with "Excess Bond Premium" added to the baseline specification, using identification strategy I. The dashed black lines show the responses from the baseline specification. The dashed blue lines show the 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)

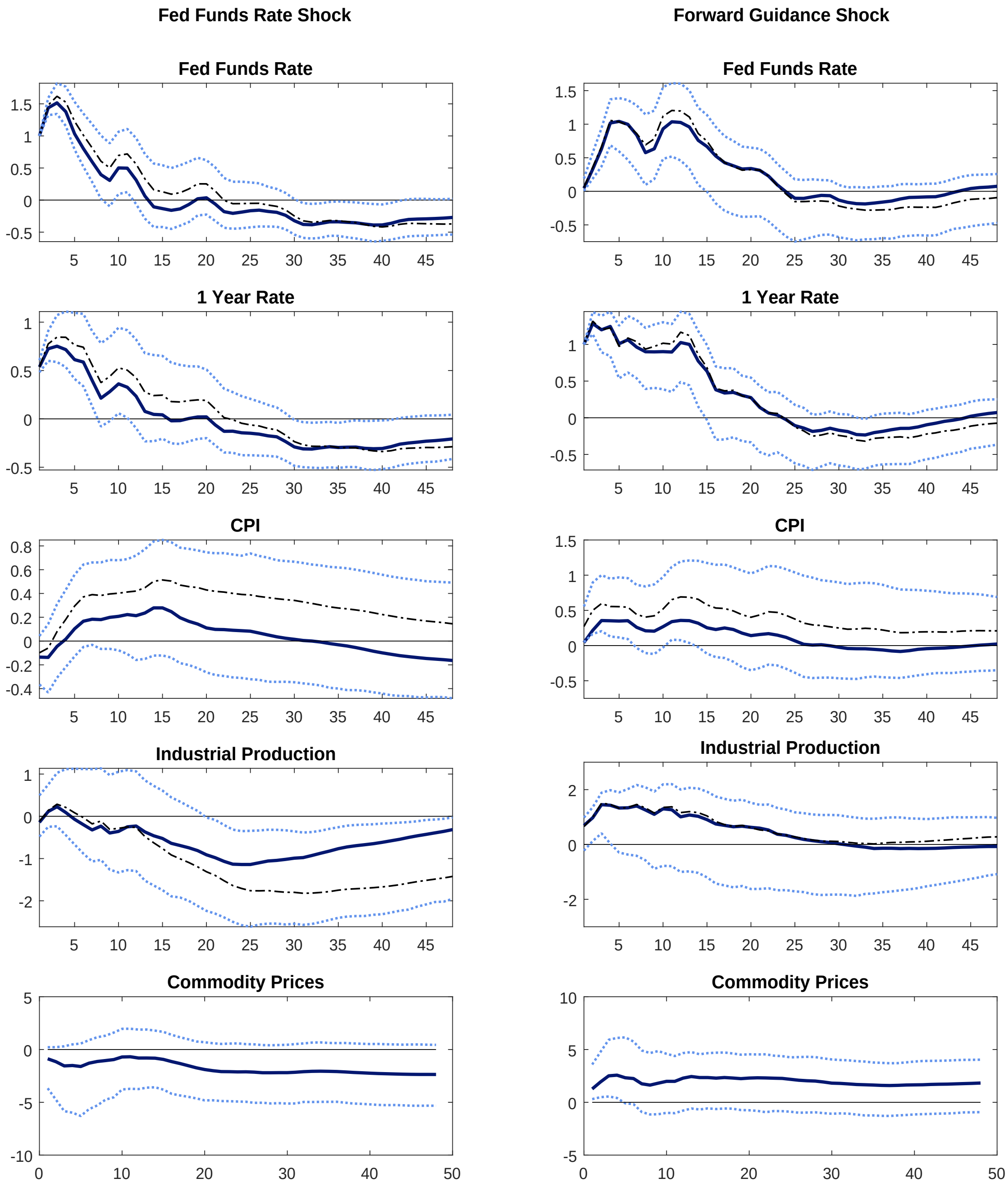

Figure 10: The solid blue lines show the impulse responses to a unit monetary policy shock for the VAR with commodity prices added to the baseline specification, using identification strategy I. The dashed black lines show the responses from the baseline specification. The dashed blue lines show the 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)

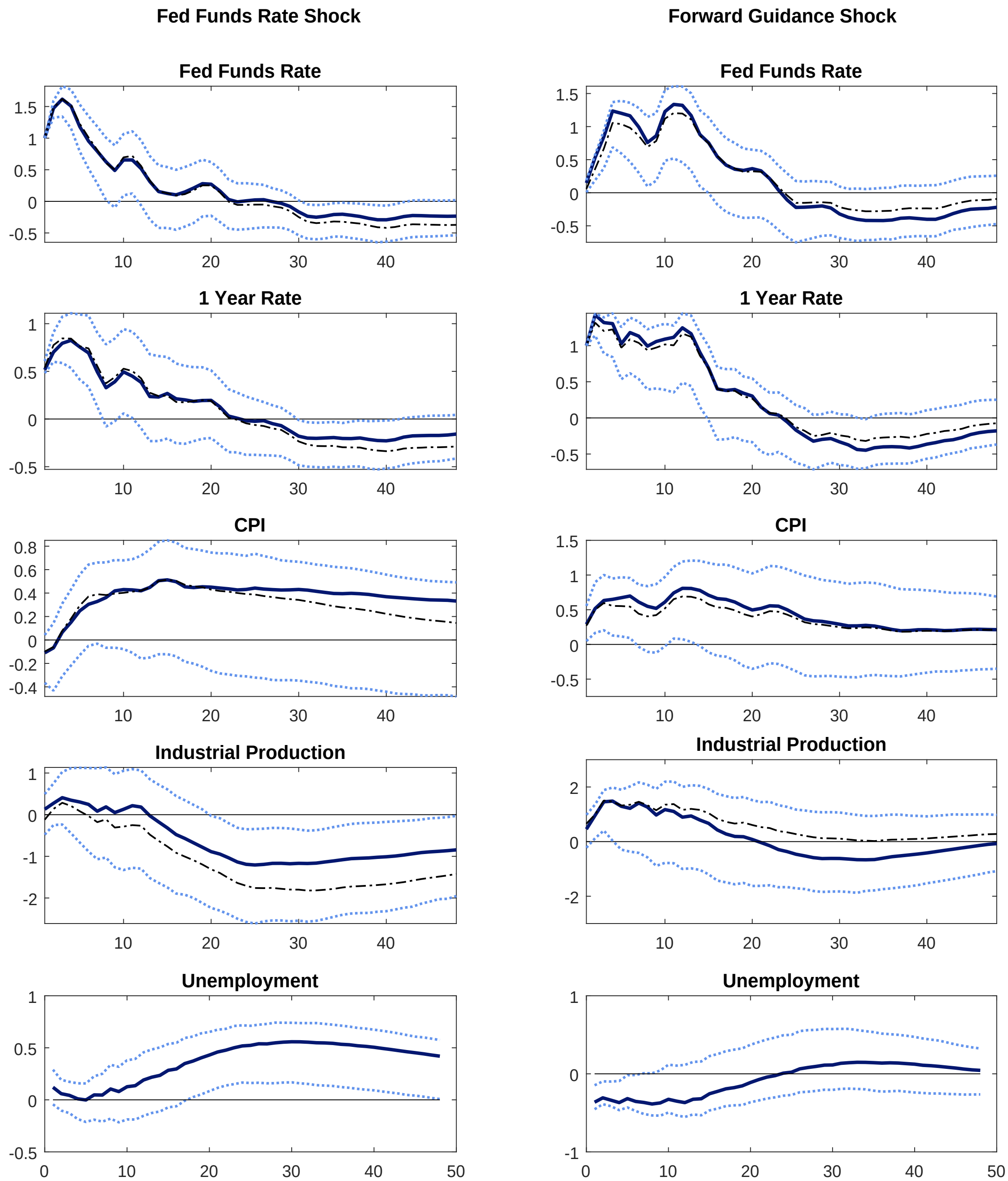

Figure 11: The solid blue lines show the impulse responses to a unit monetary policy shock for the VAR with unemployment added to the baseline specification, using identification strategy I. The dashed black lines show the responses from the baseline specification. The dashed blue lines show the 90% 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)

VARIABLES	(a) Target Factor	(b) Path Factor
GDPt1	0.006	0.004
	(0.014)	(0.013)
GDPt2	-0.006	-0.002
	(0.016)	(0.012)
GDPt3	-0.020	0.009
	(0.016)	(0.013)
GDPt4	0.016	0.029*
	(0.018)	(0.017)
CPIt1	0.001	0.010
	(0.009)	(0.008)
CPIt2	-0.012	-0.060***
	(0.018)	(0.019)
CPIt3	0.044	0.007
	(0.037)	(0.035)
CPIt4	-0.035	0.070
	(0.046)	(0.052)
GDPt1lag	0.013	0.004
	(0.013)	(0.010)
GDPt2lag	-0.018	-0.004
	(0.014)	(0.011)
GDPt3lag	0.028*	0.024*
	(0.017)	(0.013)
GDPt4lag	0.006	-0.047***
	(0.020)	(0.018)
CPIt1lag	0.003	-0.000
	(0.006)	(0.007)
CPIt2lag	0.025	-0.018
	(0.017)	(0.021)
CPIt3lag	-0.097***	0.077**
	(0.035)	(0.038)
CPIt4lag	0.060	-0.078
	(0.042)	(0.055)
Constant	-0.002	0.009
	(0.010)	(0.010)
Observations	177	177
R-squared	0.076	0.151
Adjusted R-squared	-0.0169	0.0656

VARIABLES	(c) Target Factor	(d) Path Factor
All	0.2812	0.0016
GDP	0.5847	0.0049
CPI	0.2733	0.055
Current	0.9164	0.0194
Lagged	0.1226	0.0216

Table 5: Regression results of target and path factor on measure of Federal Reserve private information. 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.

	(1)	(2)	(3)	(4)
Variables	FFR residual	1 year residual	FFR residual	1 year residual
Target Factor	0.790***	0.929***		
	(0.132)	(0.169)		
Path Factor (Pvt Res)	-0.082	0.402		
	(0.183)	(0.252)		
Target Factor			0.794***	0.925***
			(0.130)	(0.166)
Path Factor (Pvt Fit)			-0.350	0.069
			(0.429)	(0.594)
Constant	-0.006	-0.001	-0.006	-0.001
	(0.010)	(0.013)	(0.010)	(0.013)
Observations	241	241	241	241
R-squared	0.108	0.107	0.110	0.094
Adjusted R-squared	0.100	0.0990	0.103	0.0862
Robust F-statistic	18.59	15.36	19.15	15.68

Table 6: First stage regression of residuals from the reduced form VAR on the target and the two different path factors. Columns (1) and (2) use the residual from the private information regression, labeled as Path Factor (Pvt Res) and columns (3) and (4) use the fitted value, labeled Path Factor (Pvt Fit). Robust standard errors in parentheses, *** $p < 0.01$, **$p < 0.05$, *$p < 0.1$.

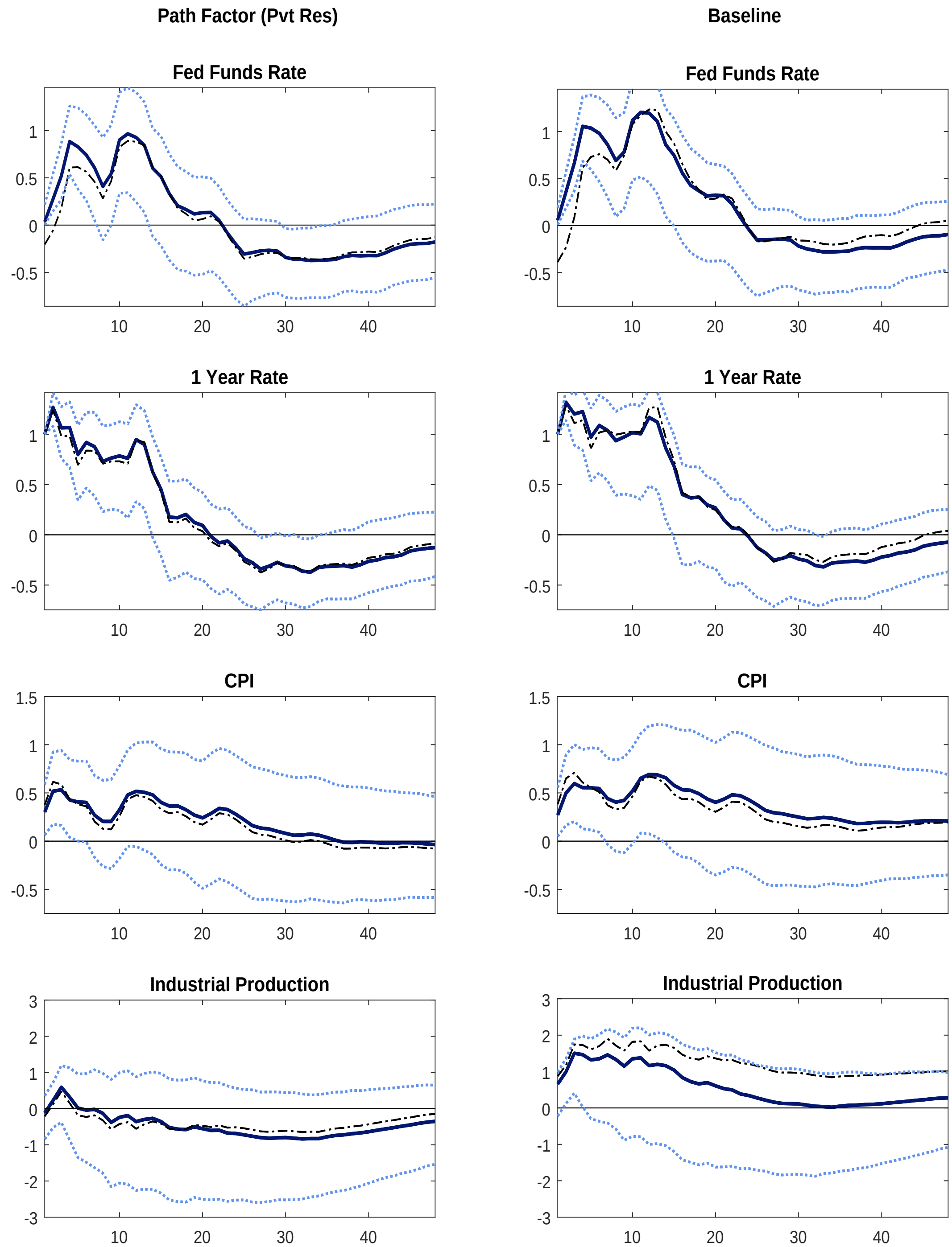

Figure 12: The impulse responses to a one unit forward guidance shock with 90% confidence intervals. The first column shows the responses using the residual from the private information regressions discussed in section 6, see the main text for more details. The second column shows the responses from the baseline specification using the full path factor as an instrument. For both columns the solid blue line shows the responses using identification strategy I, while the dashed black line show identification strategy II.

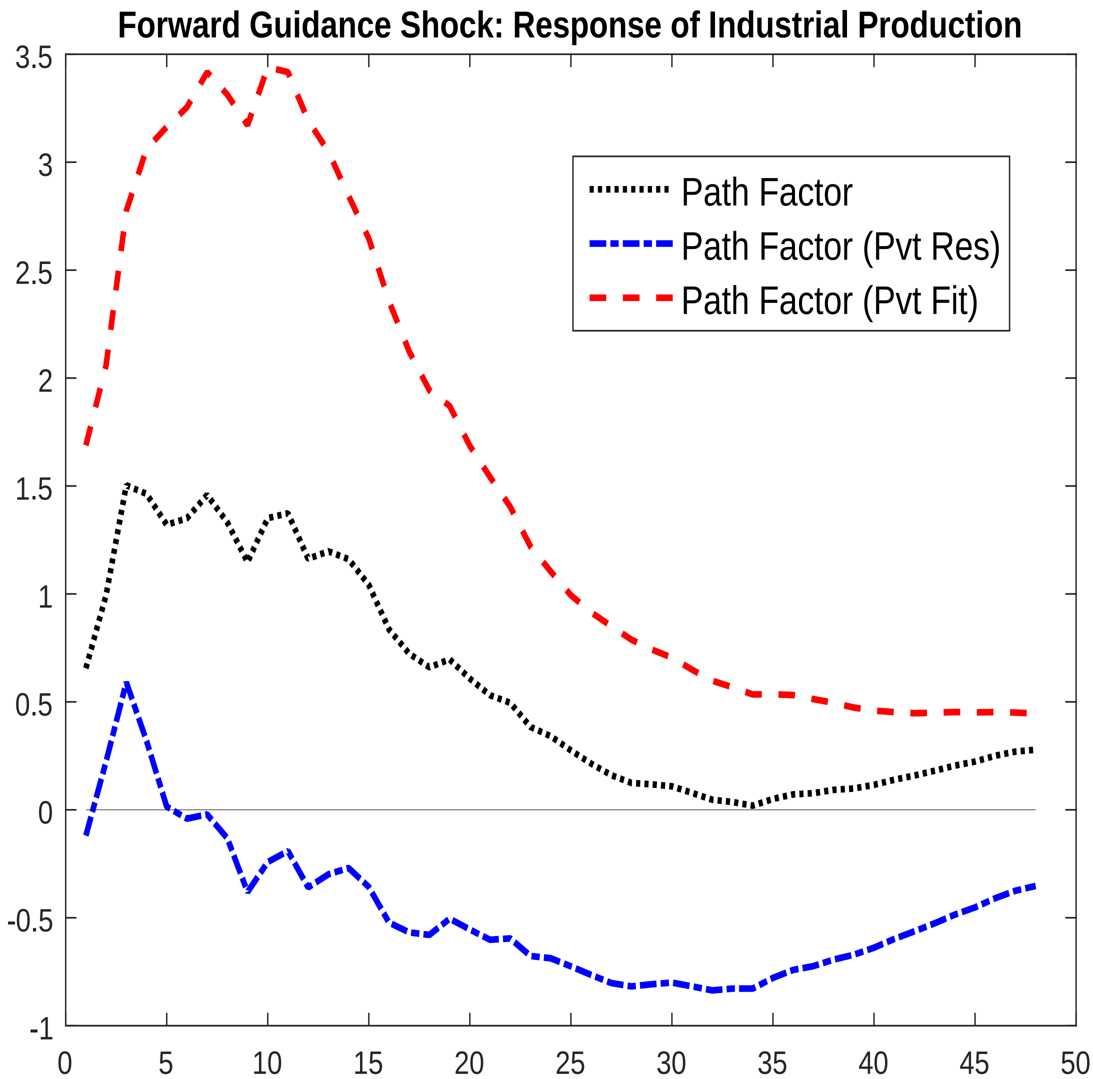

Figure 13: The impulse response of industrial production to a one unit forward guidance shock using identification strategy I. The difference in the lines is the specific measure of the path factor used as an instrument. The dotted black line is the baseline specification using the unmodified path factor. The red and the blue line show the response using the fitted value and the residual respectively from the information regressions discussed in section 6, see the main text for more details.

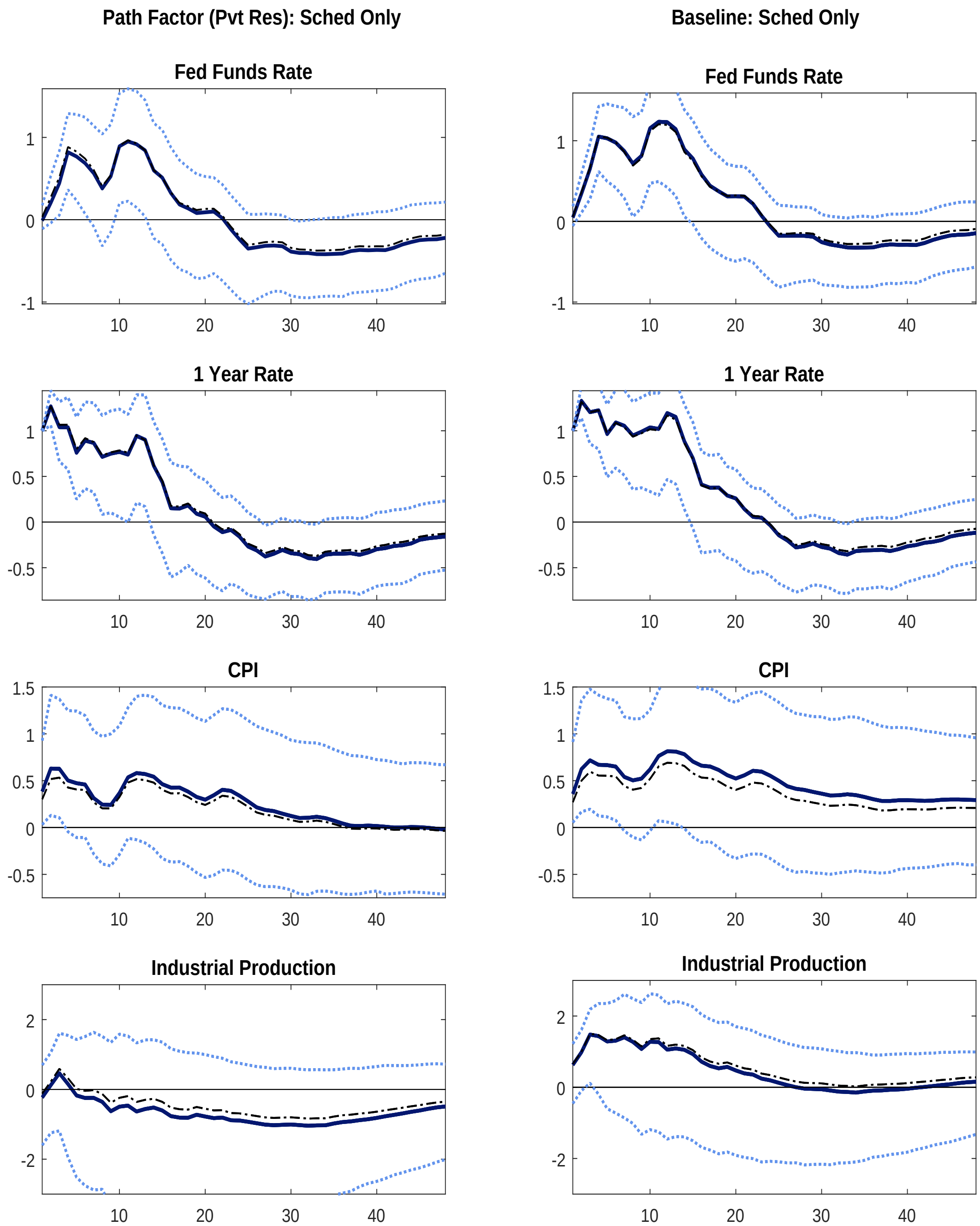

Figure 14: The impulse responses to a one unit forward guidance shock with 90% confidence intervals, leaving out the unscheduled FOMC meeting dates. The first column shows the responses using the residual from the private information regressions discussed in section 6, see the main text for more details. 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 identification strategy I, while the dashed black line show identification strategy II.