Monetary Policy Communication Shocks and the Macroeconomy*

Robert Goodhead† and Benedikt Kolb‡

26th July 2024

Abstract

Using high-frequency identification, we provide evidence that Fed communication surprises have larger macroeconomic effects than surprise actions. Three ingredients are central to show this: structurally distinguishing between Fed actions and communication, controlling for the Fed information effect, and including the surprise measures directly in a VAR system instead of using them as instruments. We also compare the macroeconomic effects of Fed communication surprises relating to varying horizons into the future. Fed communication with a two-year horizon appears most powerful during the effective lower-bound period, consistent with theoretical predictions regarding Fed forward guidance.

JEL codes: E52, E58, G23, C32
Keywords: Federal Funds Futures, FOMC, Monetary Policy, VAR Model.

*This work represents a revision of the working paper previously circulated as Goodhead and Kolb (2018). We thank the anonymous editor, and two anonymous referees, for their many helpful comments. For helpful feedback and discussions, we thank Jason Allen, Geert Bekaert, Gabriel Bruneau, Fabio Canova, Wouter den Haan, Juan Dolado, Zeno Enders, Andrea Gazzani, Refet Gürkaynak, Peter Hansen, Peter Karadi, Leonardo Melosi, Athanasios Orphanides, Michael Owyang, Evi Pappa, Esteban Prieto, Giorgio Primiceri, Barbara Rossi, Alejandro Vicondoa, Shengxing Zhang, and participants at the May 2019 EABCN Madrid conference. The opinions expressed in this paper do not necessarily reflect the views of Deutsche Bundesbank or the Central Bank of Ireland.

†Corresponding author. Central Bank of Ireland. New Wapping Street, North Wall Quay, Dublin 1, D01 F7X3, Ireland. Tel.: +353 1 224 4655. Email: robert.goodhead@centralbank.ie.

‡Deutsche Bundesbank. Wilhelm-Epstein-Strasse 14, D-60431 Frankfurt/Main, Germany. Tel.: +49 69 9566 35755. Email: benedikt.kolb@bundesbank.de.

1 Introduction

"A central bank's primary impact on the economy comes about not through the level at which it sets current overnight interest rates, but rather through the way it affects private-sector expectations about the likely future path of overnight rates."

– Michael Woodford (2003)

The idea that central bank statements regarding future interest rates affect macroeconomic outcomes has been very influential for the conduct of monetary policy in recent decades. Policymakers have sought to make public increasingly detailed forms of information regarding their projected future rate paths. At the effective lower bound, central banks used forward guidance to deliver additional stimulus when their policy rates were constrained from below. Indeed, in the New Keynesian paradigm, information regarding future policy rate changes has a large impact on macroeconomic variables, for reasons that relate to core features of such models (Del Negro et al., 2023). The question of how statements about future policy decisions influence the macroeconomy is therefore of great interest.

In this paper we provide empirical evidence that surprise Federal Reserve (Fed) communication has stronger macroeconomic effects than surprise Fed actions. Our results are in the spirit of the seminal contribution of Gürkaynak et al. (2005, henceforth GSS), who studied financial market responses. These authors documented evidence that both "target" and "path" factors play a role in explaining high-frequency variation in asset prices around Fed information releases. A key insight of GSS is that one may miss important features of transmission, were one to consider only a target surprise, or mistakenly aggregate information from the target and path surprises together.[1] Surprisingly, given the predictions of theory and the results of GSS, a number of recent studies have found that action shocks have either stronger effects on output or prices, or pose fewer puzzles, relative to shocks relating to Fed communication (Lakdawala, 2019; Degasperi and Ricco, 2021; Swanson, 2024).[2] In contrast, we report evidence that words indeed speak more loudly than actions with respect to macroeconomic transmission, and not only for long rates, as established in GSS.

We will demonstrate that three main ingredients, each well suited for the study of communication shocks, are important to obtain results in line with theory. The first ingredient is to distinguish monetary policy action from communication surprises via a recursive identification scheme applied to futures price movements on FOMC meeting days. Action surprises can affect all available futures contracts, while communication surprises only affect those futures contracts covering the next FOMC meeting and after (similar to the "path factor"). The second ingredient is that we carefully control for the potential release of internal Fed information regarding economic fundamentals during FOMC press

[1]This decomposition can be extended to include alternative forms of monetary surprise, such as those relating to asset purchases (Swanson, 2021, 2024) or "timing" forward guidance surprises (Gürkaynak, 2005; Altavilla et al., 2019).

[2]Note that the study of Swanson (2024) was released when our paper was in the revision stages at the present journal.

conferences (Romer and Romer, 2004). Our two surprises are separately purged of this "Fed information effect" by regressing them on internal Fed forecasts (Greenbook data). The third ingredient is that we use the purged surprises directly as endogenous variables in a medium-scale Bayesian VAR (using a so-called "Hybrid VAR" approach), instead of using them as instruments in a Proxy SVAR setup. The use of a Hybrid VAR means our study avoids certain problems that have plagued related Proxy SVAR treatments of forward guidance shocks, since these shocks are known to suffer from weak instrument issues (Gertler and Karadi, 2015), as well as concerns relating to a lack of invertibility (Ramey, 2016).

Controlling for internal Fed information through purging regressions has become standard procedure in econometric studies using high-frequency monetary policy surprises (Barakchian and Crowe, 2013; Miranda-Agrippino, 2016; Miranda-Agrippino and Ricco, 2021; Zhang, 2021).[3] However, when removing information effects, a number of influential contributions do not separately consider the role of orthogonalised action and communication surprises. Researchers have tended to examine measures of monetary policy surprises that aggregate both actions and communication about the future, arguing that the resulting surprise series will simply reflect the role of both. For example, Barakchian and Crowe (2013) and Nakamura and Steinsson (2018) study the first principal component of asset prices linked to future interest rates. Other studies choose to employ a single futures contract at a relatively short-term horizon to encapsulate changed expectations regarding interest rates (Gertler and Karadi, 2015; Miranda-Agrippino, 2016; Miranda-Agrippino and Rey, 2020; Miranda-Agrippino and Ricco, 2021). In these treatments no distinction is made between action and communication surprises, unlike in our setup.

Prior to purging, the action and communication shock series we examine are conceptually similar to the target and path factors of GSS. The main difference is that we eschew a factor-based approach, and instead apply recursive restrictions to futures movements relating to the concurrent meeting, and the meeting following this. For the purposes of our study, this approach has two advantages. The first is that the strength of information effects has been shown to vary with the horizon of the contract (Paul, 2020; Zhang, 2021). Our specification allows us to examine surprise Fed communication at different horizons, while information effects are allowed to vary with the horizon of the futures contract. Indeed, we report evidence that our Hybrid VAR specifications alone are sufficient to remove information effects relating to the path factor, but that additional Greenbook purging regressions are necessary for surprises constructed from the shorter portion of the yield curve. The second, related, reason is that our surprise series are comparable to those specifications that use shorter horizon futures only (Barakchian and Crowe, 2013; Gertler and Karadi, 2015; Miranda-Agrippino and Ricco, 2021). One general conclusion

[3] Alternative methods impose sign-restrictions on the responses of inflation-linked swaps or equities within the narrow window to extract information effects (Matheson and Stavrev, 2014; Andrade and Ferroni, 2021; Jarociński and Karadi, 2020; Cieslak and Schrimpf, 2019; Goodhead, 2024). See also Zhu (2023) and Jarociński (2024).

from our study is that discrepancies in results across related papers may originate from the exact futures contracts incorporated into surprise series, since the effects of purging regressions are shown to vary by futures contract.

In our first investigations we look at the period before the Global Financial Crisis in 2008, using surprises linked to federal funds futures contracts that reach out a maximum of five months into the future. In this sample, we robustly show that the communication component of monetary policy has stronger effects on macroeconomic variables than the action component. This is true whether we purge the surprises of information effects or not. In our preferred specification, we study purged action and communication shocks that have comparable effects on expectations regarding the federal funds rate next month (implying an increase by 2.4bps). We find that the action shock contracts industrial production by 0.17% after 25 months. In contrast, a communication shock of comparable size leads to a contraction of 0.34% after 18 months, twice as large as for the action shock.

When instead looking at the responses of *unpurged* surprises—those not regressed on Greenbook forecasts—we robustly do not find real activity puzzles, in contrast to Campbell et al. (2012) and Nakamura and Steinsson (2018). We argue that our Hybrid VAR specification helps avoid these puzzles: incorporating surprises as endogenous variables within the VAR is sufficient to deliver output responses in line with theory. However, purging the communication surprise does matter for *prices*, insofar that it improves on weak or puzzling CPI responses. This suggests the added usefulness of orthogonalising surprises with respect to Greenbook data mostly relates to the nominal impact of the communication surprise.

Examining the transmission mechanism, we find strong and persistent effects of Fed communication on macroeconomic uncertainty, sentiment and financial conditions. Communication surprises have a hump-shaped effect on the Excess Bond Premium (Gilchrist and Zakrajšek, 2012). Thus, a persistent financial tightening explains part of the forceful effect of communication surprises.

In our study we examine responses to two purged monetary policy surprises, embedded directly in a Hybrid VAR. This sets it apart from many studies that instead estimate Proxy SVARs, using high-frequency surprises as instruments for the monetary policy shock. The Proxy SVAR approach requires the assumption that the surprise is orthogonal to the endogenous variables, other than through its effect on a given structural shock. Hybrid VARs, in contrast, simply add the surprises as additional variables into the system. In general, researchers using Proxy SVARs have often reported weak instrument issues when attempting to utilise orthogonalised surprises as instruments (Gertler and Karadi, 2015). This may explain the tendency to focus on more reduced-form measures of the surprise, i.e. looking at one factor or one futures contract only.[4] Our Hybrid VAR approach does not suffer from weak instrument issues,

[4]For discussions, see Gertler and Karadi (2015), Bauer and Swanson (2023a), and the appendix of Bundick and Smith (2020).

and we are therefore able to consider the effects of numerous surprises in a comparable manner, without having to search for particular points on the yield curve for which instruments are not weak.

Beyond weak instrument issues, there are other reasons to believe that Hybrid VARs are well suited to the study of communication shocks. A number of authors have argued that Proxy SVARs may not be appropriate for the case of forward guidance shocks, since these represent a form of news surprise, and therefore a type of non-fundamental shock that cannot be recovered from the vector of data in the VAR (Ramey, 2016; Bundick and Smith, 2020).[5] Miranda-Agrippino and Ricco (2023) emphasise that Hybrid VARs can be used in cases of non-invertible shocks, and suggest comparing Proxy SVAR responses to Hybrid VAR responses as a means to establish the severity of such issues. In a similar vein, Plagborg-Møller and Wolf (2021) argue that surprises are best modelled endogenously within the VAR system. Bauer and Swanson (2023a) have recently argued in favour of using lagged realised data in order to control for confounding effects relating to the inability of market participants to differentiate between monetary policy surprises and changes to the central bank reaction function. Earlier Hybrid VAR treatments, such as Barakchian and Crowe (2013), implicitly perform such purging operations by including the shock series as an endogenous variable within the system. A Hybrid VAR will also control for any potential auto-correlation of the high-frequency shock series, a property that has been documented in several studies (Ramey, 2016; Miranda-Agrippino and Ricco, 2021). Therefore, the Hybrid VAR automatically incorporates many features that have recently been emphasised as "best practice" for the study of high-frequency monetary policy surprises (Bauer and Swanson, 2023a).

The two most closely related studies to ours are the interesting contributions of Lakdawala (2019) and Degasperi and Ricco (2021). Both distinguish between conventional monetary policy and forward guidance shocks in Proxy SVAR setups, by employing factors based on Gürkaynak et al. (2005), which are purged of internal Fed information. Unlike our study, both papers report some responses to shocks relating to Fed communication that are contrary to theory. While Lakdawala (2019) does find a response of industrial production in line with theory when the shock is purged, the reported responses are insignificant at all horizons. Moreover, his study finds price puzzles across all specifications for the forward guidance shock. Degasperi and Ricco (2021) report puzzling responses of the excess bond premium and real exchange rate for their path factor shock, and find statistically significant effects on prices only in the very short run. We argue that the effects of Fed communication and forward guidance shocks can be heavily influenced by the VAR specification. Indeed, when we repeat our analysis using a Proxy SVAR approach we also obtain some puzzling results.[6] Like us, Bundick and Smith (2020) employ a Hybrid VAR to study monetary policy effects. Unlike these authors, however, we control for the information ef-

[5] Ramey (2016) finds unstable results for high-frequency surprises in Proxy SVARs and local projections and argues that for forward guidance, specifications in which measures of news are treated as endogenous variables are preferred.

[6] We use the VAR-X representation of the Proxy SVAR, following Paul (2020).

fects of FOMC announcements. Overall, we find that Proxy SVARs display many anomalous responses for our sample period, and we favour our baseline Hybrid VAR specification.

We additionally contribute by studying how information effects vary with the horizon of the communication signal. We create a sequence of communication shocks by orthogonalising surprise movements in yields at progressively longer horizons with respect to the action surprise. We then infer the strength of information effects at given points of the yield curve by examining the extent to which a second orthogonalisation, this time with respect to internal Fed information, alters impulse responses. Again, we find little evidence for strong information effects in the responses of industrial production. Nor do we find price puzzles for unpurged communication surprises with horizons more than one year into the future. Moreover, the effect on real activity tends to decrease in the horizon of the surprise studied, contravening predictions from theoretical frameworks in which surprises about interest rates at longer horizons have greater effects (Del Negro et al., 2023). Although Fed communication with a two-year horizon has plausible macroeconomic effects in our sample extending until mid-2008, its effects on output are smaller than for communication with a three-month horizon. Our overall conclusion from these exercises is that for the pre-crisis period, information effects seem more prominent for communication shocks relating to the short-to-medium portion of the yield curve, and are less evident for shocks relating a year or more into the future.

Finally, we document the importance of central bank communication during the effective lower bound (ELB) episode. For this sample, we use Eurodollar futures, which have longer horizons than federal funds futures and remained liquid even during the ELB period. We look at responses to Eurodollar contracts corresponding to communication surprises at respective horizons of one, two and three years into the future, which we orthogonalise recursively. We are among the first to show results of such communication shocks purged by Greenbook forecasts, which became available for the ELB period only in 2020. We contrast results for the whole sample for which Greenbook purging is feasible (March 1994 to December 2015) to those from the ELB sub-sample (July 2008 to December 2015)—in line with studies arguing that information effects in the US case may be confined to sub-periods (Lunsford, 2020; Hoesch et al., 2023). The results again underline the importance of communication. In particular, surprise communication with a two-year horizon appears most powerful during the ELB period, consistent with theoretical predictions regarding the effects of Fed forward guidance.

The paper is structured as follows. Section 2 introduces our empirical approach. Section 3 presents results for the sample 1994-2008. Section 4 investigates robustness and compares our Hybrid VAR with a Proxy SVAR setup. Section 5 looks into the effects of communication across horizons. Section 6 presents results for a sample covering the ELB period. Section 7 concludes.

2 Empirical Specification

This section outlines our empirical approach. We describe how we map futures price changes into changes in market expectations during FOMC meetings about policy rates valid in two time intervals: before the next FOMC meeting in the future and after it. As Fed communication about its future actions will only affect policy rates after that future meeting, we separate action from communication shocks by placing a zero restriction on the change in market expectations before the next FOMC meeting for communication shocks. The structural shocks are then separately purged of the effects of Fed information transmission by orthogonalising them with respect to internal Fed Greenbook forecasts. Finally, we outline the Bayesian Hybrid VAR that we use to trace the dynamic effects of our shocks.

From futures prices to anticipated rate changes between future FOMC meetings. Federal funds futures allow one to bet on the average level of the federal funds rate in future months. The Fed has been explicitly announcing its federal funds rate decisions since March 1994, which marks the start of our sample. From March 1994 to June 2008, six futures contracts, relating to federal funds rate levels in the concurrent month until five months into the future ("FF1" to "FF6"), are liquid enough to be used in our analysis (Barakchian and Crowe, 2013). Our treatment of the futures contracts is close to that of Gürkaynak (2005), though we introduce an iterated weighted averaging procedure to incorporate information from months without meetings.

We are interested in how FOMC press conferences shift market expectations about policy rates in two different time intervals—between today's meeting in month t and the first FOMC meeting in the future, and after that future FOMC meeting. We transform daily futures data into expectational changes with respect to FOMC meetings taking place eight times a year (around every six weeks and at most once per month). The shift in market expectations about policy rates prior to the next future meeting will be reflected in the contemporaneous futures contract. If there is no meeting in the following month, the movement of that month's future will reflect the same information. As this expectational change will only be affected by Fed *actions* in month t, we denote it by $\Delta\rho_t^A$. Moreover, we denote the change in the expected rate after the next meeting by $\Delta\rho_t^C$, because this change in expectations will be also be affected by Fed *communication* in month t about potential changes in the next meeting.

Figure 1 illustrates this decomposition for the historical FOMC meeting of May 17, 1994. The FOMC meeting schedule is published one year in advance and is thus known to markets. We start with changes in federal funds futures during the FOMC meeting day, from the concurrent month (May 1994) up to five months into the future—$\Delta f_t^{(0)}$ to $\Delta f_t^{(5)}$. We seek to map these into today's changes in market expectations about policy rates before and after the next FOMC meeting (July 6)—$\Delta\rho_t^A$ and $\Delta\rho_t^C$.

[Figure 1 about here]

First, we obtain $\Delta\rho_t^A$ from the futures rate change for the concurrent month, $\Delta f_t^{(0)}$, corrected for the days that have already passed before the current FOMC meeting (May 17 in Figure 1), following Kuttner (2001). If no FOMC meeting takes place in the next month (as for June in our example), we can use the additional information from $\Delta f_t^{(1)}$ by setting $\Delta\rho_t^A$ equal to an average of the (corrected) $\Delta f_t^{(0)}$ and $\Delta f_t^{(1)}$, weighted by the days for which these are valid.

Second, note that the futures movement for the month of the next FOMC meeting (July 6 in our example) will be an average of $\Delta\rho_t^A$ and $\Delta\rho_t^C$, weighted by the days in the month before and after the meeting day. So given $\Delta\rho_t^A$ and $\Delta f_t^{(2)}$, we can solve for $\Delta\rho_t^C$. Again, we potentially utilise extra information from the ensuing month if there is no meeting ($\Delta f_t^{(3)}$), weighted by the number of days in the respective months. Note that this is not the case in our example as there is a meeting in August.

Importantly, we only rely on *scheduled* meetings here, as our shock identification depends on markets knowing the date of the next FOMC meeting in the future.[7] Appendix 2 provides further technical details on our conversion of futures rate changes $f_t^{(n)}$ to the $\Delta\rho_t^j$.

Action and communication shocks. Given changes in market expectations about policy rates between the current and the first future FOMC meeting ($\Delta\rho_t^A$), and after that future meeting ($\Delta\rho_t^C$), we want to identify the structural shocks that generate these surprises. Target rate changes by the Fed are highly persistent (Coibion and Gorodnichenko, 2012), and therefore any rate decision announced during the FOMC meeting will shift market expectations across our six-month spectrum of maturities. This is conceptually similar to the "target factor" in GSS. An unexpected policy rate change by the FOMC will therefore lead to an updating of expectations about current as well as future rates, meaning both of our expectations measures $\Delta\rho_t^A$ and $\Delta\rho_t^C$ will be affected. We refer to these surprise announcements of immediate policies as *action shocks*.

On the other hand, the Fed may simultaneously deliver independent surprise information relating to future policy. Surprise communication about potential policy actions in the next meeting, referred to as *communication shocks*, ought to affect all futures rates after this next meeting, i.e. $\Delta\rho_t^C$, but not rates before them, $\Delta\rho_t^A$ (in their factor-based setups, GSS, Altavilla et al., 2019 and Swanson, 2021 similarly assume that their respective "path", "timing", "forward guidance", "LSAP" and "QE" factors are orthogonal to contemporaneous futures contracts). This recursive feature motivates the use of a Cholesky

[7] The occurrence of unscheduled meetings will only bias our shock measures if the market expectations about the likelihood of an unscheduled meeting are changed *during the day* of the previous (scheduled) FOMC meeting. From inspection of the minutes, the committee has never hinted at unscheduled meetings during the preceding meeting (see Appendix 1). Therefore, we do not believe that unscheduled meetings present a concern. We could additionally create measures of expectation changes for policy rates between the next meeting, and the one after that. Experimentation showed that such a second communication shock, orthogonal to the first one, did not yield meaningful responses. This is in line with the finding by GSS that two factors are sufficient to capture the futures-spectrum dynamics before the 2008 financial crisis.

decomposition of the vector of expectational changes, $[\Delta\rho_t^A, \Delta\rho_t^C]$. We refer to the second surprise as "communication shocks" since we interpret these surprises as the provision of information relating to future actions by the Fed, orthogonal to actions taken today. Note, however, that we do not distinguish between news and noise in this study (Beaudry and Portier, 2006; Barsky and Sims, 2012), nor separately examine the *manner* of communication (see Hansen and McMahon, 2016 for a study partialing out the separate roles of textual signals).

Formally, the changes in expectations about the future monetary policy rate, $\Delta\rho_t^A$ and $\Delta\rho_t^C$, are decomposed into two orthogonal shocks: surprises about monetary decisions today (the action shock, ε_t^A), and surprise communication about potential future actions (the communication shock, ε_t^C) as follows:

$$\Delta\mathbf{R}_t \equiv \begin{bmatrix} \Delta\rho_t^A \\ \Delta\rho_t^C \end{bmatrix} = \begin{bmatrix} m_{11} & 0 \\ m_{21} & m_{22} \end{bmatrix} \cdot \begin{bmatrix} \varepsilon_t^A \\ \varepsilon_t^C \end{bmatrix} \equiv \mathbf{M} \cdot \varepsilon_t. \tag{1}$$

Rearranging, we obtain the expression for the vector of structural shocks, $\varepsilon_t = \mathbf{M}^{-1} \cdot \Delta\mathbf{R}_t$, where $\mathbf{M}$ is the lower-triangular Cholesky decomposition of the variance-covariance matrix of $\Delta\mathbf{R}_t$. Note that, by construction, our communication surprises will be present (to some degree) for every event day in our sample, irrespective of whether the FFR does or does not move.

Our action and communication surprises employ a recursiveness assumption on the contemporaneous futures contract, in the tradition of GSS. However, our construction of the surprises does differ from the GSS "target" and "path" factors. The first main difference is that we only rely on federal funds futures between 0 and 5 months out (FF1 to FF6) to construct the surprises, while GSS include several longer-horizon yield responses (up to one year into the future). In investigations reported in Appendix 4.2, we confirm that our communication surprise is more closely related to the short-to-intermediate portion of the yield curve (two to six months), relative to the path factor of GSS, which correlates more strongly with longer-horizon interest rate futures. In line with this, correlations between the GSS target factor and our action shock, and between the GSS path factor and our communication shock, are large, but well below one.[8] The second main difference is that we eschew a factor-based approach, and simply apply the recursiveness assumption to a vector of (re-weighted) futures movements relating to the concurrent FOMC meeting, and the meeting following this.[9] In later extensions, we apply the recursiveness assumption to futures contracts at sequentially greater horizons into the future. For the purposes of our investigations, there are two main advantages to our implementation of the recursiveness assumption. The first advantage is that the implications of Greenbook purging regressions can vary with the horizon of the contract (Paul, 2020; Zhang, 2021). Our approach allows the relation between asset price

[8]The correlation of our action shock to the GSS target factor is a significant 0.87 and that of our communication shock with the path factor a significant 0.58, while cross-correlations are very small and statistically insignificant, see Appendix 4.2.

[9]We also use incorporate an iterated weighted averaging algorithm when preparing the futures data, which differs to that of Gürkaynak (2005), as discussed in the Appendix.

responses and internal information to vary with horizon of the forward curve. This will prove useful for our later investigations of (purged) communication shocks at different horizons. The second advantage of our approach is that it allows for comparability between our study, and influential related studies that focus on the shorter portion of the yield curve when constructing shocks (Barakchian and Crowe, 2013; Gertler and Karadi, 2015; Miranda-Agrippino and Ricco, 2021). Generally, our results suggest that differences in findings across studies employing purging regressions could relate to the fact that these relations can vary markedly, depending on the exact futures contracts used to construct the shock.

Purging of Fed information effects. Having extracted action and communication shocks, we separately orthogonalise the changes in expectations ε_t^A and ε_t^C with respect to Fed Greenbook forecasts, in order to remove any potential transmission of internal information. It is important to emphasise that here we are separately purging orthogonalised surprises. This is unlike a number of other influential studies in this area (Barakchian and Crowe, 2013; Miranda-Agrippino and Ricco, 2021), who purge reduced-form surprises, which are correlated with both action and communication components. Greenbook forecasts are made public with a lag of five years and are therefore unknown by market participants at the time of FOMC announcements. The final purged surprises, denoted $\tilde{\varepsilon}_t^j$ where $j \in \{A, C\}$, are the residuals from an OLS regression of ε_t^j on a vector of Greenbook forecasts for the month of the FOMC meeting day, GB_t. We include the following Greenbook variables: (1) contemporaneous unemployment; (2) contemporaneous output growth and its lag and first two forecasts; (3) the GDP deflator and its lag and first two forecasts; (4) the previous values of the output growth forecasts; (5) the previous values of the GDP deflator forecasts. We include lagged values of the Greenbook values following observations in Campbell et al. (2017) that information from Greenbook data appears to transmit to high-frequency surprises with some delay, meaning that lagged values are significantly correlated with the surprises. The purged shock measures are therefore constructed as $\tilde{\varepsilon}_t^j \equiv \varepsilon_t^j - \hat{\beta}_{GB} \cdot \text{GB}_t,\ j \in \{A, C\}$.

We show the results from our purging regression in Table 1 in the Appendix. Although individual explanatory variables are significantly correlated with both surprises, the p-value associated with the F-statistic of our purging of the communication surprise is only borderline significant, with a value of 0.12. However, we choose to follow a conservative approach by adding many potential Greenbook variables. The R^2 of the regressions is rather low, which is a common finding of the literature (Lakdawala, 2019; Miranda-Agrippino and Ricco, 2021). Nevertheless, despite the low R^2, we will establish that the purging regressions do influence the estimated responses of variables in our system, particularly the response of prices to the communication shock. Appendix 4 displays our unpurged and purged shock measures and documents their correlation to other measures of monetary policy shocks identified using futures data. Note that, unlike Miranda-Agrippino and Ricco (2021), we do not employ a second-stage purging regression on the lags of the extracted surprise. This is because our Hybrid VAR specification allows us to examine responses to shock series that are internally orthogonalised relative to lagged values of the shock, since the shock is included as an endogenous series. This is conceptually very similar to the second-stage purging of Miranda-Agrippino and Ricco (2021), and was also a property of the Hybrid VAR in Barakchian and Crowe (2013).

Our empirical BVAR model. We gauge the effect of our two measures of policy surprises on a set of monthly macroeconomic variables using a structural Bayesian VAR model of the following form:

$$\mathbf{Y}_t = \mathbf{C}_c + \sum_{l=1}^{p} \mathbf{C}_l \mathbf{Y}_{t-l} + \mathbf{D}\nu_t, \tag{2}$$

where $\mathbf{Y}_t = [\mathrm{Y}_t^{macro}\ S_t\ \mathrm{Y}_t^{fin}\ ]'$ is of dimension $(n\times 1)$, and where the variance-covariance matrix of the $(n\times 1)$ vector of Gaussian errors, ν_t, is given by Σ_ν. We take $\{\mathbf{Y}_t\}_{t=1}^{p}$ to be given as initial conditions. We assume $\mathbf{C}_c$ is an $(n\times 1)$ vector of intercepts, and $\{\mathbf{C}_l\}_{l=1}^{l=p}$ are the $(n\times n)$ coefficient matrices associated with each lag l of the vector of endogenous variables. Here Y_t^{macro} denotes the row vector of (slow-moving) macroeconomic variables, and Y_t^{fin} denotes the row vector of (fast-moving) financial variables. The set of variables within Y_t^{macro} are (log) industrial production, (log) CPI, the unemployment rate, and (log) real estate loans. The set of variables within Y_t^{fin} are the federal funds target rate, the one-year Treasury yield, the EBP, and the VIX.[10] We enter a zero value for the surprise series for the months without meetings, as in Barakchian and Crowe (2013). We then cumulate the surprises over time to form a monthly time series in levels, S_t.[11] We only ever enter one surprise into the VAR systems at a time, meaning that when we compare responses to different surprises, we do so in different systems.[12]

We make the assumption that $\mathbf{D}$ has a recursive structure, which implies, as in Romer and Romer (2004) and Barakchian and Crowe (2013), that monetary policy surprises do not affect the macroeconomic variables in the same period. We order the shocks before the financial and interest rate variables in the vector, meaning these surprises are allowed to affect these series contemporaneously (see for example Bundick and Smith, 2020).[13] We choose twelve lags ($p = 12$).

[10]Data are taken from the monthly macro-dataset of McCracken and Ng (2016) and the FRED database of the Federal Reserve St. Louis. The VIX and EBP are monthly averages. The two interest rate variables are converted to monthly frequency using end-of-month values. This ensures that our identified shock precedes the monthly interest rate observations chronologically. Were we to use monthly averages, we would bias our estimate of the impact effect of the shock downward, since the average would include n days of data from the period before the shock, when the shock comes from a meeting on the nth day.

[11]These series are I(1) by construction, and are entered directly into the VAR in this form (as in Romer and Romer, 2004, and Barakchian and Crowe, 2013). Here the argument of Sims et al. (1990) should hold that "the OLS estimator is consistent whether or not the VAR contains integrated components, as long as the innovations in the VAR have enough moments and a zero mean, conditional on past values of the endogenous variables" (p. 113).

[12]This avoids orthogonalising shocks twice and prevents small endogenous reactions between the lags of the two surprise series. It also facilitates comparison to one-shock systems deployed in many other papers. Results are virtually unchanged, however, when we include both surprises simultaneously, with the action surprise ordered before the communication surprise. This is true both when we enter the orthogonalised series or raw futures movements into the VAR (results available upon request).

[13]The recursiveness assumption is not strictly necessary if the high-frequency surprises are already exogenous. We impose recursiveness in order to purge any remaining information effects from the surprises. Essentially, this operation directly

We estimate the VAR using Bayesian methods, using a Normal inverse-Wishart prior according to the standard Minnesota scheme, implemented using dummy observations. We provide detailed information about the implementation of the prior in Appendix 5, and only briefly summarise the main features of the estimation strategy here. We set the prior mean for each variable to imply that variables depend only on their own first lag. We vary the prior for the mean of the first auto-correlation coefficient according to whether the variable is stationary (when the prior mean is set to zero) or non-stationary (in which case the prior mean is set to equal one), see Bańbura et al. (2010). Although our system has a large number of parameters, the use of Bayesian methods handles this by allowing for a degree of shrinkage towards the prior. In our scheme the overall level of shrinkage is determined by the parameter λ, which we set to 0.2. The prior for the intercept has a zero mean, and a large variance (10^5). We set the scale matrix for the inverse-Wishart prior distribution of the error term to $\text{diag}(\sigma_1^2, \ldots, \sigma_n^2)$, where σ_j indicates the standard deviation of the residual from OLS estimation of a p-order auto-regressive process. We set the parameter governing the degrees of freedom of the inverse-Wishart distribution, υ_0, to 2. To conduct inference we draw directly from the posterior distribution, which can be expressed analytically, using Monte Carlo sampling.

3 Baseline Results

Responses to unpurged action and communication surprises. Figure 2 displays the impulse responses of key macroeconomic variables for BVAR systems in which we include the unpurged action and communication surprises, i.e. surprises that have *not* been orthogonalised with respect to internal Fed information. We initially describe the responses of (log) industrial production and (log) CPI, and discuss the responses of other variables subsequently. We report impulse responses to one standard deviation contractionary innovations in the shock series.[14] For comparison, we also include responses to the monetary policy surprise of Barakchian and Crowe (2013), defined as the first principal component of daily movements in the first six federal funds futures.

[Figure 2 about here]

The responses of industrial production (IP) are in line with theory for all of the shocks. A one standard deviation action shock, which is equivalent to a 3.0bp increase in FF1 at meeting day frequency, leads to a contraction in IP, with a minimum of -0.14% after 29 months. In contrast, a one standard deviation communication shock, increasing FF2 by 2.4bp, leads to a larger contraction in IP of -0.40%

controls for information effects relating to contemporaneous macroeconomic shocks. Moreover, recursiveness is often used as a form of "exogeneity insurance" for monetary policy shock measures that are arguably already exogenous, such as narrative or futures-based surprises (Ramey, 2016). We show robustness to a non-recursive Hybrid VAR in Section 4.

[14]Technically, here we refer to the standard deviation of the residual from the BVAR equation containing the shock series.

after 23 months. The action shock also happens to lead to an increase in FF2 of 2.4bp, making the two shocks comparable in terms of their effects on this contract. Both IP reactions are significant for the 68% credible set. Based on the unpurged shocks, we conclude that the communication shock has an effect on IP that is about three times as large as that of the action shock.

Turning to the effects on prices, the median response of the price level to the action shock is positive, contradicting theory, although the zero line lies within the credible set. For the case of the communication shock, however, we find that the sign of the price reaction differs across the horizon of the response. In the short run, we find a statistically significant price puzzle, since an ostensibly contractionary shock leads to a price level increase of 0.04% after 4 months. However, from around 18 months onwards the sign of the response is negative, and the price level continues to fall in the medium run, reaching a minimum of -0.06%. Given these puzzles, we see some prima facie evidence that information effects might be particularly related to the responses of prices, and seem less evident for output.

Figure 2 also shows responses to the first principal component surprise of Barakchian and Crowe (2013). The responses are qualitatively comparable to the baseline system of their paper, and any difference in the shape of the responses will be driven by our use of a Bayesian estimation approach and the inclusion of additional variables. As might be anticipated, responses to this surprise lie somewhere between responses to the action and communication surprise, since the first principal component surprise is correlated with both. Our results indicate that the near-term price puzzle for the Barakchian and Crowe (2013) surprise is driven by the communication component in the unpurged case.

In summary, we observe no output puzzles, even prior to orthogonalising the surprises with respect to Greenbook data. This is in contrast to the puzzles reported in related work, as discussed in the Introduction. Further, we only find statistically robust price puzzles for the case of the communication shock in the short term.

Responses to purged action and communication surprises. Figure 3 shows responses to our surprise measures purged by Greenbook data, our preferred specification. For comparison, we also report the responses to the unpurged shock series, which are identical to those of Figure 2. Impulses are contractionary and of one standard deviation, with the purged action and communication shock respectively increasing FF1 by 2.6bp and FF2 by 2.2bp on meeting days.

[Figure 3 about here]

Orthogonalising the action surprise with respect to Greenbook data has little impact on the IP response, which remains negative. The purging regression, rather than in any sense bringing the price response to the action surprise in line with theory, actually seems to increase it further into positive territory relative to the unpurged case. We therefore do not see evidence that the purging regressions are able to remove price puzzles relating to the action shock. Turning to the orthogonalised communication surprise, we see that the IP response is actually slightly less negative than was the case for the unpurged surprise, with the minimum value being equal to -0.34% at the 18-month horizon. While the purging weakens the output reactions by a small degree, the communication surprise still moves IP by twice as much as the action shock (-0.17% after 25 months). The median response to the orthogonalised communication surprise lies within the credible set for the unpurged case. When we examine the response of the price level, we observe that the orthogonalisation of the communication surprise leads to the removal of the short-run price puzzle previously observed, and the negative medium-run effect increases in absolute value. We therefore conclude that the communication surprise has a greater effect on output than the action surprise regardless of whether it is orthogonalised with respect to internal Fed information, and that the communication surprise affects prices in line with theory only in the case that it is purged of information effects.

Summary and discussion. Our result that Greenbook purging affects communication shocks more than action shocks are consistent in a broad sense with the event-day regressions of Campbell et al. (2012). These authors find greater evidence for information effects relating to the Gürkaynak et al. (2005) path factor relative to the target factor in their 1994 to 2007 sample, when considering the responses of private sector forecasts (for related results, see Paul, 2020). However, Campbell et al. (2012) document more statistically precise counter-intuitive reactions for unemployment, not prices, in this sub-sample. In contrast, for our VAR system the purging of Fed information removes price puzzles from responses to the communication shock, while real activity puzzles were not evident from the beginning.

There are important differences between our results and those of Lakdawala (2019), who studies the responses to monetary policy shocks identified using the target and path factors of Gürkaynak et al. (2005) in a Proxy SVAR setup. Lakdawala (2019) examines the effects on macroeconomic variables of a path factor shock that is orthogonalised with respect to measures of internal Fed information, which is conceptually similar to our study of the purged communication surprise. The responses of macroeconomic variables to the unpurged action surprise in our study are very much comparable to those of Lakdawala (2019)—contractionary actions reduce output and lead to a positive but uncertain effect on prices. However, our findings for communication surprises are very different. We find little evidence for the output puzzle reported in Lakdawala (2019)—our response is significantly negative and large, irrespective of whether the communication surprise is purged with respect to internal information or not. We do find a price puzzle, which however disappears for the purged communication surprise. In contrast, when Lakdawala (2019) uses a purged path factor as an instrument in a Proxy SVAR, the drop in industrial production in response to the purged path surprise is in line with theory but statistically not different from zero at 68% confidence, and there is no mitigation of the price puzzle. We argue below that our results and conclusions differ due to our use of a Hybrid VAR in place of a Proxy SVAR (see Section 4).[15]

Transmission channels. We now discuss the responses of the other variables in the VAR system, in order to understand the transmission mechanisms at play. These results are presented in Figure 4. When we consider the response of the federal funds rate, we note that both the unpurged and purged action shocks increase this rate at impact, which is entirely in line with their interpretation as action shocks. The end-of-month increase in the federal funds rate to the purged action shock is 2.9bp, which is close to the 2.6bp increase in FF1 at meeting frequency associated with a shock of this scale. In contrast, the estimated response of the federal funds rate to the communication shock is very close to zero at impact. This effect was not imposed directly within the VAR system, but follows from the fact that the communication surprises are orthogonal to movements in FF1 contracts on meeting days. The maximum response of the federal funds rate to the purged communication shock is 1.4bp after two months, consistent with our interpretation of the communication shocks as forms of relatively near-term forward guidance, relevant for imminent meetings.

The quantitative reaction of interest rates to the communication shock is rather small relative to their effect on macroeconomic variables. Bauer and Swanson (2023a) report a similar finding from their orthogonalised monetary surprise, and suggest that consumption habits could provide a potential explanation. There is also a relatively persistent endogenous decrease of the federal funds rate in the medium run, reaching a minimum of -12.3bp after 20 months in the purged case. Our estimates indicate that the Fed reacts to the macroeconomic contraction prompted by the communication surprise with monetary expansion in the medium term. Generally, we also observe that the one-year Treasury yield closely tracks the dynamics of the federal funds rate responses, with the main important qualitative difference being that the communication shock affects this yield at impact, since it is not designed to be orthogonal to the prices of such contracts. In the baseline system, neither shock generates persistently contractionary effects on safe rates. However, in Appendix Figure 1 we show evidence that the communication shock tends to drive up interest-rate expectations by financial markets (summarised by Eurodollar futures), professional forecasters and households (constructed from survey-based measures). In Appendix Figure 2 we show evidence that the action shock increases corporate yields, as well as mortgage rates. We do therefore report contractionary impacts on interest rates (or their expectations) in expanded VAR systems. In any case, it is well known that monetary policy shocks influence

[15] Another difference is that Lakdawala (2019) uses a measure of FOMC private information that is constructed as the difference between Greenbook and private sector (Blue Chip) forecasts, following Barakchian and Crowe (2013), whereas we favour the use of Greenbook data (as do Miranda-Agrippino and Ricco, 2021). When we make use of forecast differences between Greenbook and Blue Chip as orthogonalisation controls, the drop in IP becomes weaker, although results for our purged communication surprise remain comparable (see Section 4).

measures of financing conditions more broadly (Bernanke and Gertler, 1995; Adrian and Shin, 2010), meaning we can only fully understand transmission when the responses of multiple financial variables are considered.

[Figure 4 about here]

Moving beyond safe rates, we document some evidence in favour of the risk-taking channel of monetary policy (Adrian and Shin, 2010; Bauer et al., 2023), as can be seen from the responses of the excess bond premium (EBP). All of the contractionary shocks raise the EBP on impact. The purged action shock increases the EBP by 3.7bp at impact, and has a very persistent effect, with the median response remaining positive for more than two years. For the communication surprise, the effects on the EBP are even stronger, and display a pronounced hump shape irrespective of whether the purged or unpurged surprises are used.[16] These results are broadly comparable to those of Gertler and Karadi (2015), who also study the effects of high-frequency surprises on the EBP and find an important role for a transmission channel via this variable. However, since we study two orthogonalised monetary policy surprises, as opposed to the use of FF4 in their paper, we are able to shed light on the exact structural components of monetary policy surprises that are likely to give rise to their result. Regarding the role of information effects, purging the action surprise appears to increase its effect on the EBP. For communication surprises, the unpurged EBP response is greater, although it takes place with a delay, and purging the surprise dampens the magnitude of the estimated effect. After purging, the two surprises have a comparable effect on the EBP, though as mentioned the effect of the communication surprise has more of a hump shape.[17]

We also observe effects of both our shocks on uncertainty, sentiment, and broader measures of financing conditions. The VIX, which measures financial uncertainty and risk aversion in equity markets, increases sharply at impact after both shocks. However, the effect on the VIX is quickly reversed, so we conclude that these shocks raise implied volatility, but only for a very short time. To explore this channel further, we have investigated the responses of additional measures of financing conditions, entered on a one-by-one basis into the baseline system. Figure 2 in the Appendix shows responses to these additional variables for our purged surprises. For both shocks, macroeconomic uncertainty as

[16] The oscillatory movements in EBP could be related to some decentralised information and learning or belief updating by market participants (e.g. Townsend, 1983, and more recently Bianchi et al., 2022). Taken together with the interpretation of the EBP as a measure for the effective risk aversion in the financial sector suggested in Gilchrist and Zakrajšek (2012), this might indicate a staggered processing of monetary policy communication by the financial sector.

[17] Caldara and Herbst (2019) have emphasised the importance of the EBP when identifying monetary policy shocks in Proxy SVARs. In additional investigations, we have established that our results hold when we remove the EBP from our VAR system. Results for purged shocks are also robust to additionally purging with an average over daily lags of corporate spreads as in the treatment of the Romer and Romer (2004) shocks in Caldara and Herbst (2019). Therefore, even though the EBP response highlights an important transmission channel, its inclusion is not statistically necessary in our approach. Results are available upon request.

measured by Jurado et al. (2015) increases significantly, consumer sentiment from the Michigan Survey drops, and financial conditions tighten, as seen from the response of the Chicago Fed's National Financial Conditions Index (NFCI). The TED spread measure of risk in inter-bank markets increases for the communication shock, but not the action shock. Lending spreads for firms (BAA spread) and households (30-year mortgage spread) both increase on impact after the shocks. We conclude that both the action and communication surprises have broad-based effects on financing conditions, in addition to their effects on safe rates.

Regarding the reaction of the remaining macroeconomic variables in our baseline system, we find that the response of unemployment is consistent with that of output, with the effect of the communication surprise on this variable being considerably stronger than that for the action surprise. Finally, for the case of real estate loans, action and communication surprises tend to have different effects. For purged shocks, the contractionary action surprise appears to slightly stimulate credit, while the communication surprise reduces it.

Overall, in spite of the differences in the impacts on interest rates across the two shocks, both have similar effects on measures of financing conditions. Fed communication affecting (financial) sentiment and lending conditions is in line with the risk-taking channel of monetary policy.

4 The role of our Hybrid VAR setup and robustness

In this section we explore the robustness of our main findings. First, we examine the role of our recursiveness assumption, and contrast results from our Hybrid VAR with those from a Proxy SVAR. Second, we discuss robustness to the use of alternative controls for our purging regressions.

Alternative VAR specifications. In Figure 4 we reproduce responses for core macroeconomic variables under alternative specifications of our VAR system. In the baseline VAR we applied a recursiveness assumption, in the sense that within the VAR the surprises were orthogonalised with respect to contemporaneous values of slow-moving macroeconomic variables (similar assumptions are applied in Barakchian and Crowe, 2013 and Bundick and Smith, 2020). We consider specifications where this assumption is relaxed, by ordering the shock series first in the vector. We refer to this system as a Hybrid non-recursive VAR. In our second system we employ a form of Proxy SVAR, pioneered by Mertens and Ravn (2013) and Stock and Watson (2012), and follow the VAR-X specification of Paul (2020). It is shown in Paul (2020) that, under certain standard assumptions regarding the exogeneity of the instrument, one can compute (relative) impulse response functions that consistently estimate those of a full Proxy SVAR by simply entering the instrument into an exogenous block. This approach requires that one normalise the response of one of the endogenous variables in the system. We normalise the impact response of the federal funds rate to equal that of the baseline Hybrid VAR for the case of the action surprise, and the impact response of the one-year Treasury yield to the communication surprise.[18] The VAR-X approach does not impose any recursiveness assumptions. To assess the importance of these assumptions in the VAR-X case, we explore specifications where we additionally orthogonalise the surprises with respect to the endogenous variables in the baseline system, before entering the surprise as an instrument in the exogenous block. Specifically, we regress the surprises on: (1) the first lag of all of the endogenous variables; (2) lags one to 12 of the shock itself; (3) the contemporaneous value of the macroeconomic variables. In principle, this places very similar structural restrictions on the behaviour of the responses to the surprise as was the case in the baseline Hybrid VAR, which also ensures that the surprises are orthogonal to lagged data for the endogenous series (including the surprise), and the contemporaneous value of macroeconomic variables.

[Figure 5 about here]

We report results from these exercises for purged shocks in Figure 5 (results for unpurged shocks are shown in Figure 2 in the Appendix). Responses to the Hybrid non-recursive VAR are close to those for the baseline system, implying that the recursiveness assumptions implicit in the baseline scheme do not overly affect results.[19] In contrast, the responses to the VAR-X differ substantially to the baseline, with markedly weaker effects on output and prices recorded throughout, despite the fact the responses are normalised to affect the federal funds rate (for action shocks) and the one-year Treasury yield (for communication shocks) to the same degree.[20] The use of an instrument that has been additionally orthogonalised with respect to contemporaneous values of slow-moving endogenous variables tends to influence the median responses in the direction of our baseline estimates (particularly evident in the responses of the communication surprise in Figure 5), however the magnitudes of the estimates are still not comparable. We conclude that the use of a Hybrid VAR specification does affect results, and indeed this specification was chosen because it is well suited to handle non-invertible communication surprises about the future (Ramey, 2016), controls for any auto-correlation of the shock series due to sticky information (Miranda-Agrippino and Ricco, 2021), and controls for the ability of realised data to predict high-frequency surprises (Bauer and Swanson, 2023a).

[18] We also do this for the previously discussed Hybrid non-recursive VAR, for simplicity.

[19] Note that the counter-intuitive impact reaction of IP to the communication shock (circled line in the upper-right panel) is statistically significant, as is the medium-term decrease from period 7 onwards. The fact that we obtain this output puzzle on impact in the non-recursive Hybrid VAR speaks in favour of our recursiveness assumption. One could interpret such responses as being driven by information effects relating to contemporaneous macroeconomic shocks that are not removed by the Greenbook purging regression, but that we control for with the recursiveness assumption.

[20] These differences also hold for the unpurged case, see Figure 2 in the Appendix. One explanation for the weakness of the Proxy SVAR findings relative to Gertler and Karadi (2015) or Miranda-Agrippino and Ricco (2021) is that we restrict the data sample to the 1994-2008 period for all systems and do not utilise earlier data to estimate the VAR parameters.

Alternative purging regression specifications. We additionally examine the robustness of our results with respect to our purging regressions. Specifically, we use an alternative measure of the information gap between markets and the Fed as controls for the purging. The logic behind this is that a portion of the Greenbook data used as a measure of Fed private information in the baseline specification can be forecast by market participants. One could argue that market participants would only react to the unforecastable component of the information revealed during the event. For this reason we collect survey expectations based on Blue Chip data and subtract these from the associated Greenbook forecast for each event day (as in Barakchian and Crowe, 2013), for an identical set of variables. We then use these measures in place of the controls in our baseline purging regressions.

[Figure 6 about here]

Results are displayed in Figure 6.[21] In general, the use of Greenbook subtract Blue Chip controls weakens the inflation and industrial production responses in absolute value relative to the baseline. One explanation for this finding is that the Greenbook data of the baseline purging regressions serve a dual role. The use of these control variables not only partials out effects that stem from information revelation channels, but also from channels relating to the tendency of high-frequency surprise series to be predictable given realised data series (Miranda-Agrippino, 2016; Bauer and Swanson, 2023a,b). For these reasons, we favour purging using Greenbook data.

5 Information Surprises and Information Revelation across Horizons

In our main results we charted evidence that the communication surprise is contaminated by information effects with respect to its short-term impact on prices, since we observed a price puzzle at the closer horizons for the unpurged shock (though there is a significant drop in prices in the medium term). This issue was removed by an orthogonalisation regression that controls for a Fed information effect. These observed differences in the role of the purging regressions naturally lead to the question as to exactly which part of the yield curve the information channel affects most. In this section we document the changing role of the information effect for communication surprises at different horizons.

Specifically, we extract a communication shock at an extended horizon by increasing the maturity of the forward contract in the Cholesky decomposition of Equation (1), i.e. replacing $\Delta\rho_t^C$ with changes in increasingly "far ahead" interest rate futures contracts or Treasury yields (the latter are taken from the dataset of Gürkaynak et al., 2007). We compare the responses of output and prices to unpurged and purged shocks as we extend the horizon of the second contract in our orthogonalisation scheme.

[21] The coefficient estimates and diagnostic statistics for the purging regressions are reported in Table 2 in the Appendix.

[Figure 7 to be positioned at the end of the paper]

In columns (2) to (5) of Figure 7 we observe little qualitative change from the baseline for responses generated by shocks that orthogonalise FF3 through FF6 with respect to the action shock, though the IP response falls somewhat with the communication horizon. This suggests that the effects of extending the horizon of the communication shock by small amounts into the future are limited. There is an important exception, however. The counter-intuitive positive response of prices one month after the shock, which is not significantly different from zero in the case of the purged baseline communication shock, is now significantly positive for 2 to 5 months after the surprise. The weighting in our baseline case hence seems to improve the ability of the purging regressions to fully remove the observed short-horizon price puzzle.[22]

We start to detect more substantial differences to our baseline results when we extend the measure of the communication surprise to the ED contracts, i.e. surprises based on market expectations for Eurodollar interest rates between one and three years ahead, see column (6) and (7) of Figure 7 and column (2) of Figure 8. In the unpurged case for this surprise, there is no evidence for either an output or a price puzzle. The unpurged output response is less consistently negative than for shocks based on federal funds futures. The price response to this surprise is positive for the first four months, but not significantly so. Purging for Fed information weakens the IP response substantially and shortens the duration of the effect. However, it strengthens the response of prices. Again we conclude that there is little evidence for output or price puzzles even prior to our purging regressions, for communication surprises defined over these medium portions of the yield curve.

[Figure 8 to be positioned at the end of the paper]

Predictably, the responses to communication shocks related to movements in two-year Treasury yields, displayed in column (3) of Figure 8, are similar to that of the ED8 contract, given that the term of these contracts is similar. When considering surprise communication reaching even further out by looking at five- and ten-year Treasury yields in columns (4) and (5), we again observe progressively smaller effects of communication surprises on IP at longer horizons. Moreover, for the ten-year Treasury yield, the price response is somewhat weaker, in both the purged and unpurged cases, and zero values lie within the credible set.

Finally, we study the responses to an alternative measure of a communication-related surprise, the forward guidance (FG) factor developed in Swanson (2021). It shares the property of our surprises in-

[22] A discussion of the impact of the iterative weighted averaging procedure on the responses of macroeconomic variables can be found in the earlier version of this study for a smaller frequentist VAR, see Goodhead and Kolb (2018).

sofar that it is orthogonal to changes in contemporaneous federal funds futures by construction, and is thus uncorrelated with action surprises. In column (6) of Figure 8, we examine responses to the FG surprise computed over all event days studied in Swanson (2021), i.e. inclusive of unscheduled meetings. The IP responses to this surprise look very similar to those documented in response to the other surprises, and a purging regression again seems to weaken the response of real activity. However, the response of prices to the Swanson (2021) surprise is stronger and more sustained than the further forward communication surprises we have previously studied. Again, purging appears to make the depth of the response greater. However, we can observe that the price response of the unpurged FG shock is also negative, in a more persistent manner relative to the longer-horizon communication surprises studied previously. This effect seems to be driven by the inclusion of unscheduled meeting days. When we plot responses to the Swanson (2021) shock defined only over scheduled days in column (7), we note that the price response in the unpurged case is comparable to the response of the unpurged orthogonalised Treasuries responses studied in columns (3) to (5). Overall, the CPI responses to the Swanson (2021) FG surprise look very similar to those following shocks to Eurodollar futures (which are included in the bundle of contracts used for its estimation).

Summary and discussion. This analysis leads to three main conclusions regarding the nature of the information effect. The first conclusion is that in our Hybrid VAR specification we robustly do not observe output puzzles to unpurged surprises. This suggests that in Hybrid VARs like ours, the responses of real activity are not too strongly affected by information effects of the kind documented in Campbell et al. (2012) and Nakamura and Steinsson (2018). Moreover, our purging regressions do not typically increase the magnitude of the output response in absolute value—in fact it is typically reduced. The second conclusion is that, relative to one standard deviation surprises, the magnitude of the IP response tends to attenuate with the horizon of the surprise studied. This is true irrespective of whether we purge these surprises or not. These results would be informative for theoretical treatments attempting to reconcile New Keynesian frameworks with the data. New Keynesian models tend to make the prediction that communication with a longer horizon is more effective (Del Negro et al., 2023), and our investigation provides empirical evidence to the contrary. The third conclusion is that the evidence for puzzling responses of prices to high-frequency surprises is largely confined to surprises constructed from shorter horizons. Surprises with a horizon of more than one year do not exhibit strong evidence of price puzzles. In line with this, we find that Hybrid VAR specifications are sufficient to remove information effects relating to the Swanson (2021) forward guidance factor, which is essentially constructed according to the same assumptions as the GSS path factor. This suggests that additional Greenbook purging regressions may be necessary for those shock series that load more on shorter-term futures contracts (such as our communication shock) and unnecessary for series that are more closely related to the longer end (such as a path factor).

6 Communication Surprises at the Effective Lower Bound

In this section we examine the role of communication surprises until 2015, covering the ELB period. To construct surprises from this period, we utilise Eurodollar futures contracts at horizons greater than or equal to one year. During the ELB period, markets tended not to expect imminent changes in short-term rates, and none were realised, meaning that federal funds futures at short horizons display little volatility. For this reason we do not orthogonalise our Eurodollar derived surprises to changes in those futures, as in the previous analysis. We prefer to recursively regress surprise movements in the Eurodollar contract eight quarters out (ED8) on the Eurodollar contract four quarters out (ED4), taking the residual as a measure of a communication surprise at the two-year horizon. We then define a communication shock relating to ED12 as the component of ED12 that is orthogonal to the ED4 and ED8 communication surprises. This way, we obtain measures of surprise monetary policy communication one, two and three years out. Importantly, this allows us to capture forward guidance, an explicit Fed communication tool generally thought to have an horizon of around two years into the future.[23]

Our orthogonalisation is implemented using a lower-triangular Cholesky decomposition of the variance-covariance matrix formed by daily movements in ED4, ED8, and ED12:

$$\Delta \mathbf{R}_t \equiv \begin{bmatrix} \Delta \mathrm{ED4}_t \\ \Delta \mathrm{ED8}_t \\ \Delta \mathrm{ED12}_t \end{bmatrix} = \begin{bmatrix} m_{11} & 0 & 0 \\ m_{21} & m_{22} & 0 \\ m_{31} & m_{32} & m_{33} \end{bmatrix} \cdot \begin{bmatrix} \varepsilon_t^{C,1} \\ \varepsilon_t^{C,2} \\ \varepsilon_t^{C,3} \end{bmatrix} = \mathbf{M} \cdot \varepsilon_t. \tag{3}$$

In the subsequent discussion we will refer to the surprises $\varepsilon_t^{C,1}$, $\varepsilon_t^{C,2}$, and $\varepsilon_t^{C,3}$ as the ED4, ED8, and ED12 surprises respectively. It should be borne in mind that these surprises are the output of a recursive decomposition, and not the raw movements in Eurodollar contracts themselves. We purge these surprise series using Greenbook data in an identical manner to the procedure followed for the federal funds futures. We keep the VAR system and estimation approach identical to that of the baseline, with one exception. Since the federal funds rate does not move for a sizeable portion of the full sample, to capture monetary policy we include only a measure of long-term rates in the system, namely 10-year Treasury yields.

Figure 9 displays results for the purged Eurodollar surprises. We compare two sub-samples: from March 1994 to December 2015 (full sample) and from July 2008 to December 2015 (financial crisis and

[23]This two-year horizon is in line with FOMC communication on 9 August 2011, stating that then current rates would be appropriate "at least through mid-2013", almost exactly two years into the future (see https://www.federalreserve.gov/newsevents/pressreleases/monetary20110809a.htm.

ELB period).[24] Here we display impulse responses to one standard deviation innovations in the recursively defined Eurodollar communication surprises. In general, dynamics are quite different over the two sub-samples.

For the full sample, the ED4 surprise shows intuitive responses—significant and persistent IP and CPI decreases, an increase in the 10-year rate, and increases in EBP and VIX (albeit statistically insignificant). In contrast, the ED8 and ED12 surprises show some puzzles: a significant decrease in 10-year rates after 3 months and in EBP after 9 months for ED8, and a price puzzle and very weakly significant IP response for ED12. A likely explanation for these puzzling responses is that they result from mixing sub-samples during which monetary policy operated at different horizons.

[Figure 9 about here]

For the post-2008 sample, a different picture emerges. Now the ED4 surprise yields some puzzles, including a robust increase in IP and a strong positive reaction of the price level in the medium run. This gives reason to believe that our purging scheme is less effective at handling information effects at short horizons for this period. In contrast, responses of the variables to the purged ED8 surprise are consistent with theory for the post-2008 sample. The negative IP response is very persistent, with statistical significance for 21 months. The price level falls significantly in response to this shock. The 10-year yield rises by more than 5bp on impact, leading to increases of financial risk aversion and uncertainty as measured by EBP and VIX, between around 6 and 12 months into the future. Overall, communication surprises with a two-year horizon as captured by the ED8 shock have significant macroeconomic effects, with a plausible transmission mechanism. Finally, communication surprises with an even longer horizon of three years yield more transient macroeconomic effects: the ED12 shock causes a persistent increase in the 10-year rate, but only brief hikes in EBP and VIX. This translates into a small initial decrease in IP, followed by a counter-intuitive increase, and an equally puzzling, persistent CPI increase. We conclude that the effect of ED8 surprises are closest to standard theoretical predictions for this sub-sample.

Summary and discussion. Overall, our analysis of the post-ELB period indicates that Fed communication surprises mattered also after 2008, but at a longer horizon. This finding is in accordance with arguments that the Fed was able to conduct monetary policy effectively also during the ELB period (Swanson, 2018; Debortoli et al., 2020). During this period, the Fed used the policy tool of forward guidance, generally thought to have an horizon of two years into the future (Swanson and Williams, 2014). And in fact, our communication surprises pertaining to two years into the future (ED8) are very much

[24] Results for the unpurged case are displayed in Figure 3 in the Appendix. In general, purging ED surprises with respect to internal Fed information makes little difference qualitatively or quantitatively to the responses—in line with the responses to communication shocks derived from Eurodollar futures in the pre-ELB sample above.

in line with predictions on the effects of forward guidance from theory (Del Negro et al., 2023).[25]

7 Conclusion

In this study we use high-frequency futures data to quantify the effects of Fed action and communication surprises, in the spirit of the seminal contribution by Gürkaynak et al. (2005, GSS). We create action shocks as surprise Fed announcements that move federal funds futures across horizons. In contrast, communication shocks are surprise Fed announcements that can only affect futures pertaining to dates after the next FOMC meeting in the future, i.e. linked to communication about future actions. Importantly, we separately purge our structurally decomposed surprises from potential spillovers of internal Fed information using regressions on Greenbook forecasts.

Three broad findings emerge from our study. First, and most importantly, we consistently find that monetary policy communication surprises have stronger macroeconomic effects than action surprises. In our preferred specification for the sample 1994-2008, communication surprises have twice the effect on industrial production as action surprises. While the action shock transmits mostly via interest rates, the communication shock more strongly affects variables related to sentiment, uncertainty and risk aversion in the financial sector.

Second, the choice of a medium-scaled Hybrid VAR instead of the widely used Proxy SVAR specification makes a difference. In contrast to other recent papers contrasting "target" and "path" effects of Fed policy, we do find Fed communication surprises to have strong and significant effects on both output and prices. This is in line with theoretical predictions from New Keynesian frameworks, and in line with the results of GSS for long rates. We argue that Hybrid VARs have many properties that make them well suited to the study of Fed communication, such as their ability to handle non-invertible shocks, and the way they internally orthogonalise surprises with respect to their own lags, as well as realised data.

Third, the horizon of Fed communication matters. We investigate the effects of the communication horizon by looking at shocks from futures contracts reaching increasingly further into the future. For our baseline sample up to 2008, the effect of communication surprises on output diminishes in their horizon—in contrast to the theoretical "forward guidance puzzle" literature (Del Negro et al., 2023). However, we find that after the Global Financial Crisis, there was a shift towards longer-term communication. For our post-2008 sample, characterised by the effective lower bound, communication with a two-year horizon has the strongest effects on output and prices. Overall, and adopting the phrasing of GSS, our findings suggest that regarding the macroeconomic effects of monetary policy, words might

[25]This contrasts to the puzzles for related forward guidance surprises reported in Miranda-Agrippino and Ricco (2023) for a similar sample period in a Proxy SVAR specification.

indeed speak louder than actions.

References

Adrian, Tobias and Hyun Song Shin (2010) "Financial Intermediaries and Monetary Economics," in Friedman, Benjamin M. and Michael Woodford eds. *Handbook of Monetary Economics*, Chap. 12, 601–650: Elsevier.

Altavilla, Carlo, Luca Brugnolini, Refet S. Gürkaynak, Roberto Motto, and Giuseppe Ragusa (2019) "Measuring Euro Area Monetary Policy," *Journal of Monetary Economics*, 108, 162–179.

Andrade, Philippe and Filippo Ferroni (2021) "Delphic and odyssean monetary policy shocks: Evidence from the euro area," *Journal of Monetary Economics*, 117 (C), 816–832.

Bańbura, Marta, Domenico Giannone, and Lucrezia Reichlin (2010) "Large Bayesian Vector Auto Regressions," *Journal of Applied Econometrics*, 25, 71–92.

Barakchian, S. Mahdi and Christopher Crowe (2013) "Monetary Policy Matters: Evidence from New Shocks Data," *Journal of Monetary Economics*, 60 (8), 950–966.

Barsky, Robert B. and Eric R. Sims (2012) "Information, Animal Spirits, and the Meaning of Innovations in Consumer Confidence," *American Economic Review*, 102 (4), 1343–77.

Bauer, Michael D., Ben S. Bernanke, and Eric Milstein (2023) "Risk Appetite and the Risk-Taking Channel of Monetary Policy," *Journal of Economic Perspectives*, 37 (1), 77–100.

Bauer, Michael D. and Eric T. Swanson (2023a) "A Reassessment of Monetary Policy Surprises and High-Frequency Identification," *NBER Macroeconomics Annual*, 37 (1), 87–155.

——— (2023b) "An Alternative Explanation for the "Fed Information Effect"," *American Economic Review*, 113 (3), 664–700.

Beaudry, Paul and Franck Portier (2006) "Stock Prices, News, and Economic Fluctuations," *American Economic Review*, 96 (4), 1293–1307.

Bernanke, Ben S. and Mark Gertler (1995) "Inside the Black Box: The Credit Channel of Monetary Policy Transmission," *Journal of Economic Perspectives*, 9 (4), 27–48.

Bianchi, Francesco, Sydney C. Ludvigson, and Sai Ma (2022) "Belief Distortions and Macroeconomic Fluctuations," *American Economic Review*, 112 (7), 2269–2315.

Bundick, Brent and A. Lee Smith (2020) "The Dynamic Effects of Forward Guidance Shocks," *The Review of Economics and Statistics*, 102 (5), 946–965.

Caldara, Dario and Edward Herbst (2019) "Monetary Policy, Real Activity, and Credit Spreads: Evidence from Bayesian Proxy SVARs," *American Economic Journal: Macroeconomics*, 11 (1), 157–192.

Campbell, Jeffrey R., Charles L. Evans, Jonas D.M. Fisher, and Alejandro Justiniano (2012) "Macroeconomic Effects of Federal Reserve Forward Guidance," *Brookings Papers on Economic Activity*, 44 (1), 1–80.

Campbell, Jeffrey R., Jonas D. M. Fisher, Alejandro Justiniano, and Leonardo Melosi (2017) "Forward Guidance and Macroeconomic Outcomes since the Financial Crisis," *NBER Macroeconomics Annual*, 31 (1), 283–357.

Cieslak, Anna and Andreas Schrimpf (2019) "Non-monetary news in central bank communication," *Journal of International Economics*, 118 (C), 293–315.

Coibion, Olivier and Yuriy Gorodnichenko (2012) "Why Are Target Interest Rate Changes So Persistent?," *American Economic Journal: Macroeconomics*, 4 (4), 126–62.

Debortoli, Davide, Jordi Galí, and Luca Gambetti (2020) "On the Empirical (Ir)Relevance of the Zero Lower Bound Constraint," *NBER Macroeconomics Annual*, 34 (1), 141–170.

Degasperi, Riccardo and Giovanni Ricco (2021) "Information and Policy Shocks in Monetary Surprises," June, *mimeo*.

Del Negro, Marco, Marc P. Giannoni, and Christina Patterson (2023) "The Forward Guidance Puzzle," *Journal of Political Economy Macroeconomics*, 1 (1), 43–79.

Gertler, Mark and Peter Karadi (2015) "Monetary Policy Surprises, Credit Costs, and Economic Activity," *American Economic Journal: Macroeconomics*, 7 (1), 44–76.

Gilchrist, Simon and Egon Zakrajšek (2012) "Credit Spreads and Business Cycle Fluctuations," *American Economic Review*, 102 (4), 1692–1720.

Goodhead, Robert (2024) "The economic impact of yield curve compression: Evidence from euro area forward guidance and unconventional monetary policy," *European Economic Review*, 164 (104716), 1–19.

Goodhead, Robert and Benedikt Kolb (2018) "Monetary policy communication shocks and the macroeconomy," Discussion Papers 46/2018, Deutsche Bundesbank, December.

Gürkaynak, Refet S. (2005) "Using federal funds futures contracts for monetary policy analysis," Finance and Economics Discussion Series 2005-29, Board of Governors of the Federal Reserve System.

Gürkaynak, Refet S., Brian Sack, and Eric T. Swanson (2005) "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," *International Journal of Central Banking*, 1 (1), 55–93.

Gürkaynak, Refet S., Brian Sack, and Jonathan H. Wright (2007) "The U.S. Treasury yield curve: 1961 to the present," *Journal of Monetary Economics*, 54 (8), 2291–2304.

Hansen, Stephen and Michael McMahon (2016) "Shocking language: Understanding the macroeconomic effects of central bank communication," *Journal of International Economics*, 99, 114–133.

Hoesch, Lukas, Barbara Rossi, and Tatevik Sekhposyan (2023) "Has the Information Channel of Monetary Policy Disappeared? Revisiting the Empirical Evidence," *American Economic Journal: Macroeconomics*, 15 (3), 355–387.

Jarociński, Marek (2024) "Estimating the Fed's unconventional policy shocks," *Journal of Monetary Economics*, 103548.

Jarociński, Marek and Peter Karadi (2020) "Deconstructing Monetary Policy Surprises – The Role of Information Shocks," *American Economic Journal: Macroeconomics*, 12 (2), 1–43.

Jurado, Kyle, Sydney C. Ludvigson, and Serena Ng (2015) "Measuring Uncertainty," *American Economic Review*, 105 (3), 1177–1216.

Kuttner, Kenneth N. (2001) "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market," *Journal of Monetary Economics*, 47 (3), 523–544.

Lakdawala, Aeimit (2019) "Decomposing the effects of monetary policy using an external instruments SVAR," *Journal of Applied Econometrics*, 34 (6), 934–950.

Lunsford, Kurt G. (2020) "Policy Language and Information Effects in the Early Days of Federal Reserve Forward Guidance," *American Economic Review*, 110 (9), 2899–2934.

Matheson, Troy and Emil Stavrev (2014) "News and monetary shocks at a high frequency: A simple approach," *Economics Letters*, 125 (2), 282–286.

McCracken, Michael W. and Serena Ng (2016) "FRED-MD: A Monthly Database for Macroeconomic Research," *Journal of Business & Economic Statistics*, 34 (4), 574–589.

Mertens, Karel and Morten O. Ravn (2013) "The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States," *American Economic Review*, 103 (4), 1212–1247.

Miranda-Agrippino, Silvia (2016) "Unsurprising shocks: information, premia, and the monetary transmission," Bank of England working papers 626, Bank of England, November.

Miranda-Agrippino, Silvia and Hélène Rey (2020) "U.S. Monetary Policy and the Global Financial Cycle," *Review of Economic Studies*, 87, 2754–2776.

Miranda-Agrippino, Silvia and Giovanni Ricco (2021) "The Transmission of Monetary Policy Shocks," *American Economic Journal: Macroeconomics*, 13 (3), 74–107.

——— (2023) "Identification with External Instruments in Structural VARs," *Journal of Monetary Economics*, 135 (C), 1–19.

Nakamura, Emi and Jón Steinsson (2018) "High-Frequency Identification of Monetary Non-Neutrality: The Information Effect," *The Quarterly Journal of Economics*, 133 (3), 1283–1330.

Paul, Pascal (2020) "The Time-Varying Effect of Monetary Policy on Asset Prices," *Review of Economics and Statistics*, 102 (4), 690–704.

Plagborg-Møller, Mikkel and Christian K. Wolf (2021) "Local Projections and VARs Estimate the Same Impulse Responses," *Econometrica*, 89 (2), 955–980.

Ramey, Valerie A. (2016) "Macroeconomic Shocks and Their Propagation," in Taylor, John B. and Harald Uhlig eds. *Handbook of Macroeconomics*, Chap. 2, 71–162: Elsevier.

Romer, Christina D. and David H. Romer (2004) "A New Measure of Monetary Shocks: Derivation and Implications," *American Economic Review*, 94 (4), 1055–1084.

Sims, Christopher A., James H. Stock, and Mark W. Watson (1990) "Inference in Linear Time Series Models with Some Unit Roots," *Econometrica*, 58 (1), 113–144.

Stock, James H. and Mark W. Watson (2012) "Disentangling the Channels of the 2007-09 Recession," *Brookings Papers on Economic Activity*, 43 (1), 81–156.

Swanson, Eric T. (2018) "The Federal Reserve Is Not Very Constrained by the Lower Bound on Nominal Interest Rates," *Brookings Papers on Economic Activity*, 49 (2), 555–572.

——— (2021) "Measuring the effects of federal reserve forward guidance and asset purchases on financial markets," *Journal of Monetary Economics*, 118 (C), 32–53.

——— (2024) "The Macroeconomic Effects of the Federal Reserve's Conventional and Unconventional Monetary Policies," *IMF Economic Review*, Published Online 10 June.

Swanson, Eric T. and John C. Williams (2014) "Measuring the Effect of the Zero Lower Bound on Medium- and Longer-Term Interest Rates," *American Economic Review*, 104 (10), 3154–85.

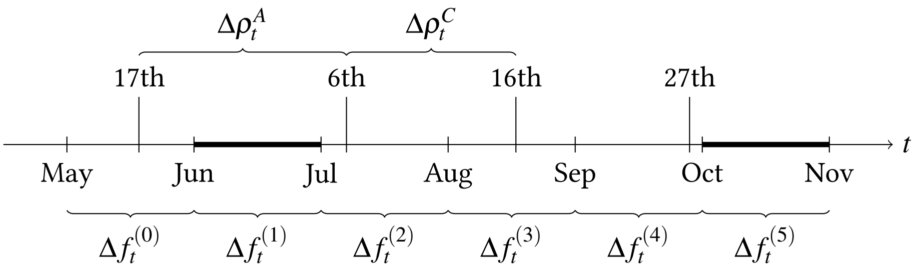
Townsend, Robert M (1983) "Forecasting the Forecasts of Others," *Journal of Political Economy*, 91 (4), 546–588.

Woodford, Michael (2003) *Interest and Prices: Foundations of a Theory of Monetary Policy*: Princeton University Press.

Zhang, Xu (2021) "A New Measure of Monetary Policy Shocks," Staff Working Papers 21-29, Bank of Canada, June.

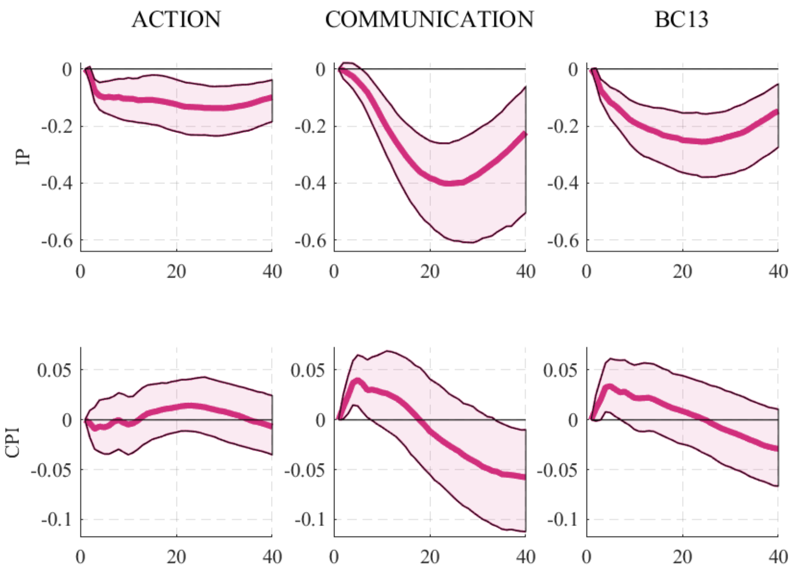
Zhu, Linyan (2023) "Let the Market Speak: Using Interest Rates to Identify the Fed Information Effect," June, *mimeo*.

Figure 1: Illustration—Conversion of FOMC-day Futures Rate Changes to Changes in Rate Expectations



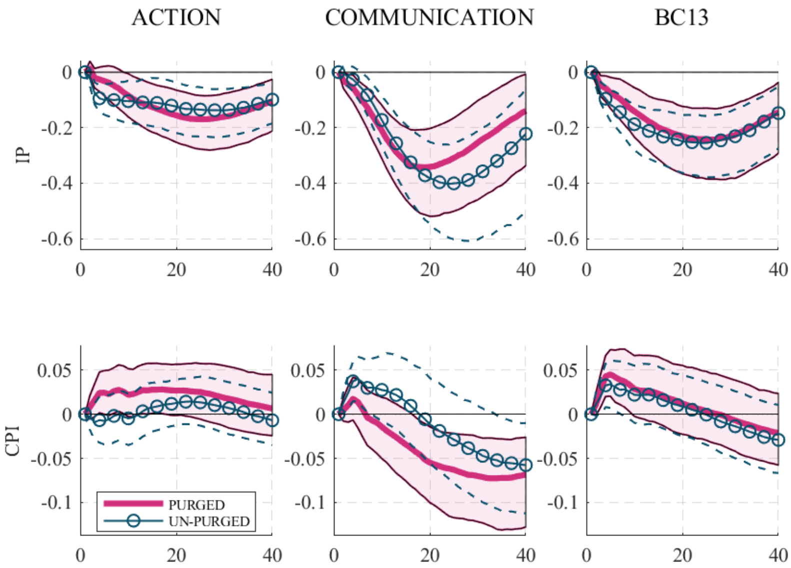
Notes: FOMC meetings between May and November 1994 (known to markets in advance). Months without FOMC meetings are marked by a thick line. We convert changes in monthly futures rates, $\Delta f_t^{(n)}$, into expected federal funds rates between meetings, $\Delta\rho_t^j$, as outlined in the text.

Figure 2: Responses to Baseline Surprises – Unpurged (1994-2008 Sample)



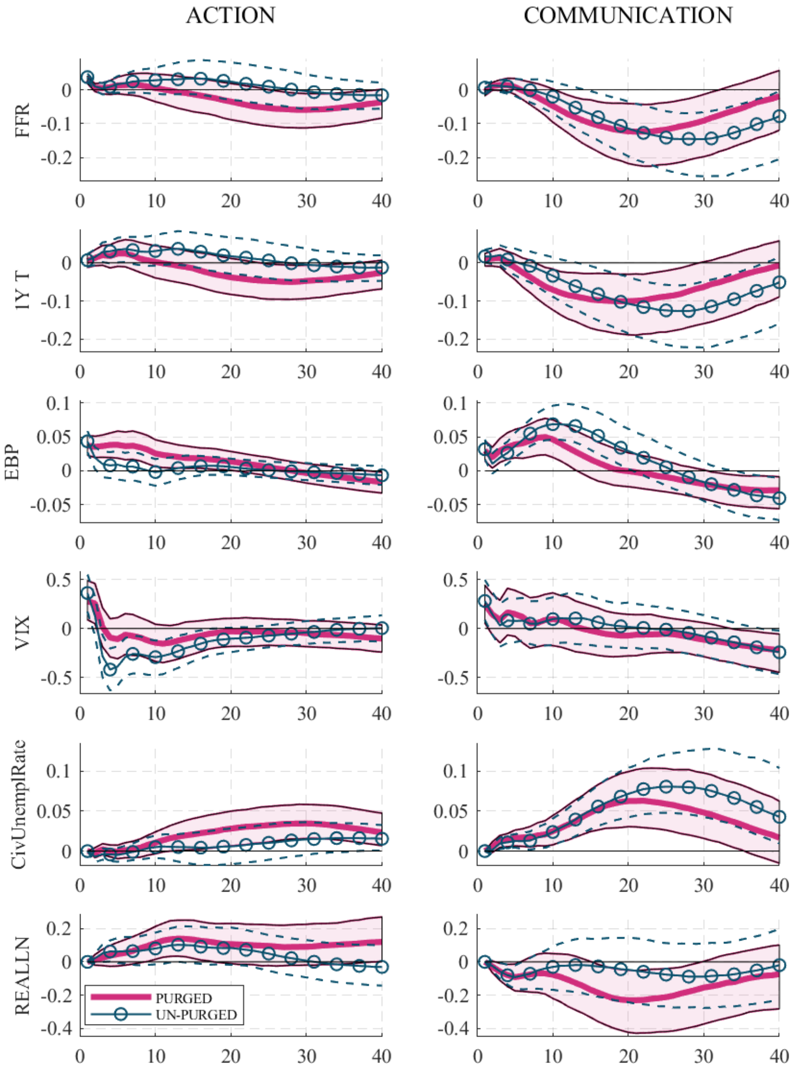
Notes: Results from the baseline Hybrid BVAR specification (sample period: 1994m3-2008m6), for shocks not purged with Greenbook data. The first two columns show responses to our action and communication shock, the third column shows responses to the Barakchian and Crowe (2013) first principal component shock. We display only the responses of (log) IP and (log) CPI from the 9-variable system. The shocks are one standard deviation. We display the 68% credible set. Estimates are derived from 1,000 draws from the posterior.

Figure 3: Responses to Surprises Purged with respect to Internal Fed Information (1994-2008 Sample)



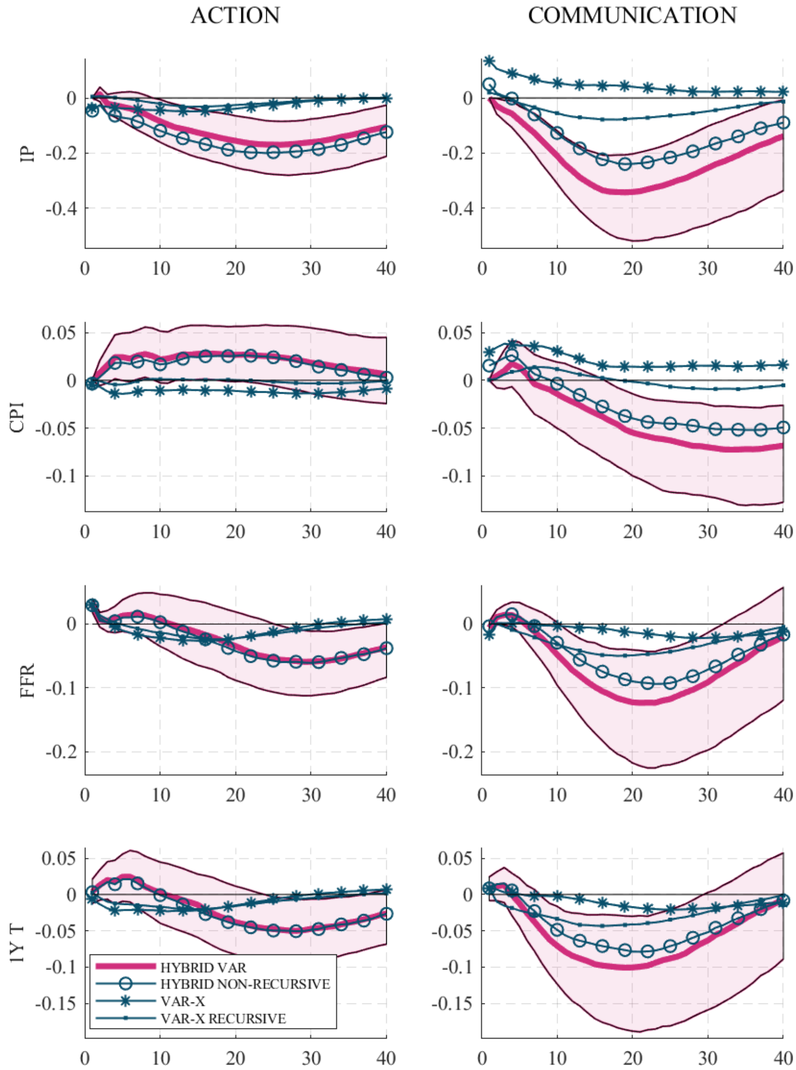
Notes: Results from the baseline Hybrid BVAR specification (sample period: 1994m3-2008m6), for shocks purged with Greenbook data (results for unpurged shocks are also displayed for reference). The first two columns show responses to our action and communication shock, the third column shows responses to the Barakchian and Crowe (2013) first principal component shock. We display only the responses of (log) IP and (log) CPI from the 9-variable system. We display the 68% credible set. Estimates are derived from 1,000 draws from the posterior.

Figure 4: Responses to Surprises, The Transmission Mechanism (1994-2008 Sample)



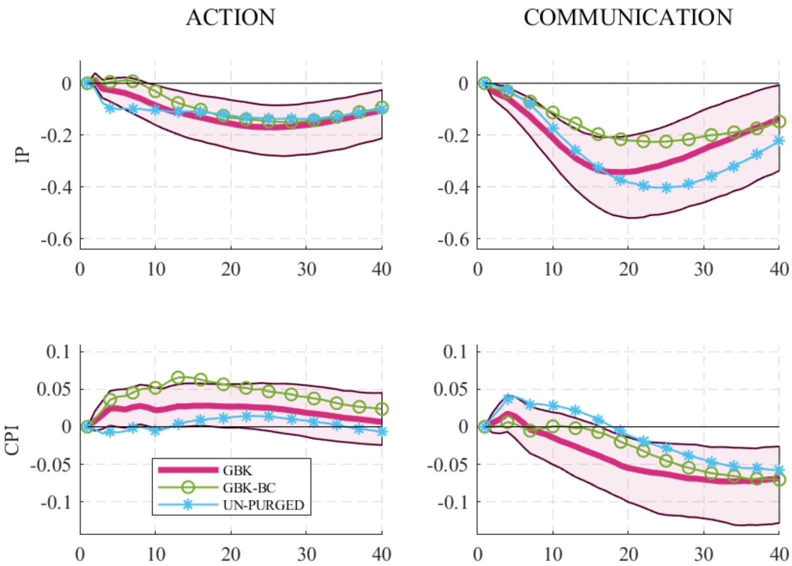
Notes: Results from the baseline Hybrid BVAR specification, for six of the macroeconomic and financial variables in the 9-variable system (sample period: 1994m3-2008m6). The two columns show responses to our action and communication shock. We show responses to shocks purged with Greenbook data and un-purged shocks. We display the 68% credible set. Estimates are derived from 1,000 draws from the posterior.

Figure 5: Comparison With VAR-X: Purged (1994-2008 Sample)



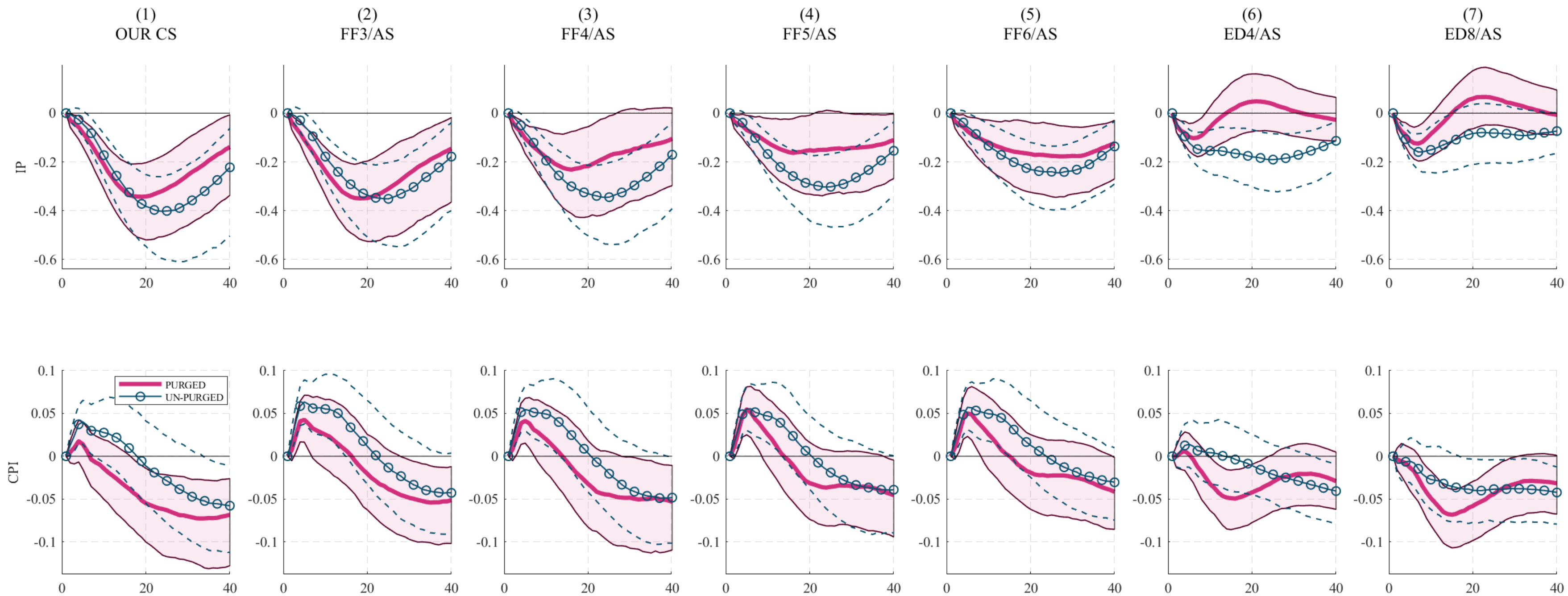
Notes: Results from different VAR models (sample period: 1994m3-2008m6). The first column shows the response to a purged action shock, the second column the response to a purged communication shock in our baseline Hybrid VAR. We display only the responses of (log) IP, (log) CPI, federal funds rate and the one-year Treasury yield from the 9-variable system. The shocks are one standard deviation. Estimates are derived from 1,000 draws from the posterior. The Hybrid non-recursive specification is a Hybrid VAR identical to the baseline with the instrument ordered first in the vector. The VAR-X specification uses the same variables as in the baseline Hybrid VAR, however the shock is entered into an exogenous block. The VAR-X recursive specification is identical to the VAR-X, however the instrument is first orthogonalised with respect to the first lag of all the endogenous variables, and contemporaneous values of slow-moving endogenous variables, and 12 lags of the shock itself.

Figure 6: Robustness to Purging With Respect to Greenbook Subtract Blue Chip Data (1994-2008 Sample)



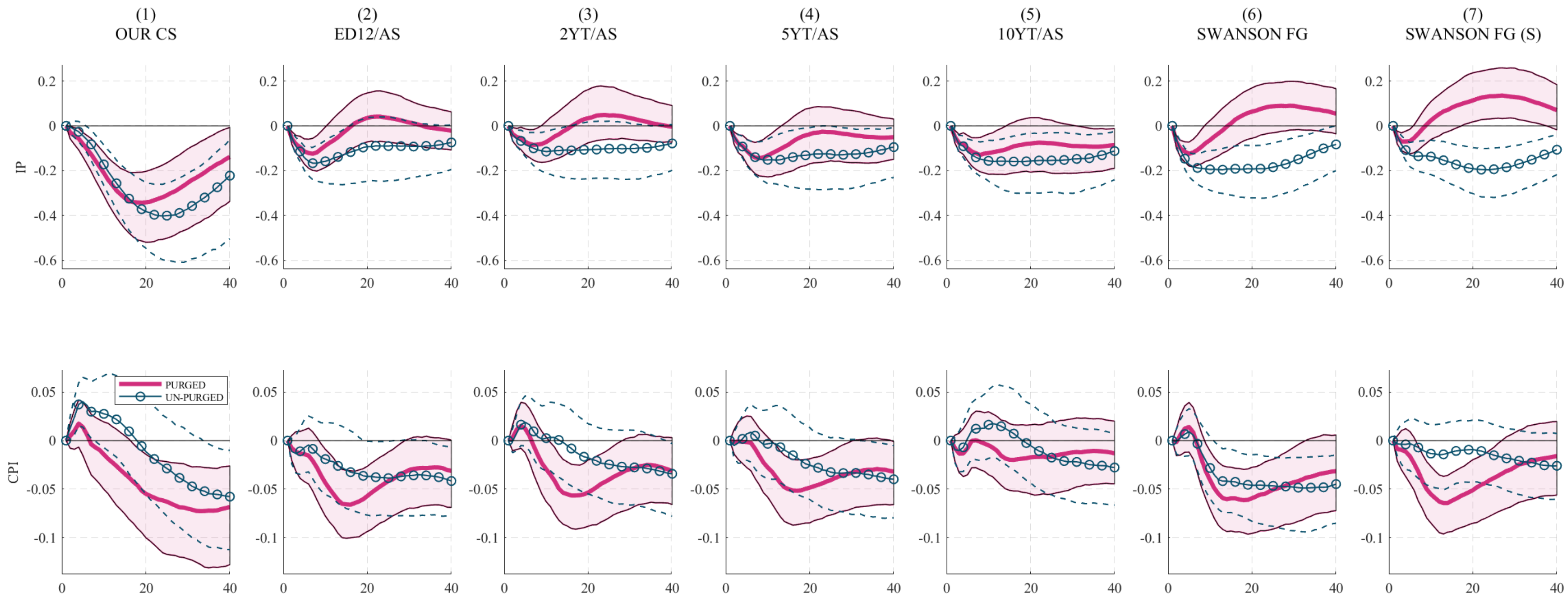
Notes: Results from the baseline Hybrid BVAR model, for two of the macroeconomic variables in the 9-variable system (sample period: 1994m3-2008m6). We display responses for multiple purging schemes: our baseline purging with Greenbook data ("GBK"), with Greenbook subtract Blue Chip data ("GBK-BC") and without purging for internal Fed information. We display the 68% credible set for the GBK variant. Estimates are derived from 1,000 draws from the posterior.

Figure 7: Baseline IRFs Compared with Alternative Shock Measures (1994-2008 Sample), Part I



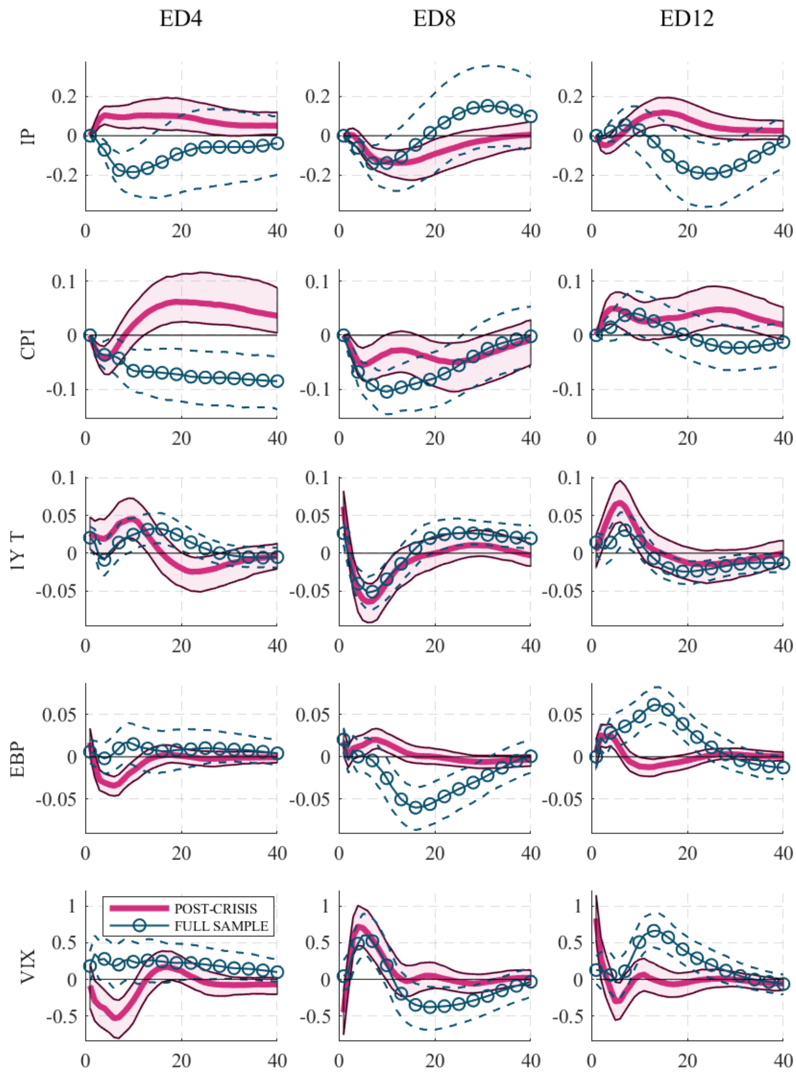
Notes: Results from the baseline Hybrid BVAR model, for two of the macroeconomic variables in the 9-variable system (sample period: 1994m3-2008m6). We display responses to multiple measures of communication surprise, purged with Greenbook data. We display also the unpurged surprises for reference. We display the 68% credible set. Estimates are derived from 1,000 draws from the posterior.

Figure 8: Baseline IRFs Compared with Alternative Shock Measures (1994-2008 Sample), Part II



Notes: Results from the baseline Hybrid BVAR model, for two of the macroeconomic variables in the 9-variable system (sample period: 1994m3-2008m6). We display responses to multiple measures of communication surprise, purged with Greenbook data. We display also the unpurged surprises for reference. We display the 68% credible set. Estimates are derived from 1,000 draws from the posterior.

Figure 9: Eurodollar Shocks – ELB (2008-2015) vs. Full Sample (1994-2015) – Purged



Notes: Results from the Eurodollar BVAR model, for five of the macroeconomic and financial variables in the 9-variable system (sample period: 1994m3-2015m12). The three columns display responses for the ED4, ED8 and ED12 shocks. We display only surprises that have been purged with Greenbook data. We compare responses to the full-sample and post-crisis periods (2008m7-2015m12). We display the 68% credible set. Estimates are derived from 1,000 draws from the posterior.