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Forward guidance shocks

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Abstract

I estimate the effects of a forward guidance (FG) shock and compare it with a traditional monetary policy (MP) shock. I find that FG shocks have smaller effects on macroeconomic aggregates than MP shocks. Structural identification is reached by a novel heteroscedascticity-based approach that exploits (i) the introduction of the forward guidance in the form of a published policy-rate path in the US in January 2012; and (ii) the zero lower bound (ZLB) constraints. My findings are consistent with the predictions of the latest theories about the FG puzzle.

JEL Classification:*E52, E32, C32*

Keywords: forward guidance, monetary policy, event study, heteroscedasticity, structural VAR.

1 Introduction

During the Global Financial Crisis (GFC), nominal interest rates hit the ZLB in several advanced economies. Having reached the limit of the conventional monetary tool, announcements about the future path of interest rates, known as FG, have become one of

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the main tools for the monetary authority to conduct policy.[1] A decade after the Great Recession, the Fed's major intervention as a response to the COVID-19 crisis marked the return of the US to the ZLB and to the use of FG. Thus, understanding the efficacy of this policy tool is crucial for optimal policy design.

A current issue in monetary economics, known as the ”forward guidance puzzle” (Del Negro et al., 2012, Carlstrom et al., 2015), is that standard New Keynesian models predict implausibly large effects of FG shocks which is at odds with the logic that news regarding the distant future should be heavily discounted. This gave rise to a large and important literature that addressed this puzzle along a number of dimensions (McKay et al., 2016, Angeletos and Lian, 2018, Andrade et al., 2019, Campbell et al., 2019, Farhi and Werning, 2019, Hagedorn et al., 2019, Gabaix, 2020, Michelacci and Paciello, 2020, Michaillat and Saez, 2021 and Pfäuti and Seyrich, 2022). One common implication of these studies is to show that FG shocks are less powerful than standard MP shocks, and such attenuation effect is higher the longer the horizon of the monetary news. However, two crucial and related questions have not yet been clarified in the literature. First, is the mitigation hypothesis of FG shocks supported empirically? Second, is the strength of the mitigation effect small enough to justify the use of FG as an alternative to the conventional monetary tool?

This paper contributes to this debate and provides an original comparison of the effects of MP and FG shocks in a unified empirical framework. Results show that both shocks have strong and significant economic effects and lead to qualitatively similar impulse responses. MP and FG contractionary shocks trigger a drop in output and prices and a tightening in the financial conditions. Term spread falls following a MP surprise while it is little affected by the FG disturbances. But importantly, the FG surprise displays delayed and attenuated effects compared to the MP shock consistent with the recent theories that address the ”forward guidance puzzle”.

[1] Throughout paper, forward guidance refers to news about future path of monetary policy, or Odyssean forward guidance as defined in Campbell et al. (2012).

The results from this empirical exercise are extremely valuable for the ongoing research on the effectiveness of non-standard monetary policies for at least two reasons. First, I bring novel empirical support to the state-of-the-art theories that have put forward the hypothesis of a mitigation effect in the dynamics triggered by FG shocks. Second, despite the attenuated impact, I show that FG has plausibly powerful effects on output and prices and is, thus, an effective alternative to the conventional monetary tool.

Analyzing the effects of FG and MP shocks is a rather daunting task due to the well known issues of endogeneity and multiple dimension of the monetary policy. To this end, I develop a novel identification design that integrates the identification through heteroscedasticity (Rigobon, 2003, Lanne and Lütkepohl, 2008 and Lewis, 2021) with event studies, as in Wright (2012). In particular, I exploit: (i) the introduction of forward guidance in the form of a published policy-rate path; (ii) the ZLB constraints; and (iii) the heteroscedasticity of intra-daily data on FOMC meetings days. This approach stably bridges periods of conventional and unconventional monetary policy, it accounts for measurement error in the data and is free from information effects. Importantly, I provide a unified empirical framework to asses and directly compare the macroeconomic effects of MP and FG shocks. This is a crucial aspect, considering that the main objective of the paper is to empirically verify the existence of a mitigation effect in the dynamics produced by FG shocks.

To be more precise, FOMC meeting participants have submitted individual economic projections for GDP, inflation and unemployment, in conjunction with four FOMC meetings a year, since October 30-31, 2007. These projections are known as the Summary of Economic Projections (SEP), and since April 2011, central tendencies of the participants' projections are released in conjunction with the Chairman's post-meeting press conference. However, it is only in January 2012 that the FED has started to provide more specific information about future policy-rate path in the SEP, in the form of the "dot plot". Each dot indicates the value of an individual FOMC participant's judgment of the appropriate level of the target federal funds rate at the end of three calendar years and over the longer run.

I exploit the introduction of the "dot plot"to identify a FG shock and a MP shock, using January 2012 as a break point. I define T_1 as the sample of 30 minutes intervals around FOMC announcements from January 1994 to December 2011 and T_2 as a sample of equally narrow time intervals around FOMC news from January 2012 to May 2019. The two samples correspond to *before* and *after* the introduction of the "dot plot".

At the core of the identification strategy there are two observations. The first observation is that, as pointed out in Svensson (2014), the publication of FOMC's members forecast of policy rate should lead to higher informativeness of the private sector regarding the Fed's plans for the future policy setting. This comes from the fact that the monetary authority should have better information about its plans than any other agent. The higher informativeness of the public is expected to lead to more accurate forecasts of the interest rates, and hence to a lower volatility of the forward guidance surprises. In fact, as reported in Table 1, both the forecast dispersion and the forecast errors for the 3-month T-Bill rate in the Survey of Professional Forecasters (SPF) have decreased substantially after January 2012. The second observation is that in the T_2 sample the standard monetary policy actions are drastically limited by the ZLB constraints while they are the prevailing tool in most of the T_1 period.

Based on these observations, I assume that the volatility of both FG and MP shocks is lower in the T_2 sample, while the variance of the other shocks occurring in the same window (*e.g.* quantitative easing, information shock, measurement error) is unchanged between T_1 and T_2. This assumption helps filtering out all the shocks occurring in the same window other than FG or MP shocks. To disentangle the MP from FG shocks, I make the additional (standard) assumption that a forward guidance shock does not affect the federal fund future in the current month (Gürkaynak et al., 2005, Swanson, 2020 and Andrade and Ferroni, 2020). These two assumptions are embedded in a heteroscedasticity-based event study framework and are sufficient to identify and extract the two shocks at intra-daily frequency. To trace out the dynamic effects of these policy changes on macroeconomic aggregates, the series of high-frequency structural shocks are used as external instruments in a monthly large Bayesian (B)VAR model.

It is worth emphasizing that the two monetary shocks estimated in this paper are highly correlated to the MP and FG shocks proposed by Swanson (2020) and Jarocinski (2021). This is so even if their identification strategies are completely different from mine. This result provides further external validation to the three identification schemes.

I conduct a series of sensitivity checks that indicate that my findings are robust along a number of dimensions. To preclude that the estimated MP and FG shocks are confounded with quantitative easing (QE) factors, I remove from the FOMC events the ones pertaining to the main QE announcements. Results are almost unaffected by this change. Moreover, cleaning the intra-daily variables from information effects as per Jarocinski and Karadi (2018) does not lead to differences in the estimates suggesting that the identification scheme is robust to this check as well. Finally, I show that the main results hold if I use the MP and FG instruments developed by Swanson (2020).

Relation to the literature. This project builds on the recent theories that help resolve the "forward guidance puzzle". Although most of these studies have one common finding which says that FG shocks display a mitigation effect compared to the traditional MP shock, there is little empirical evidence confirming it. I contribute to this literature by providing novel empirical support to the FG mitigation hypothesis.

From a methodological perspective, the closest contribution to my paper is provided by Lewis (2019) who exploits the heteroscedastictiy of asset prices on FOMC announcement days to disentangle various dimensions of the monetary policy. However, his approach is different from the current paper in a crucial aspect. Specifically, Lewis (2019) relies on a purely statistical approach to identification which does not deliver a structural interpretation of the shocks. Thus, to differentiate between FG, MP and QE shocks he resorts to a partition of the yield curve. Differently, I integrate the identification through heteroscedasticity with the event study approach, by exploiting the 2012 change in FG policy and the ZLB constraints. Through this extension I achieve an explicit structural interpretation of the shocks. Moreover, Lewis (2019) finds that FG shocks have no effect on output and prices while my results suggest that despite the mitigation effect, FG shocks are powerful enough to justify the use of this tool as an alternative to the standard monetary instrument.

This paper is also related to the fast growing literature that disentangles the effects of conventional and unconventional monetary policy from an empirical perspective. For example Gürkaynak et al. (2005) (GSS) extract two factors from high-frequency data on FOMC days and separates them in a path factor (*i.e.* forward guidance) and a target factor (*i.e.* standard monetary policy) by imposing a zero effect of FG factor on the near term interest rate. Swanson (2020) extends GSS approach to accommodate for a QE factor by minimizing the variance of the pre-ZLB QE shocks. For the Euro Area, Altavilla et al. (2019) exploit the high frequency response of asset prices during policy announcements to construct conventional and unconventional monetary policy shocks. Jarocinski (2021) uses the non-Gaussianity of financial markets response to Fed's announcement to disentangle four dimensions of the monetary policy using a statistical approach.

I differ from this literature in both the research question as well as in the identification approach. I provide a direct comparison between the macroeconomic effects of FG and MP shocks. In contrast, the above mentioned studies limit their analysis to daily or intra-daily data, hence neither examines the impact of conventional and unconventional monetary shocks on real economy. Regarding the identification strategy, as opposed to GSS and Swanson (2020) approach, my scheme accounts for information effects and for the measurement error in the data. On the other side, Jarocinski (2021) disentangles all four dimensions of the monetary policy (*i.e.* QE, FG, MP and information shocks) but his approach is purely statistical, hence the labelling of the shocks occurs ex-post estimation by analyzing the impulse responses. On the other side, one of the main disadvantages of my identification scheme compared to Lewis (2019), Jarocinski (2021), and Swanson (2020), is that it disentangles only two of the four dimensions of the monetary policy.

This paper is also linked to empirical studies analyzing the effects of monetary shocks on real activity. Jarocinski and Karadi (2018) separate a compounded measure of standard and non-standard MP shocks from information shocks, or "Delphic forward guidance "shocks exploiting the co-movement of federal funds futures and asset prices on FOMC meetings. Inoue and Rossi (2018) extract two policy dimensions corresponding to the slope and curvature factors from a Nelson and Siegel (2002) decomposition. Hachula et al. (2020) examine the effects of conventional and unconventional monetary shocks in the Euro Area countries extending the high-frequency approach of Altavilla et al. (2019). Miranda-Agrippino and Ricco (2018) clean a measure of monetary policy from information effects making use of the Greenbook forecasts, while Bu et al. (2021) (BRW) achieve the same goal exploiting the difference in the effect of information shocks on the yield curve. Cieslak and Schrimpf (2019) and Bauer and Swanson (2020) focus on the financial markets response to non-monetary news in the FOMC communication. Both papers suggest a limited role for this type of shocks, known as information shocks. While several of these papers asses the economic effects of monetary policy shocks in low frequency models, they do not interpret these responses as corresponding to particular aspects of unconventional policy.

Kaminska et al. (2021) disentangle various dimensions of the monetary policy by applying an affine term structure model to high-frequency yield curve movements around FOMC announcements. As opposed to my approach, the shocks produced by their method are reduced form in spirit. Moreover, their shock to the expected path of interest rates resembles a "Delphic forward guidance "shock rather than an "Odyssean forward guidance "shock, as in the current paper. Ben Zeev et al. (2020) use the Beaudry and Portier (2006) method and identify FG as news about future monetary policy. The monetary news shock is orthogonal to current policy residual and maximises the sum of contributions to its forecast error variance over a finite horizon. As acknowledged by the authors, the main caveat of this approach is that, apart from FG effects, it might capture any other channel that affects expectations. Bundick and Smith (2020) use the GSS path factor to examine the macroeconomic effects of FG shocks. As opposed to my paper, their focus is exclusively on FG shocks and on the ZLB period, hence they cannot provide a direct comparison of the effectiveness of the FG vs MP which is of substantial importance to the central banker.

In an analysis focusing on the Euro Area, Andrade and Ferroni (2020) show that FG shocks have plausibly sized effects on output and prices, in line with my findings. However, they do not provide a direct comparison of the effects of FG vs. MP shocks. Miranda-Agrippino and Ricco (2021) extends the Miranda-Agrippino and Ricco (2018) identification approach to accommodate for the ZLB and provide a comparison between the effects of MP shocks and information shocks. Ferreira (2020) use the GSS path and target factors in a narrative sign restricted framework and provides a comparison of the macroeconomic effects of MP and FG shocks, while Lakdawala (2019) uses a mix of external instruments and zero restrictions to disentangle a MP shock and a FG shock. However, the different identification schemes in these papers deliver results that are divergent from mine. Ferreira (2020) finds that the impact of FG shocks are at least as strong as the MP ones, while Lakdawala (2019) finds that changes in future interest rates have actually expansionary effects, which resembles more to an information shock rather than a FG shock.

The remaining of the papers is structured as follows. In section 2 I describe the data while in Section 3 I introduce the econometric model. Section 4 presents the empirical exercise while section 5 concludes.

2 Data

The high-frequency data on FOMC days comes from the GSS dataset extended to May 2019 by Gürkaynak et al. (2021). This widely employed dataset contains the changes in financial variables in a 30 minute window around FOMC announcements (going from 10 minutes before to 20 minutes after the news). Because the FED did not release public statements about monetary policy decisions until 1994 I start the sample then. Following

Nakamura and Steinsson (2018) I focus only on scheduled FOMC announcements, since unscheduled meetings may occur in reaction to other contemporaneous shocks. Thus, the sample considered here contains 209 FOMC announcements from February 1994 to May 2019.

I refer to the variables following the GSS identifiers. MP1 is the current month federal funds future adjusted for the number of the remaining days of the month as in Nakamura and Steinsson (2018). ED2, ED3, ED4 and ED8 denote the change in the second through eighth eurodollar contract while ONRUN6M, ONRUN2, ONRUN5, ONRUN10 and ONRUN30 are the 6 months through 30 -year Treasury yields. To capture FG effects, I use the first principal component of the surprises in the current month and 3-month fed funds futures and 2-, 3-, and 4- quarters ahead 3-month eurodollar futures. This is taken from Jarocinski (2020) and called hereafter the FG factor.[2]

Importantly, to make sure that my results are free from information effects, in the benchmark model I use a version of MP1 and the FG factor that are corrected for information effects according to the method of Jarocinski and Karadi (2018). However, in a robustness analysis I show that using the standard measures of MP1 and FG factor leaves the main results unaffected.

3 Econometric framework

In this section I introduce the econometric model, I discuss in detail the intuition behind the identification strategy, I report the intra-daily analysis results and the structural shock series construction.

3.1 The econometric model

The empirical model employs market responses to the FOMC announcements as follows:

[2] I am grateful to Marek Jarocinski for kindly sharing his data with me.

Let Δi_0 be the FOMC meetings 30 minutes window change in the current month federal fund future, MP1, and Δi_1 the corresponding change in some longer term instrument that should be correlated to forward guidance, which in this case is the FG factor introduced above. Δi_n is the variable of interest, which can be treasury yield at various maturities, exchange rates or asset prices. Let ε_{MP} and ε_{FG} denote a conventional monetary shock and a forward guidance shock respectively, while η_i is a vector containing any other shocks occurring during the 30 minutes FOMC window, such as quantitative easing, information shock and/or measurement error. Suppose that the movement in the three variables is governed by these shocks as follows:

$$\Delta i_0 = \varepsilon_{MP} + \eta \tag{1}$$

$$\Delta i_1 = \alpha_1 \varepsilon_{MP} + \alpha_2 \varepsilon_{FG} + \alpha_3 \eta \tag{2}$$

$$\Delta i_n = \beta_1 \varepsilon_{MP} + \beta_2 \varepsilon_{FG} + \beta_3 \eta \tag{3}$$

As customary in the literature I assume that the FG shock does not affect the federal fund future in the current month, thus ε_{FG} does not enter equation (1) (see Gürkaynak et al., 2005, Swanson, 2020 and Andrade and Ferroni, 2020). Without loss of generality I normalize to one the impact of the monetary policy shock and η on i_0 as well as the impact of the forward guidance shock on i_1. Thus, $\alpha_2 = 1$. The parameters of interest are β_1 and β_2 which should be interpreted as the impact of the MP and the FG shocks on i_n (keeping in mind the normalizations that MP raises MP1 by 1% point while FG increases the FG factor by 1% point).

Define T_1 as the sample of 30 minutes intervals around FOMC announcements from January 1994 to December 2011 containing 150 data points and define T_2 as a sample of equally narrow time intervals around FOMC news from January 2012 to June 2019, with a size of 59 data points. The splitting point is January 2012 and coincides with the introduction of the dot plot projections for the federal fund rate.

The main identifying assumption in this application is that the variances of both MP and FG shocks decrease in the sample following the publication of FOMC participants' policy-rate projections, while the variance of any other shock does not change between T_1 and T_2. The variance of the MP shock is expected to be lower after 2012 since in the second sample the conventional MP tool is severely restricted by the ZLB while it is the prevalent tool in T_1 sample. As for the FG shock, the introduction of the "the dot plot"is expected to increase the private sector information about the future path of monetary policy which should translate into smaller surprises regarding future interest rates. The identifying assumptions can be written as

$$\sigma_{\epsilon_{MP},T_1} > \sigma_{\epsilon_{MP},T_2} \tag{4}$$

$$\sigma_{\epsilon_{FG},T_1} > \sigma_{\epsilon_{FG},T_2} \tag{5}$$

$$\sigma_{\eta,T_1} = \sigma_{\eta,T_2} \tag{6}$$

Let $\mathit{\Pi}_{T,i}$ denote the variance-covariance matrix of $[\Delta i_0, \Delta i_1, \Delta i_n]$ in regime T_i. Then $\mathit{\Pi}_{T,i}$ is given by

$$\begin{bmatrix} \sigma^2_{\epsilon_{MP},T_i} + \sum_j \sigma^2_{\eta,j} & \alpha_1 \sigma^2_{\epsilon_{MP},T_i} + \sum_j \alpha_{3,j} \sigma^2_{\eta,j} & \beta_1 \sigma^2_{\epsilon_{MP},T_i} + \sum_j \beta_{3,j} \sigma^2_{\eta,j} \\ \cdot & \alpha_1^2 \sigma^2_{\epsilon_{MP},T_i} + \alpha_2^2 \sigma^2_{\epsilon_{FG},T_i} + \sum_j \alpha_{3,j}^2 \sigma^2_{\eta,j} & \alpha_1 \beta_1 \sigma^2_{\epsilon_{MP},T_i} + \alpha_2 \beta_2 \sigma^2_{\epsilon_{FG},T_i} + \sum_j \alpha_{3,j} \beta_{3,j} \sigma^2_{\eta,j} \\ \cdot & \cdot & \beta_1^2 \sigma^2_{\epsilon_{MP},T_i} + \beta_2^2 \sigma^2_{\epsilon_{FG},T_i} + \sum_j \beta_{3,j}^2 \sigma^2_{\eta,j} \end{bmatrix}$$

Notice that $\Delta\Pi = \Pi_{T,1} - \Pi_{T,0} = \begin{bmatrix} \Delta\sigma^2_{\epsilon_{MP}} & \alpha_1 \Delta\sigma^2_{\epsilon_{MP}} & \beta_1 \Delta\sigma^2_{\epsilon_{MP}} \\ \cdot & \alpha_1^2 \Delta\sigma^2_{\epsilon_{MP}} + \alpha_2^2 \Delta\sigma^2_{\epsilon_{FG},T} & \alpha_1\beta_1 \Delta\sigma^2_{\epsilon_{MP}} + \alpha_2\beta_2 \Delta\sigma^2_{\epsilon_{FG}} \\ \cdot & \cdot & \beta_1^2 \Delta\sigma^2_{\epsilon_{MP}} + \beta_2^2 \Delta\sigma^2_{\epsilon_{FG}} \end{bmatrix}$

Thus we obtain:

$$\alpha_1 = \frac{\Delta\Pi_{1,2}}{\Delta\Pi_{1,1}} \tag{7}$$

$$\beta_1 = \frac{\Delta\Pi_{1,3}}{\Delta\Pi_{1,1}} \tag{8}$$

$$\beta_2 = \frac{\Delta\Pi_{2,3} - \alpha_1\beta_1\Delta\Pi_{1,1}}{\Delta\Pi_{2,2} - \alpha_1^2\Delta\Pi_{1,1}} \tag{9}$$

under the normalization that the forward guidance shock increases Δi_1 by one, hence $\alpha_2 = 1$.

3.2 Discussion of the identifying assumptions

It is reasonable to assume that the volatility of the MP shock is lower in T_2 compared to T_1, since T_2 is a sample mainly constrained by the ZLB with limited use of the standard monetary tools. However, when applied to the FG shock, the lower variance assumption needs a deeper discussion.

Forward guidance in the specific form of a published forecast for the interest rate, is not new to the central bankers. The Reserve Bank of New Zealand has published a path for the 90-day rate from 1997, Norges Bank for the policy rate from 2005, Sveriges Riksbank and Bank of Israel for the policy rate from 2007, and the Czech National Bank for a 90-day rate from 2008. The FOMC has used verbal forward guidance about its future policy settings since long before the GFC (see Campbell et al., 2012 and Gürkaynak et al., 2005). However, it is only in January 2012 that the FOMC started to provide more specific information about future policy-rate path, in the form of the dot plot in the Summary of Economic Projections (SEP).

There are several reasons why forward guidance in the form of a published forecast for interest rate should trigger a lower variance of the forward guidance shocks. As pointed out in Svensson (2014), the publication of FOMC's members forecast of policy rate should lead to: (i) a higher informativeness of the public since the monetary authority should have better information about its plans for the future policy rate than any other agent. Thus, a published policy-rate path should provide essential information for the private sector about future policy rates, which should evolve in more informed decisions and better forecasts of the future interest rates. Another reasons include (ii) increased transparency of the monetary policy since the policy-rate path is an essential ingredient in the forecast of both output and inflation; (iii) higher effectiveness of the monetary authority to affect market expectations about future policy rates; (iv) higher accountability of the monetary authority since large and systematic deviations of the actual policy path from the FOMC's members forecasted path would bring about a loss in the credibility of the central bank.

To further support the argument that FG surprises have a lower variance in the post-2012 period, in Table 1 I report the private sector's forecast dispersion (computed as the difference between 75 percentile and the 25 percentile) and the absolute forecast errors (computed as the difference between forecast value and actual realization) for the 3-month T-Bill rate using data from the Survey of Professional Forecasters, available at www.philadelphiafed.org. Results suggest that after 2012 the private sector's forecast dispersion for the short term rates, one year ahead, has fallen substantially, from 0.62 to 0.32. Moreover, this effect is not triggered by the ZLB constraint since the forecast dispersion is far higher in the pre-2012 ZLB period as well (0.54 vs 0.32). The same message is delivered by the forecast accuracy, with absolute standard errors that dropped considerably after 2012. This brings evidence in favor of my identifying assumption that FG shocks have experienced a decrease in variance following the introduction of the "dot plot".

Table 1 – Forecast dispersion and forecast error of SPF for the 3-month T-Bill rate

Statistic (mean over sample)	1994Q1: 2011Q4	2012Q1:2019Q4	2009Q1:2011Q4
Forecast dispersion	0.62	0.32	0.54
Absolute forecast error	1.14	0.32	1.10

Notes. The table reports the forecast dispersion and the absolute forecast error (mean over sample) of the SPF for the 3-month T-Bill rate, 4 quarters ahead.

3.3 Baseline estimates

The empirical model described in this section is an application of the identification through heteroscedasticity proposed by Rigobon (2003) intergated with the event study approach as in Wright (2012) and Nakamura and Steinsson (2018). The estimation strategy follows closely Nakamura and Steinsson (2018).

Before showing the main estimates, I provide evidence that there is a substantial change in the variance-covariance matrix of the system between T_1 and T_2. This is a necessary condition for the identification through heteroscedasticity. For example, the Rigobon estimator in equations (7) and (8) is a ratio, with the difference in the variance of Δi_0 between T_1 and T_2 in the denominator. If the distribution of this difference has significant mass in the vicinity of zero, the sampling distribution of the estimator will have significant mass at large positive and negative values. Put it differently, Rigobon and Sack (2004) show that the estimator through heteroscedasticity can be formulated as an IV regression. In this light, a high probability that the elements in matrix $\Delta\Pi$ —containing the difference in the variance covariance matrices between T_1 and T_2—are close to zero, essentially leads to a problem of weak instruments.

To show that my approach satisfies this condition, I follow Nakamura and Steinsson (2018) and report the joint distribution of the elements of the matrix $\Delta\Pi$ that are used to obtain the Rigobon estimates of α_1, β_1 and β_2, across the 5000 bootstrap iterations. In particular, for β_2 I report the joint distribution of the numerator and the denominator of the estimate in equation (9). For this exercise, the variable of interest, *i.e.* the one corresponding to equation (3), is the 2 Year yield, or ONRUN2.

Results reported in Figure 1 show that the elements of the matrix $\Delta\Pi$ are away from zero across all bootstrap draws. Hence, there are no weak instrument issues in the current application. This is actually aligned with Nakamura and Steinsson (2018) who find that the small difference in variances between the two samples is an issue only when daily and intra-daily variables are combined, but not in the model using exclusively intra-daily data.

Table 2 presents the baseline estimates of MP and FG shocks on Eurodollar contracts (ED) and treasury yields (ONRUN) for different maturities, as well as for the stock prices (SP500). Each estimate in the table comes from a separate Rigobon heteroscedasticity-based estimation of the system described by equations (1) to (3). Thus, I run a separate estimation for each variable of interest by keeping fixed equations (1) and (2) while varying equation (3) accordingly. Each variable represents a 30 minutes change around FOMC announcements. Bootstrap standard errors are computed across 5000 iterations.

The first column of Table 2 presents the effects of the MP shock on several variables. This is basically β_1 in equation (3). Recall that the policy news shock is scaled such that the effect on the current month federal fund future MP1 is 1 percentage (%) point. Looking across different maturities of treasury yields and Eurodollar contracts, we see that the effect of the shock peaks at short maturities to then decline monotonically until it gets insignificant for 10 and 30 year yields. The MP shock has strong and significant effects on stock prices generating a fall of 6.39 percent as a response to a monetary tightening of 1% point in the current interest rate.

The second column of Table 2 presents the effects of the FG shock which corresponds to β_2 in equation (3). The FG shock is scaled such that the effect on the FG factor is +1% point. As opposed to the MP shock, the FG shock has a hump-shaped effect on the yield curve, with a peak at the two- to five year maturity and with significant effects on the long

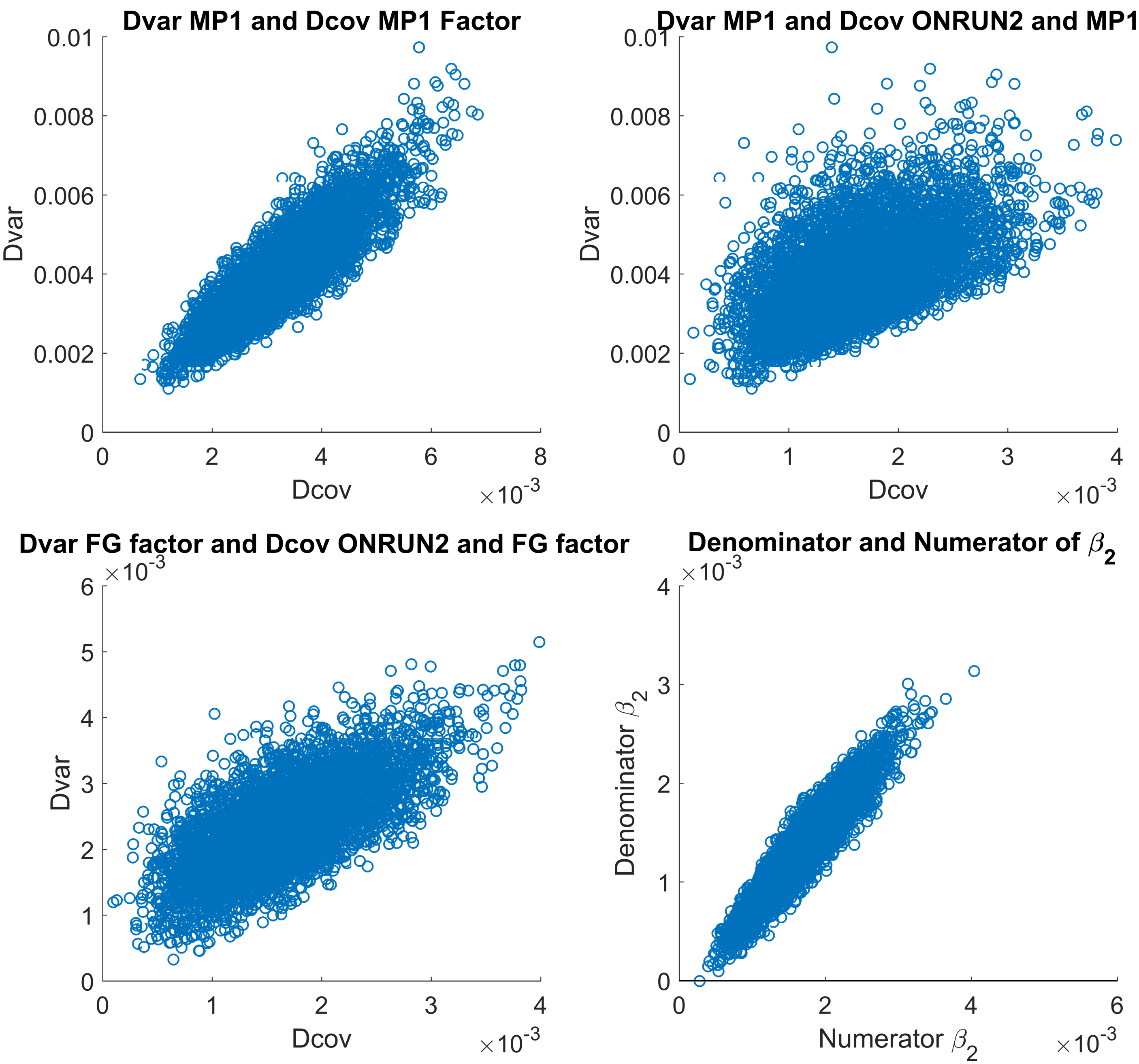

Figure 1 – Scatter of joint distribution of the difference in covariances (Dcov) and difference in variances (Dvar) between T_1 and T_2 for MP1, FG factor and ONRUN2, and the joint distribution of the numerator and denominator of β_2 in equation (9). Each point in the figure is a bootstrap draw.

Table 2 – The response of asset prices to MP and FG shocks

	Monetary policy shock	Forward guidance shock
ED1	0.67	0.69
	(0.11)	(0.09)
ED2	0.61	1.03
	(0.13)	(0.05)
ED3	0.56	1.15
	(0.14)	(0.04)
ED4	0.52	1.16
	(0.14)	(0.08)
ED8	0.34	0.84
	(0.12)	(0.18)
ONRUN6M	0.53	0.52
	(0.09)	(0.11)
ONRUN2	0.41	0.79
	(0.13)	(0.1)
ONRUN5	0.23	0.75
	(0.13)	(0.13)
ONRUN10	0.1	0.67
	(0.1)	(0.12)
ONRUN30	-0.08	0.51
	(0.09)	(0.12)
SP500	-6.39	-3.07
	(1.33)	(2.03)

Notes. Each estimate comes from a separate Rigobon's heteroscedasticity-base estimation. All variables are changes over a 30-minute window around the time of FOMC announcements. The T_1 sample period is all regularly scheduled FOMC meetings from 4/2/1994 to 13/12/2011 and contains 150 observations, while the T_2 sample period is all regularly scheduled FOMC meetings from 25/1/2012 to 1/5/2019 containing 59 observations. Bootstrap standard errors in parenthesis.

term assets as well. The impact on stock prices is negative but of a smaller magnitude and with higher standard errors compared to the MP shock. This is in line with a mitigation effect of news about changes in the future interest rates.

The yield responses to MP and FG shocks in Table 2 are in agreement with findings in GSS, Campbell et al. (2012), Swanson (2020) and Jarocinski (2021) who use the same intra-daily data but different identification schemes. Apart from GSS, the other contributions find stronger effects of FG on asset prices.

3.4 The structural shock series

The econometric framework described in this section has many desirable properties but it comes with an important drawback: it relies on high frequency data. This can be an important limitation if one wants to analyze the monetary policy effects on real activity since the main macro-variables are available at monthly or lower frequency. To overcome this issue, I extract the series of structural MP and FG shocks from the intra-daily model and use them as an instrumental variables in a lower frequency model.[3]

In Figure 2 I plot the MP shock series (upper side) and FG shocks series (lower side) over time and I discuss the consistence of my estimated shocks with relevant FOMC announcements. The sample considered is February 1994 to May 2019. Both shocks record substantial variation in the 1994-2009 sample. The MP shock displays a larger magnitude than FG, reaching four times values below -0.2% points. Interesting to notice that the largest negative surprises in the baseline MP shock coincide with the ones in GSS and Swanson (2020) and correspond to December, 1994 (the surprising not tightening), the two large intermeeting cuts in October 1998, and December 2001, and the September 2007 and January 2008 interest rate cuts in face of the liquidity worries due to the banking system instabilities.[4]

The spikes in FG shocks are as well aligned with previous studies. These include July 1995 when there was the first numerical target mention for the interest rates, October 1999, when FOMC announces a change in the policy bias going forward from neutral to tightening, and the January 2004 meeting when the drop in the commitment of future low rates is announced. The lowest value for FG is -0.18% point on December 2008 which

[3]The structural shock extraction follows Känzig (2021) who shows that in the heteroscedasticity-based approach the structural shocks can be extracted from the following formulae:

$$\epsilon_{i,t} = s_1^{'}\Pi_{T1,2}^{-1}I_t(s_1^{'}\Pi_{T1,2}^{-1}s_1)^{-1}$$

where s_1 is the impact vector/matrix of the two shocks containing Rigobon's estimates of α_1, α_2, β_1, β_2, the unit effect of ϵ_{MP} on Δi_0 and the zero effect of ϵ_{FG} on Δi_0. I_t is the matrix collecting the data Δi_0, Δi_1 and Δi_n, which in a model with lags would correspond to the matrix of residuals. As discussed in Känzig (2021), it is indifferent whether Π_{T1} is used or Π_{T2}

[4]See Gürkaynak et al., 2005 and Swanson, 2020 for more details on the events description

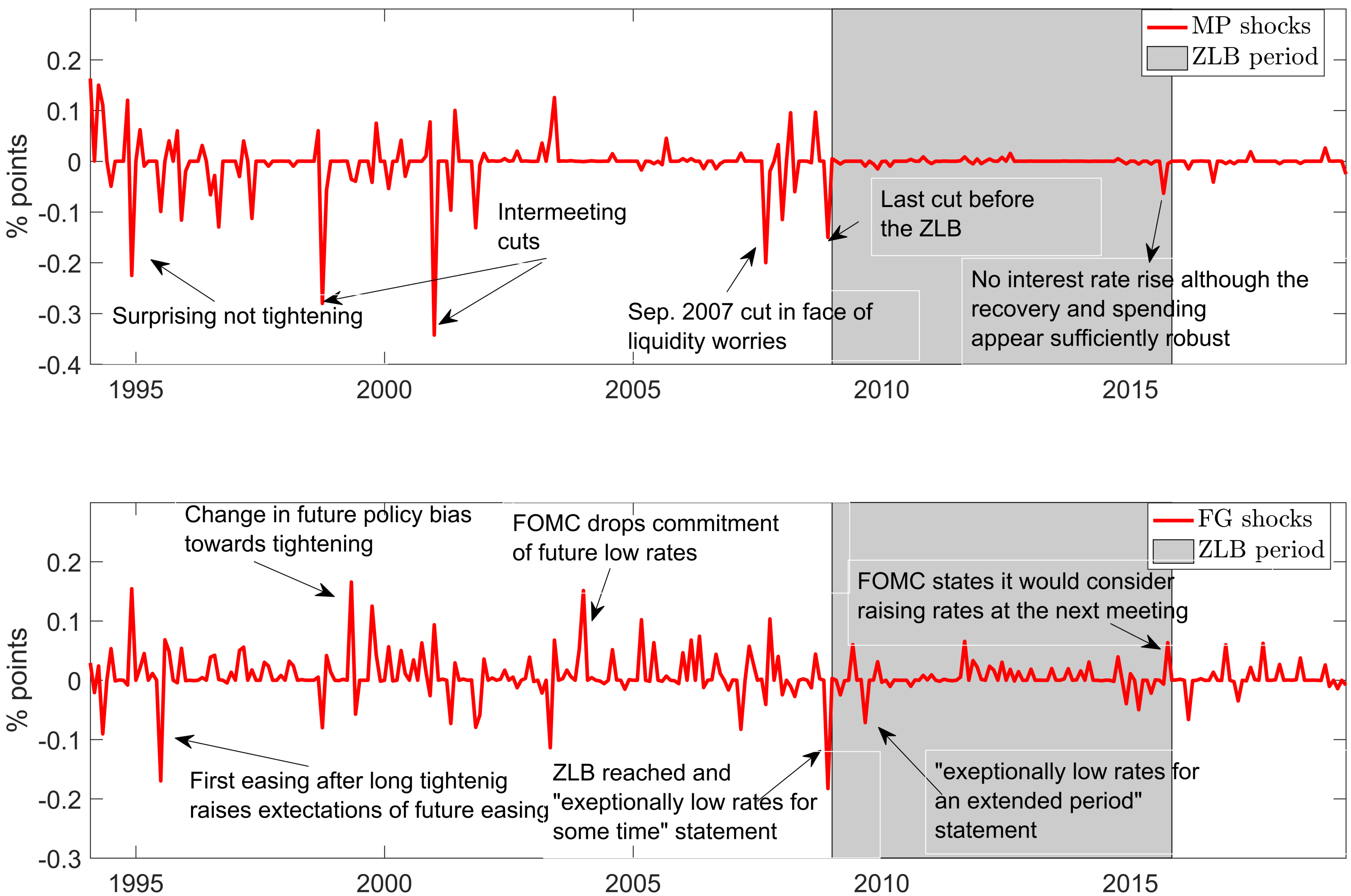

Figure 2 – Estimated MP (upper side) and FG (lower side) shock series over the sample February 1994 to May 2019. Shaded area denotes the ZLB period. Notable FOMC announcements are labeled for reference. More details and events are discussed in the text.

marks the beginning of the ZLB accompanied by the FOMC statement that "exceptionally low rates will be maintained for some time ". Over the ZLB, negative FG shocks are recorded on September 2009, when the FOMC announces to keep "exceptionally low rates for an extended period "despite the improvements in the financial market conditions, on December 2014, when FOMC announces that "it can be patient in beginning to normalize the stance of monetary policy ", and on March 2015 when it is announced that "an increase in the target range for the federal funds rate remains unlikely at the April FOMC meeting ". Unsurprisingly, a positive FG shock is recorded on October 2015 when FOMC states that it would consider raising rates at the next meeting.

Overall, MP shocks are close to zero during the ZLB while the FG shocks still display a relevant variation. This result emerges naturally without any additional assumptions on the behaviour of the two shocks over the ZLB period.

Table 3 – Correlation of the MP and FG shock series with alternative measures

Shock	Instrument	Correl. with MP	p-value	Correl. with FG	p-value
MP	Swanson (2020)	0.72	0.00	0.13	0.03
FG	Swanson (2020)	0.06	0.33	0.79	0.00
MP	Jarocinski (2021)	0.75	0.00	0.08	0.18
FG	Jarocinski (2021)	0.02	0.67	0.64	0.00
Compounded	Bu et al. (2021)	0.30	0.00	0.38	0.00
Compounded	Nakamura and Steinsson (2018)	0.70	0.00	0.67	0.00
Compounded	Jarocinski and Karadi (2018)	0.66	0.00	0.65	0.00

Notes. The table reports the correlation of the baseline MP and FG shock series with other alternative measures. All instruments are aggregated at monthly frequency by taking the sum over daily/intra-daily surprises. Compounded refers to monetary measures that contain a mix of the various dimensions of the monetary policy.

Correlation with alternative monetary shock series. In Table 3 I present the correlation between MP and FG shocks in the benchmark model, with alternative measures available in the literature. [5] Shock series are all aggregated at monthly level by taking the sum over daily/intra-daily surprises. The sample considered is February 1994 to May 2019 for all

[5] Note that MP and FG baseline shocks are uncorrelated by construction

shocks. The baseline MP and FG shock series are highly correlated with the correspondent MP and FG shocks in both Swanson (2020) and Jarocinski (2021) but not between them, *i.e.* the baseline MP measure is not correlated with any of the FG measures and neither the other way around. The high correlation between these measures obtained with completely different identification strategies, can be interpreted as an external validation of the three methods. On the other side, when we look at the compounded measures which contain a mix of the various dimensions of the monetary policy, unsurprisingly we notice a high and significant correlation of these measures with both the MP and FG baseline shocks.

4 Empirical application

While financial series are available at high frequency, the key macroeconomic indicators of ultimate importance to central banks are mainly available at lower frequencies. As a result, little previous work has analyzed and compared the real effects of conventional and unconventional policy shocks in a unified manner.

In this section I present the main empirical exercise. I first introduce the data used in the estimation phase and the econometric method to then discuss the results.

4.1 Data

I estimate separate models for each of the two shocks. Both models contain the same data at monthly frequency on 10 time series (listed in Table 4). The sample covered goes from February 1994 to May 2019. The lag length P is set to 12. Variables are in log levels except for the Global financial factor (GFF) which is in original units; interest rates are expressed in % points. The structure of the VAR model includes measures of real activity (Industrial Production and Capital Utilisation), prices (Consumer Price Index and Producer Price Index), the Excess Bond Premium of Gilchrist and Zakrajšek (2012) that measures corporate bond spread net of default considerations, and the Term Spread computed as the difference between 10 and 1 year treasury bonds. Moreover, I follow Miranda-Agrippino and Rey (2020) and include as well the GFF which is meant to account for the international dimension of the shock.

Importantly, for each shock I use the BRW measure as the monetary tool. This choice is crucial for two main reasons. First, it allows to equally scale and evaluate the two shocks with the same model. BRW is a compounded exogenous monetary measure, thus it contains a combination of conventional and unconventional monetary policy shocks. Hence, it should be highly correlated with both MP and FG shocks. This aspect is all but trivial since it might be difficult to find a treasury bond rate that satisfies this requirement since MP is expected to be correlated with short rates while FG with longer term rates. Second, the inclusion of lags of the shocks in the model (through lags of the BRW measure) is particularly desirable when shocks fail invertibility due to anticipation effects. In fact, Plagborg-Møller and Wolf (2021) and Noh (2017) show that controlling for past shocks helps deliver unbiased impulse responses even in the case of non-invertible shocks, such as FG shocks. Finally, in order to have a more precise idea on the scaling of the shocks, I include in the model the 1 Year Treasury rate (DGS1) .[6]

4.2 Large BVAR model identified with external instruments

To asses and compare the effects of the two shocks on economic activity I use the baseline MP and FG structural shock series from the intra-daily VAR framework as instruments in a large proxy BVAR model. The rich-information BVAR model is preferred to the small VAR alternative since it permits to jointly evaluate the response of several domestic and international variables and it alleviates the potential bias due to non-invertibility of the small VAR model.[7] On the other side, relying on the instrumental variable identification

[6]The reason why DGS1 is not used as a monetary tool is because it does not pass the relevance test for the FG shock, while BRW is a relevant tool for both shocks.

[7]The non-invertibility of a VAR model is essentially an omitted variable issue and is usually addressed by using a data-rich environment. See Stock and Watson (2018) for details.

Table 4 – Data series used in the model estimation

Variable name	Transformation	Source
Monetary tool measure (BRW)	none	Bu et al. (2021)
SP500	log	FRED data
Consumer Price Index (CPI)	log	FRED data
Produce Price Index (PPI)	log	FRED data
Global Financial Factor (GFF)	none	Miranda-Agrippino and Rey (2020)
Industrial Production (INDPRO)	log	FRED data
Capital Utilisation (CAPUTIL)	log	FRED data
Term Spread (10Y- 1Y)	none	FRED data
Excess Bond Premium (EBP)	none	Gilchrist and Zakrajšek (2012)
1Y US Treasury rate (DGS1)	none	FRED data

Notes. The table lists the variables included in the baseline model. Two separate VAR models contaning the same variables, over the sample February 1994 to May 2019 are estimated for each instrument.

preserves all the properties of the heteroscedasticity-based event study approach.

Consider a standard VAR model:

$$Y_t = X_t B + u_t \tag{10}$$

where Y_t is $1 \times N$ matrix of endogenous variables, $\underbrace{X_t}_{1\times(NP+1)} = [Y_{t-1}, .., Y_{t-P}, 1]$ denotes the regressors in each equation and B is a $(NP+1) \times N$ matrix of coefficients. The reduced form errors u_t are linked to the structural shocks ε_t through matrix A as follows:

$$u_t = A\varepsilon_t \tag{11}$$

The external instruments identification assumes that there exists an instrument m that satisfies two conditions:

$$\mathbb{E}\left[m_t \epsilon_{1,t}\right] = \alpha \neq 0 \tag{12}$$

$$\mathbb{E}\left[m_t \epsilon_{2:n,t}\right] = 0 \tag{13}$$

Without loss of generality I assume that $\epsilon_{1,t}$ is one of the two monetary shock series while $\epsilon_{2:n,t}$ is the $(n-1) \times 1$ vector of the remaining shocks in the model. The assumption (12) is associated to the relevance of the instrument and is testable. Assumption (13) corresponds to the exogeneity of the instrument, is not testable and it requires that m is uncorrelated with the other shocks in the model. Conditional on the validity of the heteroscedasticity-based event study identification scheme, (13) should be verified by construction. If (12) and (13) hold, m is considered a valid instrument and the first column of A, *i.e.* $\mathbf{a_1}$, is identified up to scale as follows:

$$\tilde{a}_{1,1} \equiv \frac{a_{2:n,1,}}{a_{1,1}} = \frac{\mathbb{E}\left[m_t u_{2:n,t}\right]}{\mathbb{E}\left[m_t u_{1,t}\right]} \tag{14}$$

For ease of interpretation and consistency with the intra-daily framework, I assume that the normalization is such that it increases the BRW monetary tool by 1% points, so that $a_{1,1} = 1$.

I estimate the model using Bayesian methods. Specifically, I impose a standard Normal-Wishart prior choosing the overall tightness parameter optimally as proposed by Giannone et al. (2015). Details on the estimation are provided in Appendix A.

4.3 Main results

First stage statistics. I investigate the strength of the two instruments computing the F statistics of the BRW residual on the instrument, as well as the reliability measure proposed by Mertens and Ravn (2013). If the F-statistic is well above the threshold level of 10 (see Stock et al., 2002), we are confident that there is no weak instrument problem. Results in Table 5 show that our instrument attains levels of relevance above the required threshold.

Table 5 – Tests for instrument relevance

Model	F-stat (median)	90 HPDI	Reliability (median)	90 HPDI
MP	22	[16 26]	37	[33 41]
FG	51	[38 57]	54	[36 57]

Notes. The table reports first-stage F statistics, statistical reliability and 90% HPDIs. Both VAR innovations and the first stage statistics are computed from the sample going from 1994 to 2019.

Impulse response analysis. I next turn my attention to the key empirical questions. What are the effects of FG shocks compared to the conventional MP shock? Is the US data supporting the existence of a mitigation effect in the dynamics produced by the FG shock?

Figure 3 plots the estimated impulse responses of both MP and FG shocks along with the 90 % high probability intervals (HPDIs). Both shocks are scaled to increase the BRW exogenous monetary measure by 1% point. This translates into an impact rise of 2.1% points in the 1 year treasury yield following the MP shock. In contrast, the effect of FG on the 1 year rate is hump shaped with an impact effect of 1% points which builds up over time to reach its peak of 1.9% points after 11 months. This result fits well the anticipated (FG) versus unanticipated (MP) monetary shocks definition.

The contractionary MP shock depresses output and prices in agreement with standard transmission channels. The fall in industrial production and capital utilisation is not sudden but builds up over time and reaches its peak of -11.7% and -8.4% respectively after 9 months. A similar pattern follow the prices, which peak after 7 months for both CPI (-3.5%) and PPI (-7.3%). This is in line with the presence of price rigidities. The shock has also substantial effects on the domestic financial markets increasing on impact the EBP by 3.6% points and depressing the GFF and stock prices by 3.2 units and 46% respectively, after 4 and 5 months. As expected, the monetary shock at the short end of the yield curve leads to a drop in the term spread and a sharp increase in the excess bond premium signalling a strong tightening in the financial conditions. This brings evidence in favor of a strong financial amplification channel of MP shocks at domestic level. The expectations of a drop in economic activity are straightaway priced in by the stock market that registers a sudden drop in the SP500 index. Finally, as in Miranda-Agrippino and Rey (2020) I find that the contractionary monetary shock has a strong effect on global asset markets as well, with a sudden and sharp contraction in the GFF.

The FG shock has qualitatively similar effects to the conventional monetary shock but there are important differences in the shape and magnitude of the impulse responses. First, the peak effect on output and prices is delayed in the FG shock, by around 4 months. This is in line with FG shocks behaving as anticipated or news monetary shocks. Moreover, there is a clear mitigation effect in the FG shocks which is strongly reflected in the real activity and financial variables. Specifically, the effect of FG peaks on IP (-8.3%) and capacity utilization (-5.%) after 13 months, while on financial variables the effect is the strongest on EBP (+1% points), on GFF (-2.11 units) and on SP500 (-23.7%) after 8, 7 and 9 months respectively. On the other side, we observe delayed peak effects on CPI(-2.96%) and PPI (-7.3%) reached after 11 months but the magnitude is comparable between the two shocks. Since the FG shock affects mainly the middle part of the yield curve it is not surprising that the term spread defined as the difference between 10 and 1 year yield, is little affected by this shock.

Regarding the magnitude of the results, I find stronger effects of MP on output and prices compared to Gertler and Karadi (2015), Caldara and Herbst (2019), and Miranda-Agrippino and Ricco (2018). However, these studies do not disentangle various dimensions of the shock. Thus, they capture a mix of MP, FG, information shocks and/or QE. Moreover, they use a different sample. On the other side, the estimated effect of FG shocks on output in my analysis is comparable to the findings in Bu et al. (2021), while the price reaction is smaller in my model. The reaction of both prices and capital utilization is aligned with what reported in Bundick and Smith (2020).

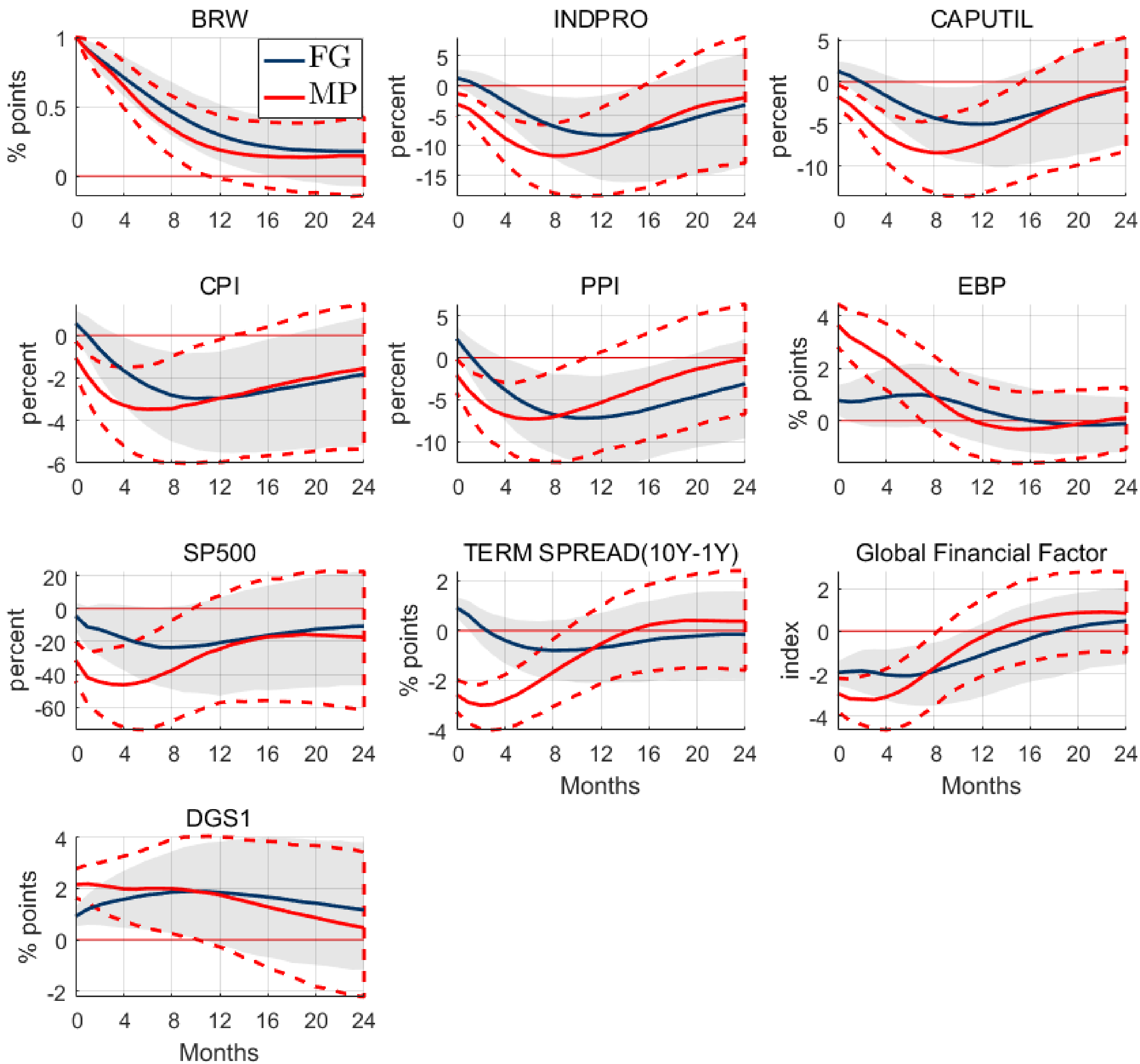

Figure 3 – IRFs of US variables to a MP shock (red line) and FG shock (blue line) in the monthly BVAR model. Shaded areas and dotted lines are the correspondent 90 credibility sets.

Discussion. From these results, we can discern two primary points. The first one is that FG shocks have powerful effects on macroeconomic variables, and is, thus, an efficient alternative to the conventional monetary tool when short rates are constrained at the ZLB. The second insight is to show that there are substantial differences in the shape and magnitude of the responses generated by the two monetary shocks. I find evidence of a delayed and attenuated effect recorded for the FG shocks, which is in agreement with the recent theories that rationalize the "forward guidance puzzle". In fact, most of this literature suggests that FG policies are accompanied by a mitigation effect. To the best of my knowledge, this is the first analysis to provide empirical evidence on this matter. [8] Other contributions that focus on comparing MP and FG shocks convey either that FG shocks are at least as strong as the MP shocks (see Ferreira, 2020) or that the contractionary FG shocks have expansionary effects (see Lakdawala, 2019). Lewis (2019) compares QE shocks with FG shocks and find that the latter has no significant effect on prices and output. This result is in contrast with most of the empirical studies that examine the effects of FG shocks on macroeconomy (Bundick and Smith, 2020, Andrade and Ferroni, 2020).

Variance decomposition analysis. Both MP and FG shocks explain the largest share of the BRW measure of 61% and 86% respectively, which confirms the monetary policy nature of the two shocks. The MP shock explains 0.21% in the variation of the term spread and 0.13% and 19% in the GFF and the EBP, respectively. The effect on output peaks a year after the shock and is around 13% which is slightly lower than previous findings related to conventional monetary shocks. For example, Bundick and Smith (2020) estimate variance decomposition of MP shocks using the models of Romer and Romer (2004) and Christiano et al. (2005) and find that in these models conventional policy shocks explain 25% and 41% (respectively) of the unexpected fluctuations in output over the two year horizon. However, the differences can be due either to the different identification strategy or the

[8] Andrade and Ferroni, 2020 suggest that the FG shocks, for the Euro Area, do not have implausibly large effects. However, they do not perform a direct comparison of the effects of conventional and unconventional shocks as in the current analysis.

different sample employed. The variance decomposition analysis confirms the mitigation effect of the FG shock which has an effect on output and prices with delayed and lower shares explained by the shock in output and prices compared to the MP sock. In terms of magnitude, my estimates align well with findings in Bundick and Smith (2020).

Table 6 – Forecast error variance decomposition

Part A: Monetary Policy

	BRW	IP	CPI	EBP	Term Spread	GFF
0	0.53	0.02	0.01	0.17	0.17	0.12
	(0.44 0.58)	(0 0.04)	(0 0.03)	(0.11 0.20)	(0.11 0.21)	(0.06 0.15)
6	0.46	0.11	0.08	0.15	0.22	0.15
	(0.34 0.54)	(0.04 0.16)	(0.02 0.13)	(0.8 0.20)	(0.11 0.29)	(0.07 0.22)
12	0.36	0.12	0.09	0.12	0.14	0.11
	(0.24 0.46)	(0.04 0.18)	(0.02 0.17)	(0.06 0.17)	(0.06 0.20)	(0.05 0.17)
24	0.23	0.07	0.07	0.11	0.08	0.09
	(0.13 0.32)	(0.02 0.113)	(0.01 0.15)	(0.06 0.16)	(0.03 0.12)	(0.04 0.14)

Part B: Forward Guidance

	BRW	IP	CPI	EBP	Term Spread	GFF
0	0.80	0.01	0	0.01	0.03	0.08
	(0.73 0.84)	(0 0.02)	(0 0.02)	(0 0.02)	(0 0.05)	(0.05 0.1)
6	0.78	0.03	0.03	0.02	0.02	0.10
	(0.66 0.83)	(0.01 0.05)	(0.01 0.08)	(0 0.06)	(0 0.04)	(0.03 0.16)
12	0.67	0.06	0.08	0.03	0.02	0.10
	(0.51 0.74)	(0.01 0.11)	(0.01 0.16)	(0 0.08)	(0 0.06)	(0.03 0.17)
24	0.42	0.06	0.09	0.04	0.02	0.08
	(0.25 0.54)	(0.01 0.11)	(0.01 0.18)	(0.01 0.08)	(0 0.06)	(0.03 0.13)

Notes. The table shows the forecast error variance of the key US variables explained by the US monetary policy shock and forward guidance shock at horizons 0,6, 12 and 24 months. The 90 credibility sets are displayed in brackets.

4.4 Robustness checks

I test the robustness of my results along a number of dimensions. To begin with, the identification scheme relies on the assumption that on FOMC meeting days, before and after the introduction of the "dot plot", MP and FG shocks display changes in the variance while the variance of the other shocks occurring in the same window remains unchanged. Thus, there might be concerns that QE shocks or information shocks could change variance as well in the two samples, in which case my results would be confounded with these effects. To preclude that information effects are not affecting my estimates, in the baseline model I clean the MP1 and FG factor (*i.e.* the variables corresponding to equations (1) and (2)) from information effects by following the procedure described in Jarocinski and Karadi (2018), thus removing the observations with positive correlation between in federal fund futures and stock prices. However, I show that the main findings still hold even without this transformation. I then reconstruct the two instrumental variables removing the main QE events (*i.e.* 25 November,2008 when QE measures are announced; 18 March, 2009 or QE1; 3 November, 2010 or QE2; and, 21 September 2011 or "The operation twist "). This exercise is meant to see if my findings are confounded with QE effects. I show that results are by all practical purposes unchanged with these additional restrictions. I also test the robustness of my findings with respect to the variables choice in equation (3), which in the baseline model is represented by the 2 Year Yield, *i.e.* the ONRUN2. I replace ONRUN2 with SP500 and reconstruct the two instruments and show that results survive this check as well. The estimates related to this exercise are presented in Figures B.1 and B.2, in Appendix B.

Finally, to preclude that my main results are driven by the identification strategy employed in the empirical application, in Figure B.3 I show that the main findings hold if I use the MP and FG instruments developed by Swanson (2020) instead of the baseline ones.

5 Conclusions

Forward guidance is a central tool of the monetary policy. State-of-the-art theories suggest that FG shocks have attenuated effects compared to the more traditional MP ones. However, there is little empirical evidence performing a direct comparison between the macroeconomic effects of the two shocks. Thus, the FG mitigation hypothesis lacks of empirical support. In this paper I fill this gap performing a two-stage analysis. First, I develop a novel identification scheme to disentangle FG and MP shocks exploiting the introduction of the forward guidance in the form of a published policy-rate path and the ZLB constraints. Then, in the second part of the paper, I asses and compare the effects of the two shocks in a unified framework. In line with recent theories, I find that MP and FG shocks share the same features, but the effects of FG are delayed and attenuated compared to the MP ones.

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A The Large BVAR model

Consider a standard VAR model:

$$Y_t = X_t B + u_t \tag{A.1}$$

where Y_t is $1 \times N$ matrix of endogenous variables, $\underbrace{X_t}_{1\times(NP+1)} = [Y_{t-1}, .., Y_{t-P}, 1]$ denotes the regressors in each equation and B is a $(NP+1) \times N$ matrix of coefficients. The reduced form errors u_t are normally distributed with mean zero and variance Σ and are linked to the structural shocks ε_t through matrix A

$$u_t = A\varepsilon_t \tag{A.2}$$

We estimate the VAR following Miranda-Agrippino and Rey (2020), thus using a standard Normal-Inverse Wishart prior for the VAR coefficients which takes the following form:

$$\Sigma \sim \mathcal{IW}(s, v) \tag{A.3}$$

$$B|\Sigma \sim \mathcal{N}(b, \Sigma \otimes \Omega) \tag{A.4}$$

where B is a vector collecting all VAR parameters. The degrees of freedom of the Inverse-Wishart are set such that the mean of the distribution exists and are equal to $v = n + 2$, s is diagonal with elements which are chosen to be a function of the residual variance of the regression of each variable onto its own first P lags. More specifically, the parameters in Eq. A.3 and Eq. A.4 are chosen to match the moments for the distribution of the coefficients in Eq. A.1 defined by the Minnesota priors:

$$\mathbb{E}\left[(B_i)_{jk}\right] = \begin{cases} \delta_j & \text{for } i = 1, j = k \\ 0 & \text{otherwise} \end{cases} \tag{A.5}$$

$$\mathbb{V}\left[(B_i)_{jk}\right] = \begin{cases} \frac{\lambda^2}{i^2} & \text{for } j = k \\ \frac{\lambda^2}{i^2}\frac{\sigma_k^2}{\sigma_j^2} & \text{otherwise} \end{cases} \tag{A.6}$$

where $(B_i)_{jk}$ denotes the element in row (equation) j and column(variables) k of the coefficients matrix B at lag i $(i = 1, ..., P)$. When $\delta_j = 1$ the random walk prior is strictly imposed on all variables; however, for those variables for which this prior is not suitable we set $\delta_j = 0$ as recommended in **?**. In Eq. A.6 the variance of the elements in B_i is assumed to be proportional to the (inverse of the) square of the lag (i^2) and to the relative variance of the variables.

Importantly, λ is the hyperparameter that governs the overall tightness of the priors in the model. We treat λ as an additional parameter and we estimate it following Giannone et al. (2015). The lag is set to 12.

B Robustness checks

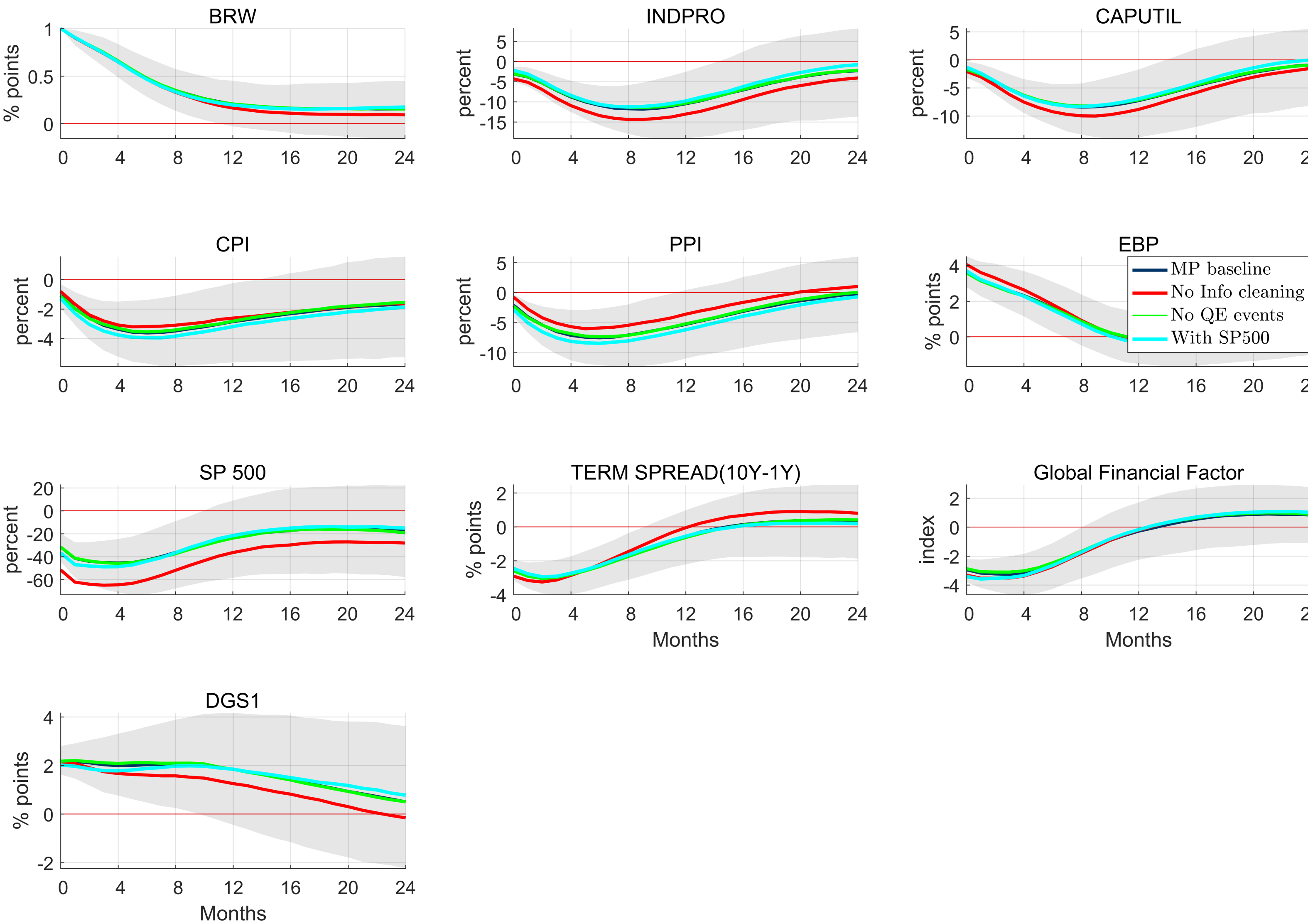

Figure B.1 – IRFs of US variables to the baseline MP shock (blue line), the model without info cleaning of MP1 and FG factor (red line), no QE events (green line) and model with SP500 instead of the ONRUN2 in equation (3) (cyan line). Shaded areas correspond 90 credibility sets in the baseline model.

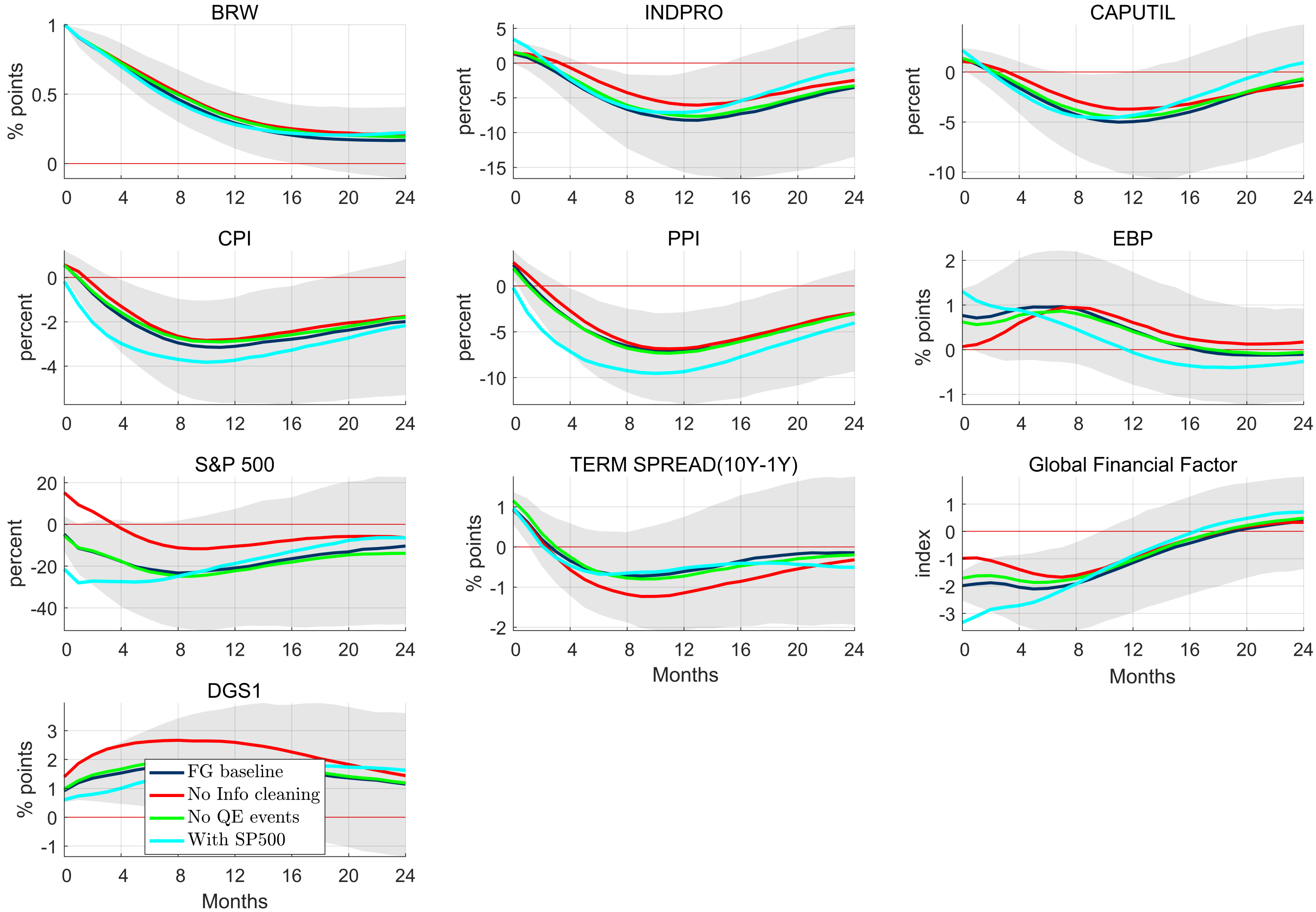

Figure B.2 – IRFs of US variables to the baseline FG shock (blue line), the model without info cleaning of MP1 and FG factor (red line), no QE events (green line) and model with SP500 instead of the ONRUN2 in equation (3) (cyan line). Shaded areas correspond 90 credibility sets in the baseline model.

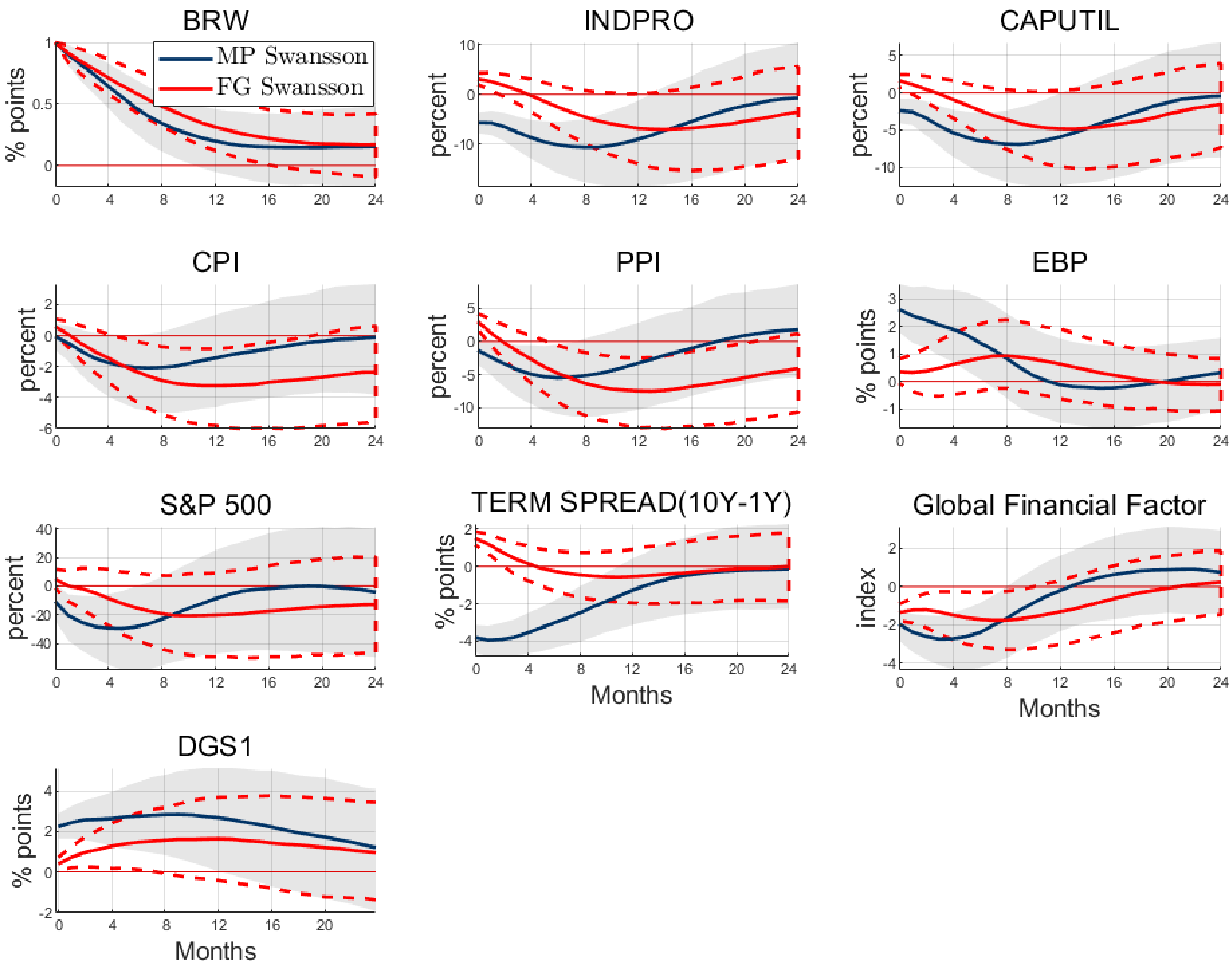

Figure B.3 – IRFs of US variables to a MP shock (red line) and FG shock (blue line) in the monthly BVAR model identified with Swanson (2020) instruments. Shaded areas and dotted lines are the correspondent 90 credibility sets.