A Unified Measure of Fed Monetary Policy Shocks

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Abstract

Identification of Fed monetary policy shocks is complex, in light of the distinct policymaking regimes before, during, and after the ZLB period of 12/2008 to 12/2015. We develop a heteroscedasticity-based partial least squares approach, combined with Fama-MacBeth style cross-section regressions, to identify a US monetary policy shock series that usefully bridges periods of conventional and unconventional policymaking. Our series has high correlation with Nakamura-Steinsson (2018) monetary policy shocks before 2008, and is strongly correlated with the forward guidance shock of Swanson (2018) during the ZLB period. The transmission effects of shocks to our measure are statistically and economically important both before and during the ZLB period, in contrast to results found using these alternative measures or the shadow rate of Wu and Xia (2016). We tie these different results to evidence on the Fed information effect.

1 Introduction

The adoption of unconventional monetary policy tools by the Federal Reserve in the wake of the Great Financial Crisis brought policymaking into new territory and rekindled challenges for research measuring monetary policy shocks and estimating their effects. Much of the new research built on influential work that pre-dated the crisis and used bond market data at daily or intra-daily frequencies (Kuttner 2001, Cochrane and Piazzesi (2002), Rigobon and Sack (2003), Gurkaynak, Sack, and Swanson (2005)). In much of this new work, monetary policy surprises are measured as the change in interest rate futures prices in narrow windows around FOMC announcements (for examples, see Wright (2012), Gertler and Karadi (2015), Nakamura and Steinsson (2018), Rogers, Scotti and Wright (2018), Swanson (2018), and Jarocinski and Karadi (2018)). This represented a departure from traditional approaches to measurement and identification such as the use of orthogonalized innovations to the Federal Funds rate in recursive VARs (Christiano, Eichenbaum and Evans (1996)) or the narrative approach of Romer and Romer (2004). An advantage of the methods developed in the recent papers is that, under certain assumptions, the resulting shock series captures both conventional policymaking, through shocks to the target Fed Funds rate, as well as unconventional policymaking, as reflected in identified shocks to forward guidance (FG) and large-scale asset purchases (LSAPs).

The focus of most of these papers, especially the early ones, was on the transmission to financial markets and expectations. For example, Nakamura and Steinsson (2018) document the effects of their policy news shock on the real interest rate, expected inflation, and expected output growth. Swanson (2018) finds that both forward guidance and LSAP shocks have highly statistically significant effects on a wide variety of assets: Treasuries, corporate bonds, stocks, exchange rates, and options-implied interest rate uncertainty. He also examines the persistence of these shocks, compares magnitudes before and during the ZLB period, and concludes with an appeal to examine the transmission to macroeconomic variables: "Going forward, there are many important issues that call for further exploration. First and foremost, estimating the effects of forward guidance and LSAPs on macroeconomic variables such as the unemployment rate should be a top priority for future research. After all, the FOMCs stated goal in pursuing these unconventional policies was to boost the economy (pg. 37)."

In this paper, we develop a heteroscedasticity-based, partial least squares approach to identify shocks to US monetary policy, compare our measure to the existing literature, and estimate the macroeconomic transmission effects of shocks before and during the zero lower bound period.[1] The general idea is to use Fama and MacBeth (1973) two-step regressions to estimate the unobservable monetary policy shock. This works initially through the sensitivity of outcome variables to FOMC announcements (Wold, 1966, 1975; Kelly and Pruitt, 2013, 2015). Specifically, in the first step we run time-series regressions to estimate the sensitivity of interest rates at different maturities to FOMC announcements. This is equivalent to the asset beta in the original Fama-MacBeth method. In order to filter out “background noise”, we employ the heteroskedasticity-based estimator of Rigobon and Sack (2003, 2004), implemented with instrumental variables (IV), into this step. In the second step, we regress all outcome variables onto the corresponding estimated sensitivity index from step one, for each time t. In this way, we derive the new monetary policy shock as the series of estimated coefficients from the Fama-MacBeth style second step regressions, and label it the BRW shock series. The application of this estimation procedure to estimating monetary policy shocks, which is novel as far as we are aware, turns out to have non-trivial effects on the results, as we elaborate below.

Our approach to estimating a monetary policy shock series has a couple of conceptual advantages. One is simplicity. Our approach has very mild data requirements and is easy to implement econometrically. Compared to the path- breaking work of Romer and Romer (2004), implementing our method involves no need to access and parse through Federal Reserve transcripts and forecasts. Nor does it require the use of intra-daily data, which is costly to acquire, as in much of the newest research. Thus, a second and related advantage of our method is its greater applicability. Our approach can be implemented over longer sample periods and for more countries compared to alternatives, for which data requirements often render the process untenable.

We also show that our series is informative in practice. To begin, we note that our shock series has high correlation with Nakamura and Steinsson (2018) monetary policy shocks prior to the period of unconventional monetary policymaking, and is strongly correlated with the relevant components of the high frequency monetary policy shocks in Swanson (2018) during the ZLB period. Focusing on the period surrounding lift-off in December 2015, we show that our shock series reflects the strong forward guidance delivered at the October 2015 FOMC meeting, and thus embodies a contractionary monetary policy shock in the meeting *before* the actual interest rate hike. Our approach produces a time series of US monetary policy shocks that usefully bridges periods of conventional and unconventional policymaking.

Next, we show that our series has different implications for monetary policy transmission than

[1] Jarocinski and Karadi (2018) also focus on transmission to macroeconomic variables, as discussed below.

do the alternative measures. Using our series, we find that a positive monetary policy shock leads to significantly negative effects on output. This is true in the full sample and in the two sub-samples before the ZLB and during the ZLB. This contrasts sharply with the estimated transmission effects using alternative monetary policy shock measures, especially during the ZLB period where output *rises* in response to a positive shock. We tie these different findings to the presence or absence of "Fed private information effects" in the series. We do not find a statistically significant private information effect in our new shock series, but do confirm its presence in the monetary policy shock series estimated by Nakamura and Steinsson (2018). We also find evidence of the information effect in the Swanson (2018) series.[2] Via a simple "encompassing" exercise, we attribute this difference to the econometric approaches used to identify the monetary policy shock series, rather than to differences in the raw data used. We subsequently orthogonalize the two alternative policy shock series with respect to the difference between Fed and Blue Chip forecasts of real GDP growth, a proxy for central bank private information. When the orthogonalized series is used in the VAR instead of the raw policy shock series (of either Nakamura and Steinsson (2018) or Swanson (2018)), the impulse responses exhibit substantially more conventional results.

In the next section, we describe our econometric approach and the data. In section 3, we display our new series and compare it to existing measures in the literature. In section 4, we estimate the transmission effects of shocks to our measure and the alternatives. A final section relates the findings to the information effect.

2 A New Monetary Policy Shock

2.1 Methodology: Fama-MacBeth Meets Rigobon-Sack

We assume that the true monetary policy shock e_t is unobservable. We further assume that the (observable) changes in Treasury yields around FOMC announcement days are driven by a monetary policy shock e_t and nonmonetary policy shock η_t. We normalize the unobserved monetary policy shock to have a one to one relationship with the 5 year Treasury yield.[3] We decompose movements

[2] For this exercise, we use the same tests as Nakamura and Steinsson (2018).

[3] This is motivated by the notion that Fed policy aims to affect interest rates at about this horizon, an assumption that became more appropriate during the ZLB period and is used elsewhere in the literature. We examine (and confirm) robustness of this choice of monetary policy indicator to 2-year and 10-year rates.

in the 5-year Treasury yield into monetary policy shocks and background noise:

$$\Delta R_{5,t} = \alpha_0 + e_t + \eta_t \tag{1}$$

where $\Delta R_{5,t}$ is the change in our policy indicator – the 5 year Treasury yield, α_0 is a constant, e_t is the monetary policy shock, and η_t is background noise that is unrelated to monetary policy news.[4]

We assume that the outcome of monetary policy decisions is reflected in the movements of zero-coupon yields with maturities of 1 year to 30 years. These outcome variables are also affected by background noise:

$$\Delta R_{i,t} = \alpha_i + \beta_i e_t + \xi_{i,t} \tag{2}$$

where $\Delta R_{i,t}$ is the change in the zero-coupon yield with i-year maturity and $\xi_{i,t}$ is the idiosyncratic noise associated with i. In the estimation, we use a 1-day window, capturing policy surprises between FOMC announcement day (end) and the previous day. Because the Fed released no public statements about monetary policy decisions until 1994, we begin estimation of our shock series then.

Our Fama-MacBeth two-step procedure extracts monetary policy shocks e_t from the common component of the outcome variables $\Delta R_{i,t}$. In the first step, we estimate the sensitivity of each outcome variable to monetary policy via time-series regressions. This could be done using OLS and high-frequency FOMC announcement day data, for example. Instead, we use the heteroskedasticity-based estimator of Rigobon (2003) and Rigobon and Sack (2003, 2004). This allows us to better filter out background noise, i.e., those factors that influence markets, even in short windows bracketing FOMC announcements, but are distinct from pure monetary policy news. This approach constructs an instrument $\Delta i_t^{IV} = (\Delta i_{t,R1} - \Delta i_{t,R2})$ for the independent variable, where $\Delta i_{t,R1}$ is the 1-day movement in the policy indicator around the FOMC announcement, and $\Delta i_{t,R2}$ is the movement with the same event window length but one week before FOMC announcement day.[5] The underlying assumption is that, on days of FOMC meetings, the variance of the true monetary policy shock increases while that of the background noise remains unchanged.

The first step of the Fama-Macbeth approach is generalized as:

$$\Delta R_{i,t} = \alpha_i + \theta_i \Delta i_t^{IV} + \mu_{i,t} \quad i = 1, 2, \cdots, 30 \tag{3}$$

[4]This includes factors associated with the Fed information effect, e.g., the market interpreting an FOMC policy announcement as (also) revealing private information on the state of the economy, its own preferences for inflation versus output stabilization, etc. See Nakamura and Steinsson (2018) for further discussion.

[5]The choice of one week follows Nakamura and Steinsson (2018). We examine (and confirm) robustness to two days before the FOMC announcement day, which is akin to the Rigobon (2003) practice.

where the event window of $\Delta R_{i,t}$ corresponds to Δi_t^{IV}, θ_i measures the sensitivity of $\Delta R_{i,t}$ to monetary policy, and $\mu_{i,t}$ is the idiosyncratic noise associated with i only.

The second step of our approach, by analogy to Fama and MacBeth, is to recover the aligned monetary policy shock from cross-sectional regressions of $\Delta R_{i,t}$ on the estimated sensitivity index $\hat{\theta}_i$ for each time t,

$$\Delta R_{i,t} = \alpha_i + e_t^{aligned}\hat{\theta}_i + v_{i,t} \quad t = 1, 2, \cdots, T \tag{4}$$

where $e_t^{aligned}$ is the coefficient of interest, which we call the BRW monetary policy shock.

2.2 The Data

We collect data on the monetary policy indicator from the Federal Reserve Board public website. As noted above, we examine 2-year, 5-year, and 10-year Treasury rates, with 5-year as benchmark. We also use data on estimated term premia, from Adrian, Crump, and Moench (2013), which are available through the New York Fed website https://www.newyorkfed.org /research/data_indicators/term_premia.html. The policy outcome variables, the zero coupon yields with maturities of 1 to 30 years, are estimated by Gurkaynak, Sack, and Swanson (2005), and available at https://www.federalreserve.gov/pubs/ feds/2006/200628/200628abs.html. To estimate impulse responses, we use monthly industrial production and CPI, both taken from https://fred.stlouisfed.org, the core commodity price index from Thompson Reuters, and the excess bond premium from Gilchrist and Zakrajsek (2012).

2.3 BRW Monetary Policy Shock Series

We display our monetary policy shock series in Figure 1. There are sizable movements before, during, and after the ZLB period. The announcements of QE1, QE2, and QE3, which are marked by navy lines, all generate large expansionary monetary policy shocks. Monetary policy shocks during Operation Twist, denoted by the orange lines, are instead contractionary. We mark with the blue line the FOMC meeting in October 2015, the meeting *preceding* lift-off in December. Zooming in on the last three meetings of 2015, our shock series takes the values -0.080 (September), 0.115 (October), and 0.038 (December). Expectations of a lift-off had been growing throughout the summer and heading into the October meeting. For a variety of reasons, including turmoil in global equity markets, the FOMC decided to keep the target Fed Funds rate unchanged at that meeting but sent a clear signal of a likely rise in December 2015.[6] Our measure indicates that this forward guidance gave rise to a sizable contractionary monetary policy shock in October 2015, one meeting before the actual rate increase. This is consonant with the dynamic pattern of alternative measures that use intra-daily data and estimate separate components of Fed monetary policy shocks.[7]

2.3.1 Comparison with Shocks in the Literature

Moving beyond the issue of plausibility of specific observations, we provide in Figure 2 and Table 1 a comprehensive comparison of our shock series to well-known measures in the literature: Kuttner (2001), Romer and Romer (2004), Nakamura and Steinsson (2018), and Swanson (2018). The updated R&R shock series, constructed using their same narrative method, runs through the end of 2007. Kuttner (2001) shocks are extracted from changes in Federal Funds futures rates in 30-minute windows around FOMC announcements. Nakamura and Steinsson also examine high-frequency movements around FOMC announcements. Their monetary policy shock is the first principal component of changes in the current month Federal Funds futures rate, the Federal Funds futures rate immediately following the next FOMC meeting, and two, three and four quarter ahead euro dollar futures in the 30-minute event window.[8] Swanson (2018) separately identifies the effects of forward guidance, large-scale asset purchases, and target Federal Funds rate shocks, also using principal components.[9]

Figures 2a and 2b display our shock series against these four measures. As can be seen in Figure 2a, prior to 2008 our shock series exhibits a similar pattern to the N&S, Kuttner, and R&R shocks. After 2008, the R&R shocks do not exist, while the two high-frequency shock series are quite small given that the Fed Funds rate is at zero during the ZLB. In contrast, our new shock series exhibits relatively large movements. This is consistent with Fed monetary policy being about more than just the target FFR. Finally, we compare our measure to those of Swanson (2018), whose identification strategy also gives rise to shocks that can bridge periods of conventional and unconventional monetary policy. As can be seen in Figure 2b, our shock series is similar to the FG and LSAP shocks of Swanson.

[6] As headlined in the Financial Times on October 29, 2015: "Federal Reserve drops warnings on global risks to US economy: Central banks hawkish statement increases chances of December rise in interest rates."

[7] For example, the corresponding values of the policy news shock of Nakamura and Steinsson (2018) are (-0.034, 0.031, 0.017), the forward guidance surprise in Rogers, Scotti, and Wright (2018) are (-0.09, 0.09, 0.03), and in Swanson (2018) (-2.77, 2.30, NA).

[8] We obtain these two shocks from Nakamura and Steinsson (2018) through 2014m3 (their sample period) and then follow their procedures to update to the present.

[9] Rogers, Scotti, and Wright (2018) implement an approach similar to Swanson (2018) in computing their three separate components of Fed policy shocks. The series are very highly correlated with those of Swanson, around 0.96.

In Table 1 we present the correlation between our measure and the alternatives during different sample periods. As seen in column 1, over the full sample our shock is reasonably highly correlated (around 0.5) with the N&S and Swanson shocks, which themselves are relatively large before and during the ZLB. The next two columns decompose the comparison into sub-periods, before and during the ZLB. Before the ZLB, our series is well correlated with N&S and the Swanson FG shock, around 0.6, implying that our series captures the long-end effect of monetary policy. In the third column of Table 1, we present correlations during the ZLB between our series and N&S, as well as with the FG and LSAP shocks of Swanson. The largest correlation, at 0.65, is with the Swanson FG shock.

2.3.2 BRW Series Construction Robustness

We examine several modifications to the construction of the baseline BRW shock series. As previewed above, we consider alternative normalizations of the monetary policy shock series to either the 2-Year or the 10-Year Treasury Rate. As seen in Columns 1 and 2 of Table 2, the correlation with our baseline shock series is above 0.9. Thus our IDH-based PLS approach is robust to different choices of the monetary policy indicator. Our second check is to extend our aligned monetary policy shock series backward to 1969. Before 1994, there was no public announcement of FOMC decisions. Thus, for this earlier period, we use the 1-day policy window between the FOMC announcement day and the following day to capture the policy effect. From the third column of Table 2, we can see that the correlation with our BRW shock is over 98%.[10]

Our third modification is to use only zero-coupon yields with 1-, 2-, 5-, 10-, and 30-year maturities, the non-synthetic cases, as the outcome variables. The correlation with the baseline shock series, as shown in column 4 of Table 2, is over 0.95. Fourth, we assess robustness to leaving out the QE1 announcement in the alignment process. This announcement,in March 2009, was a sufficiently big event occurring at a time when financial markets were so sluggish, that the markets response might not represent a typical effect of monetary policy. The new shock series without QE1 is again highly correlated with our baseline series (Column 5). Next, we extend our sample to include all unscheduled FOMC meeting dates since 1995, reconstruct our shock, and find a correlation of 0.88 (Column 6). We then consider using a 2-day event window for both policy indicator and outcome

[10] One feature of our methodology is the need to check the stability of the sensitivities of interest rates with different maturities to monetary policy shocks. Here, we do the rolling sample test for each period of 15 years, expanding the sample size to 1969 - 2017. As shown in Figure A2, when we use different monetary policy indicators of 1-, 2-, 5- and 10-year Treasury Rate, the coefficients are not completely stable until early 1990. That is why we start the sample in 1994, when the Fed first released a statement about FOMC policy decisions. The sensitivity index is flat after 1994, indicating stability of our alignment process.

variables. Doing this, we find that the correlation with the baseline shock series is over 0.8 (Column 7). Finally, we construct the instrumental variable as the daily movement in the policy indicator *one day* (as opposed to one week) before FOMC announcement day. As presented in Column 8 of Table 2, this alternative shock series has a correlation of 0.99 with the baseline series.

3 Impulse Responses to Monetary Policy Shocks

3.1 BRW Shocks

Following Romer and Romer (2004), we place our cumulative shock series in a monthly VAR model to identify the transmission effects of monetary policy shocks. We allow our monetary policy shock to contemporaneously affect all variables: output, inflation, commodity prices and excess bond premium.[11] We include commodity prices in light of the price puzzle (CEE, 1996) and the excess bond premium because of its ability to explain business cycles (Gilchrist and Zakrajsek, 2012) and as an indicator of the price of risk (Creal and Wu, 2016). The variables in our baseline model are thus ordered: cumulative monetary policy shock series, log industrial production, log consumer price index, log commodity price index, and excess bond premium. We use 12 monthly lags.

Figure 3a presents the impulse responses to a contractionary monetary shock using the full sample (1994-2017). The 68% and 90% standard error confidence intervals, displayed as deep and shallow gray areas respectively, are generated by the bootstrap. Both output and inflation decrease after a contractionary monetary policy shock. The responses reach their troughs after about 10 months. The excess bond premium increases and peaks after about 10 months. These results are conventional, in line with those of Gertler and Karadi (2015), for example.

Figure 3b shows the impulse responses when the model is estimated on the post-2008 sub-sample. The responses are similar: output and inflation significantly decrease for the first 10 months after a contractionary monetary policy shock, while the excess bond premium increases significantly. Figure 3c shows the impulse responses from the pre-2008 sub-sample estimates. Output decreases immediately and reaches its trough about 2 years later. Inflation exhibits a steady downward pattern, and the excess bond premium increases significantly 10 months after the shock.

[11] This also follows Romer and Romer. Our series and theirs are plausibly exogenous, given how they are constructed.

3.2 IRF Robustness

In light of standard concerns about potential dynamic mis-specification in VAR models, our first robustness check is to re-estimate using the Jorda (2005) local projections method, which constructs impulse responses from time-series regressions for each point in time. Results are shown in Figures 4a-c. Figure 4a presents the impulse responses to a contractionary monetary policy shock using the full sample (1994-2017). After a positive shock to our accumulated series, industrial production significantly decreases about 2 months later and reaches its trough after 15 months. Inflation immediately and sharply decreases throughout the 24 months. The excess bond premium responds positively through the first 10 months. Figures 4b and 4c show that results for the sub-periods estimated using local projections are very similar to those of the full sample and hence similar to those estimated from the VAR model.

The next robustness check concerns the term premium. For this purpose, we subtract from the raw interest rates the corresponding term premium on the 5-Year Treasury Rate and all the zero-coupon yields with 1 to 10-year maturity, as estimated by Adrian, Crump, and Moench (2013). We then reconstruct our monetary policy shock series excluding the term premium. Inserting the cumulative values of that series into the baseline VAR model, we find that the impulse responses (Figure 5) are quantitatively identical to the baseline results of Figure 3 although the negative effect on IP is dampened for the first few months. As shown in Column 9 of Table 2, the correlation between the term-premium free shock and our baseline shock is high, 0.79.

3.3 Alternative Shocks: NS, Swanson, Wu-Xia

In Figure 6, we compare the impulse responses above with those estimated by replacing our shock series with that of, alternately, Nakamura and Steinsson (2018), Swanson (2018), and Wu and Xia, 2016. The sample periods are: full (1994-2015), pre-ZLB (1994-2007) and during the ZLB (2008-2015). For the full and pre-ZLB sub-sample (Figure 6a and b), impulse responses using any of the four shocks follow the conventional monetary model. Output and inflation decrease while the excess bond premium increases after a contractionary monetary policy shock. However, during the ZLB sub-sample (Figure 6c), the impulse responses differ across cases. Following a positive shock to the Nakamura-Steinsson measure, both output and inflation *rise* significantly after about 10 months. In response to the shock identified by Swanson (FG plus LSAP), output, inflation and excess bond premium effectively do not change. Impulse responses to the Wu-Xia index shock are conventional and significant at first, but exhibit the opposite sign at long horizons.

The impulse responses to the alternative monetary policy shocks during the ZLB contrast sharply with the "conventional" impulse responses to our shock, displayed in column 1. These alternative shock results are consistent with the Nakamura-Steinsson conclusions concerning the importance of the Fed information effect. When the FOMC announces that the economy is strong in justifying a hike in interest rates, for example, market participants may adjust their assessment of the economy upward as a result of their belief that the Fed may have private information on the economic situation. This may have the effect of raising *actual* output.[12] In the section 4, we assess the extent to which the information effect can account for the different impulse responses displayed across cases in Figure 6c.

4 The Fed Information Effect

4.1 Presence in Different Shock Series?

Romer and Romer (2000) and Nakamura and Steinsson (2018), among others, advance the hypothesis of a "Fed information effect": monetary policy announcements contain information about central bank forecasts of economic fundamentals; as a by-product, macroeconomic variables such as output and inflation may be influenced not only by the announced policy itself but also by the forecasting information contained in the announcement. Use of even quite narrow windows around central bank announcements may not alleviate the issue for researchers. The opposite forces from these two sources (the policy and the reaction to it) may cause puzzling impulse responses such as output rising after a contractionary policy shock.[13]

We begin our assessment with the same approach that Nakamura and Steinsson used to document an information effect in their policy shock series. We confirm their results for their series and examine robustness to two other shocks: ours and Swanson (2018). Specifically, we run regressions of monthly changes in Blue Chip survey expectations of output growth on the monetary policy shock series of that month, and test for the Fed information effect based on the sign of the estimated coefficient. Following Nakamura and Steinsson (2018), we split the sample into: 1995-2014, 2000-2014,

[12] Nakamura and Steinsson do not directly estimate the effects of their policy news shock on output, as we do in Figure 6, but rather focus on the response of expectations of future output growth and real interest rates in a non-VAR framework. These authors also do extensive quantitative modeling and conclude from their estimation of the model that roughly two-thirds of the monetary shock is due to the Fed information effect.

[13] Campbell et. al. (2012), and Jarocinski and Karadi (2018) also provide evidence of a Fed information effect. Faust, Swanson, and Wright (2004) find no such evidence, however, while Lunsford (2018) argues that in his sample from February 2000 to May 2006 the information effect is present in the first half only.

2000-2007 and 1995-1999. Table 3 reports the results. While the information effect is significant in the measures of Nakamura and Steinsson (2018) and Swanson (2018), especially beginning in 2000, it is insignificantly different from zero in ours.

In order to understand what accounts for these differences, we begin by considering the importance of the underlying data and econometric procedure used to construct the shock series. Roughly speaking, we undertake an "encompassing" analysis, inputting our data into the NS estimation procedure (PCA), and conversely use the NS data and our Fama-Macbeth estimation technique. To simplify this, first consider an alternative BRW shock series constructed from the Fama-Macbeth two-step procedure *without the use of IDH* but with the same policy indicator and outcome variables as in the baseline. As presented in Table 2 (Column 10), the IDH-free shock is highly correlated with the baseline BRW shock.[14] Thus, the instrumental variable aspect of our estimation procedure has little effect on our baseline results. As we document next, of greater importance is our adoption of the Fama-Macbeth two-step regressions.

As noted above, Nakamura and Steinsson use a principal components analysis (PCA) to derive their monetary policy shock. This procedure extracts the first principal component from movements in their outcome variables around FOMC meetings.[15] We use our outcome variables together with the Nakamura-Steinsson PCA procedure to construct an alternative monetary policy shock series. As seen in column 11 of Table 2, the correlation between the "PCA" shock and our baseline BRW shock is only 0.25. Furthermore, in Figure A5 we show that the impulse responses to the PCA shock are unconventional: muted in the full sample and moving in the "wrong" direction during the ZLB period. Moreover, estimating the NS private information regressions with this PCA shock, we find that a positive shock leads to a significant *increase* in the Blue Chip real GDP growth rate forecast in the next quarter. Both of these findings are consistent with the Fed private information effect hypothesis, as detailed above.

Next we flip the robustness exercise, inputting the Nakamura-Steinsson data into our econometric procedure.[16] The "Tight" (window) shock generated in this way has a correlation of only 0.43 with the baseline BRW shock (Table 2, Column 12). Nevertheless, positive shocks to this new series give rise to impulse responses with the *conventional* signs, albeit with some lagged effects compared

[14] It also generates very similar impulse responses to the baseline results, as seen in Appendix Figure A4.

[15] This method and ours are similar in the sense of extracting the common part of a set of correlated variables, but the Fama-MacBeth regressions assign relatively more importance to the policy indicator.

[16] To be specific, the monetary policy indicator is the change in the 5-year Treasury bond rate, as in our baseline identification, over a tight event window of 30-minute surrounding the FOMC announcement (as in NS), with the policy outcome variables being the expected 3-month eurodollar interest rates with horizons of 1 to 8 quarters and on-the-run treasury rate of 3 months, 6 months, 2 years, 5 years, 10 years and 30 years, again as in NS.

to baseline BRW shocks (Figure A6). Moreover, the information effect essentially disappears in the Fama-MacBeth aligned Tight shock (Table 3, Row 4). We thus conclude that the Fama-MacBeth procedures play an important role in the construction of the BRW shock, and accounts for much of the difference in our findings of section 3 concerning the information effect.

4.2 Fed Forecasts, Blue Chip Forecasts, and Policy Shock Transmission

In Figure 7, we depict the difference between Fed and Blue Chip forecasts of real GDP growth, a proxy for the central bank "private information" as conceived in the literature.[17] Noteworthy are the large negative values around September 11, 2001 and the last quarter of 2008. At these times, the Fed was significantly more bearish on the economy than the private sector.[18] Table 4 reports OLS regressions of the various monetary policy shock series on these forecast differences. The coefficient is positive and significant for the NS and Swanson measures, but insignificantly different from zero in the regression using our series, a regression with an R2 of only .02.

To examine the possible role of Fed private information in accounting for the differences in the transmission effects of monetary policy shocks during the ZLB period shown in Figure 6, we replace the original shock series with the residual from the regression of Table 4.[19] This residual represents that component of the raw monetary policy shock that is not accounted for by differences in the Fed-private sector outlook differential. Impulse responses using the shock series of N&S, Swanson, and BRW are reported in Figure 8a-c, respectively. In the left panels, we depict point estimates and confidence bands from the VARs with the orthogonalized series. In the far right panels, we depict the IRFs using the original shock series. The middle column presents the comparison, omitting the confidence bands for ease of viewing. The effects are noticeable. For both N&S and Swanson shocks, the positive responses of output to a contractionary policy shock are diminished. Indeed, the responses of shocks to the orthogonalized Swanson measure take on the conventional signs (Figure 8b). In the case of BRW shocks, for which the Fed information effect is insignificant, there are no differences in the impulse responses across the two experiments (Figure 8c).

[17] The series is constructed as follows: (1) prior to December 2012, the average of the first four quarters ahead Greenbook forecasts minus the corresponding Blue Chip forecasts. (2) After January 2013, for which the Greenbook forecasts are not yet publicly available, we use the forecasts from the Fed summary of economic projections (SEP). These are available four times a year: in March, June, September, and December. For the other four FOMC meetings each year, we use the SEP from the previous meeting. We use the current year SEP forecast if the FOMC meeting happens in the first quarter of the year. Otherwise, we use the projection for the following year. We subtract from this the year-ahead Blue Chip forecast.

[18] These were of course also times when important news events occurred at a higher frequency than the available forecast data.

[19] Miranda-Agrippino and Ricco (2017) and Kane, Rogers, and Sun (2018) pursue a similar strategy.

5 Conclusion

In this paper, we implement a two-step procedure to estimate a new Fed monetary policy shock series that usefully bridges periods of conventional and unconventional policymaking. Our approach has very mild data requirements and is easy to implement econometrically. Longer-term interest rates such as 2- 5- and 10-year Treasury bill rates serve well conceptually as an effective policy indicator across the different periods. We implement a heteroskedasticity-based estimator to filter background noise, and align the monetary policy shock using Fama-MacBeth regressions. Our shock series is well correlated with the series of Nakamura and Steinsson (2018) before the ZLB and with the Swanson (2018) FG and LSAP shock series during the ZLB.

We introduce our shock series into VAR and local projections models to estimate transmission effects of monetary policy shocks before and during the ZLB period. We find that in response to contractionary monetary policy shocks, output falls significantly. This result is found in samples both before the ZLB and during the ZLB sub-period with our measure. Using alternative monetary policy shock measures, however, the decline in output is found before the ZLB sub-period, but during the ZLB the responses are either zero or positive. We explain these different findings with an appeal to the Fed information effect. Using standard specifications, we find no evidence that our new monetary policy shock series exhibits an information effect, whereas the alternative series do. When cleansed of the information effect component, these alternative series produce impulse responses that are much closer to the standard estimates.

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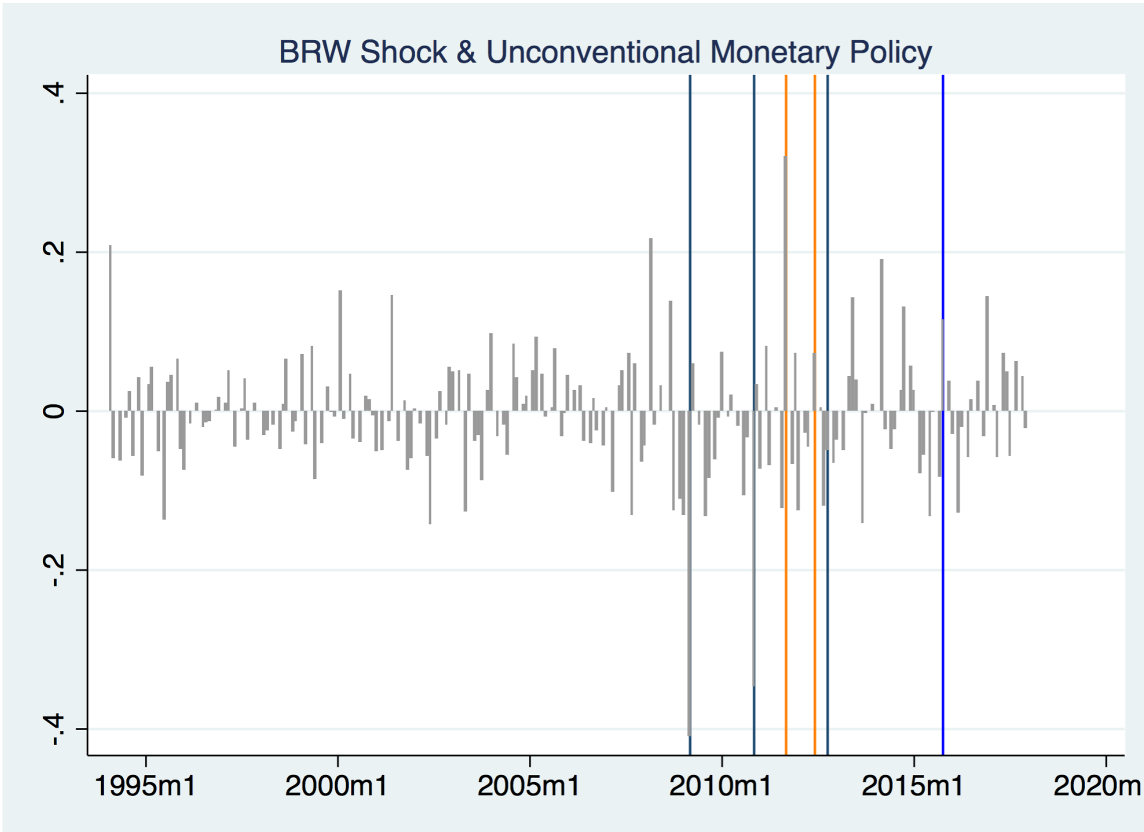
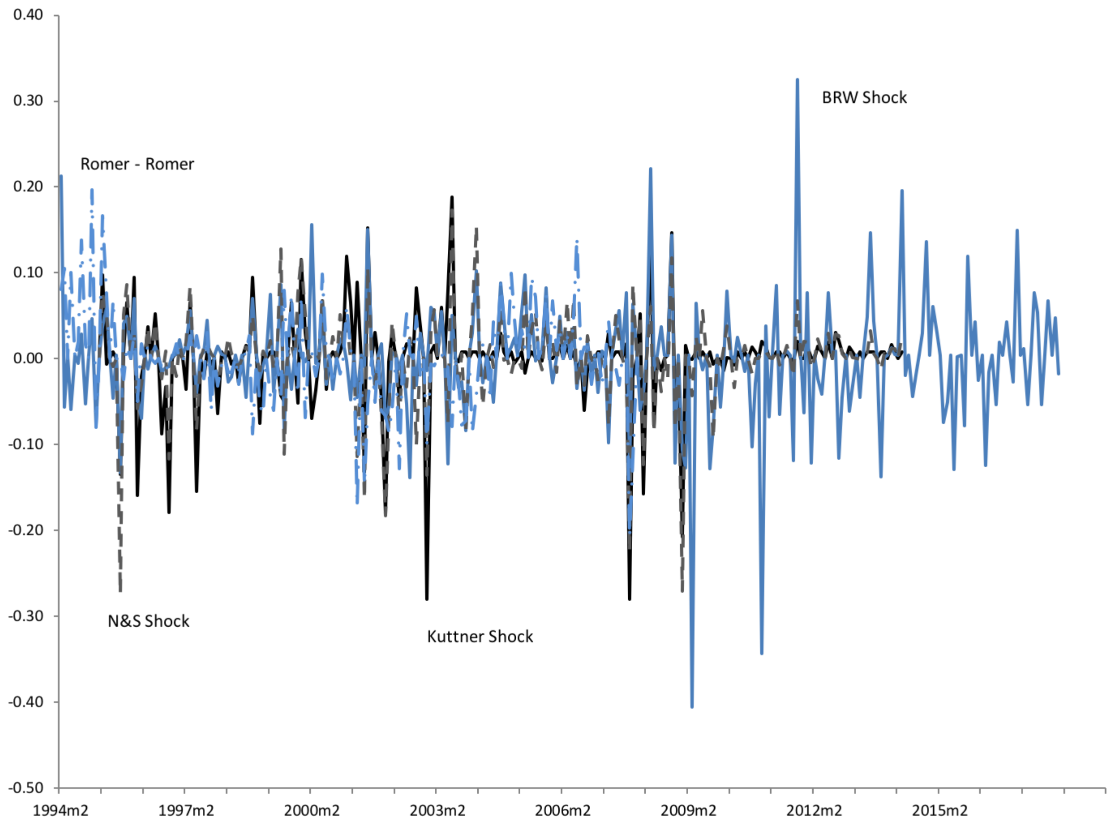
Figure 1: BRW Shock Series Jan 1994 to Dec 2017



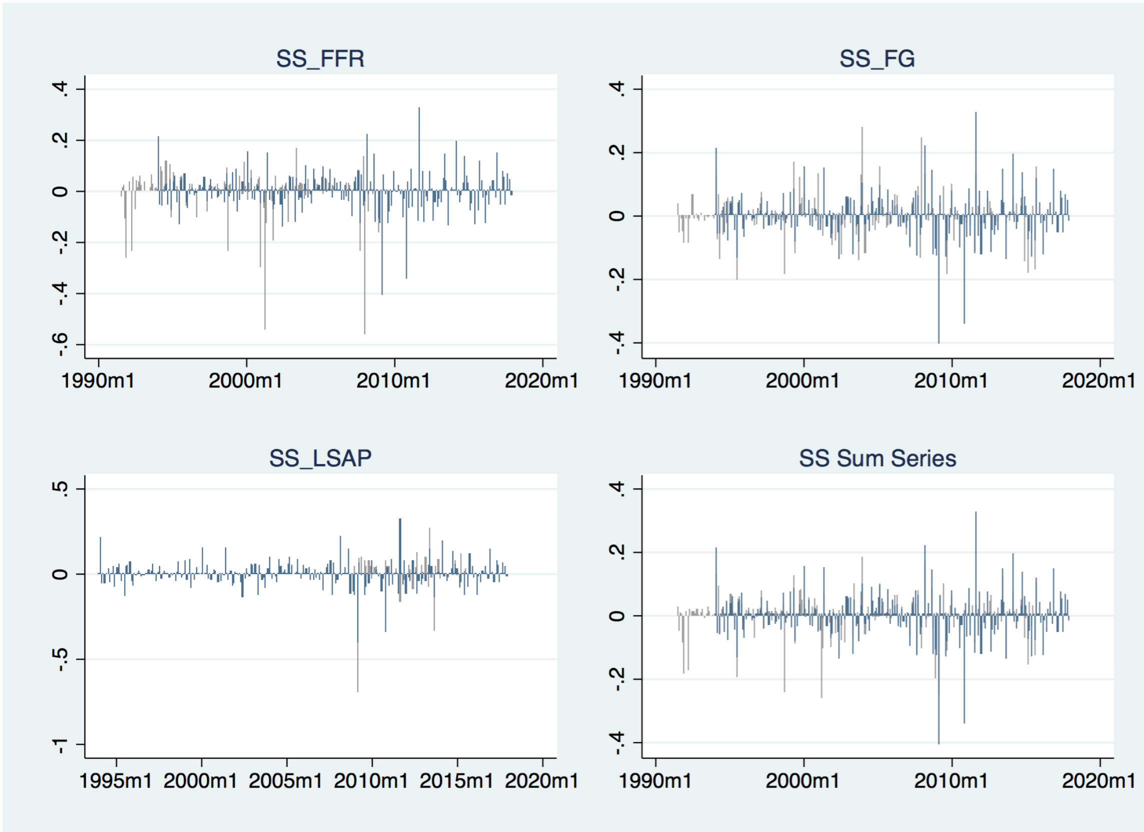
Note: The BRW shock series is estimated from Equations (3) and (4). The navy vertical lines denote announcements of QE1, QE2, and QE3; the orange vertical lines denote the Operation Twist period; and the blue line denotes Oct. 2015, the FOMC meeting prior to liftoff.

Figure 2a: BRW Shock Series and the Three Conventional Shock Series



Note: The solid blue line represents the BRW shock series estimated from Equations (3) and (4). *N&S Shock*, the black dotted line, refers to the policy factor shocks obtained from Nakamura and Steinsson (2018). *Kuttner Shock*, the solid black line, refers to the 30-minute fed funds rate changes around FOMC announcement obtained from Nakamura and Steinsson (2018). *R&R Shock*, which is the blue dashed line, refers to the estimated shock series in Romer and Romer (2004).

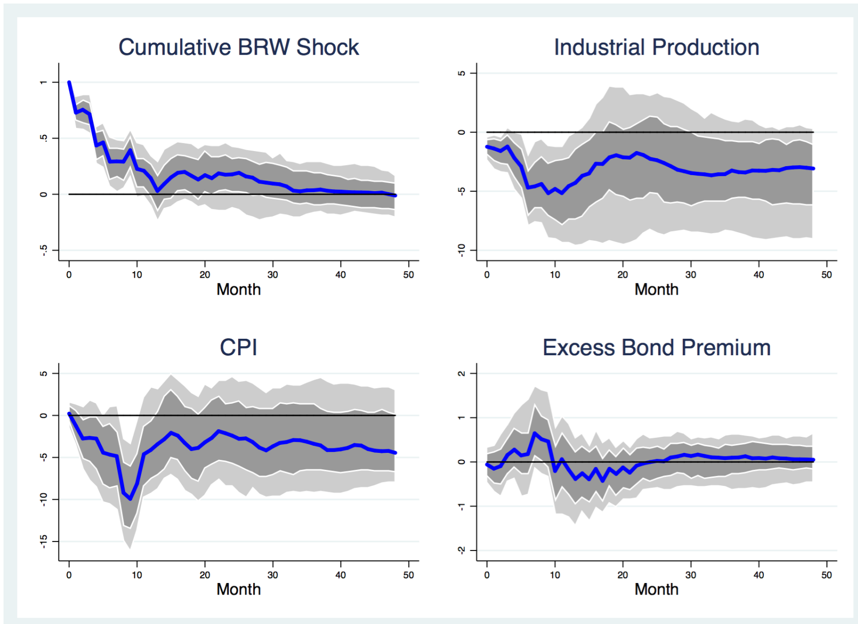
Figure 2b: BRW Shock Series & Swanson's Shock Series



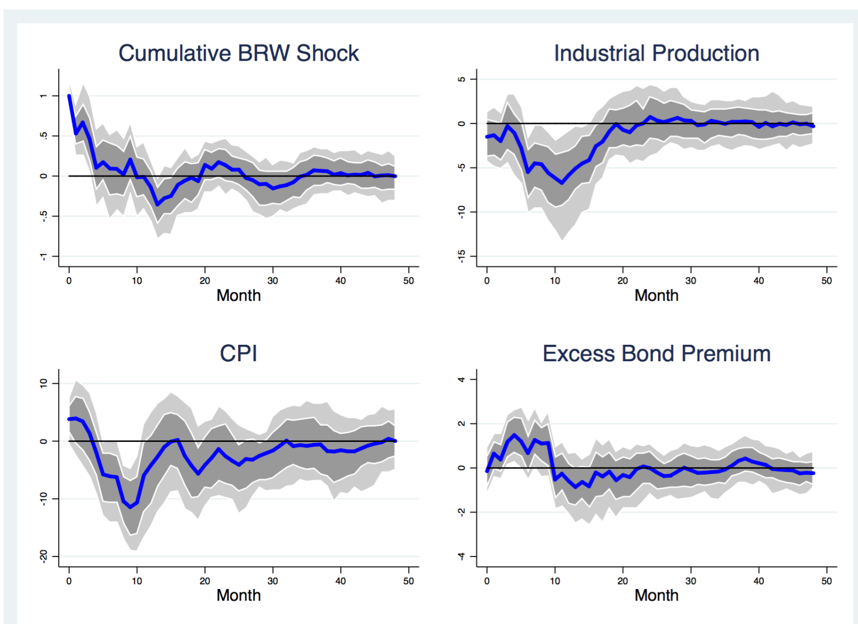
Note: All navy bars are in the graphs are are our BRW shock series estimated from Equation (3) and (4). Gray bars are corresponding benchmark shock series in each graph. *SS_FFR, SS_FG, SS_LSAP, and SS_Sum* each refer to the shock series of the federal funds rate, the forward guidance, the large asset purchases proposed, and the total of the three shocks by Swanson (2017).

Figure 3: Baseline SVAR Impulse Responses

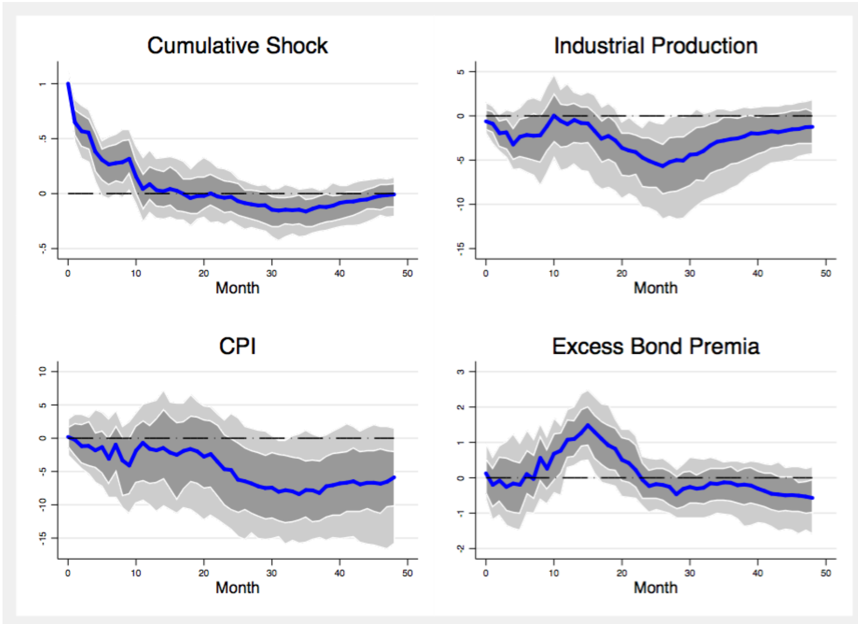
a. 1994m1-2017m12



b. 2008m1-2017m12



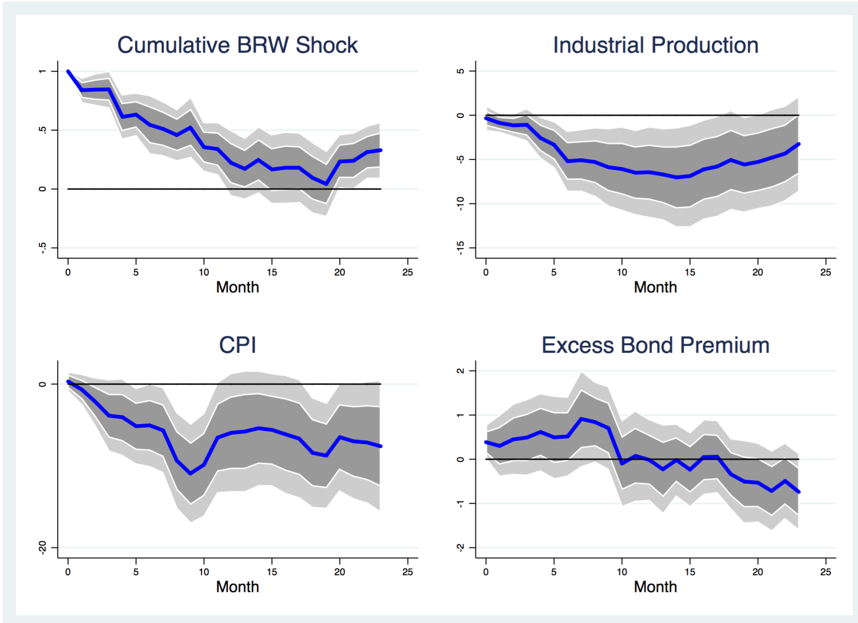
c. 1994m1-2007m12



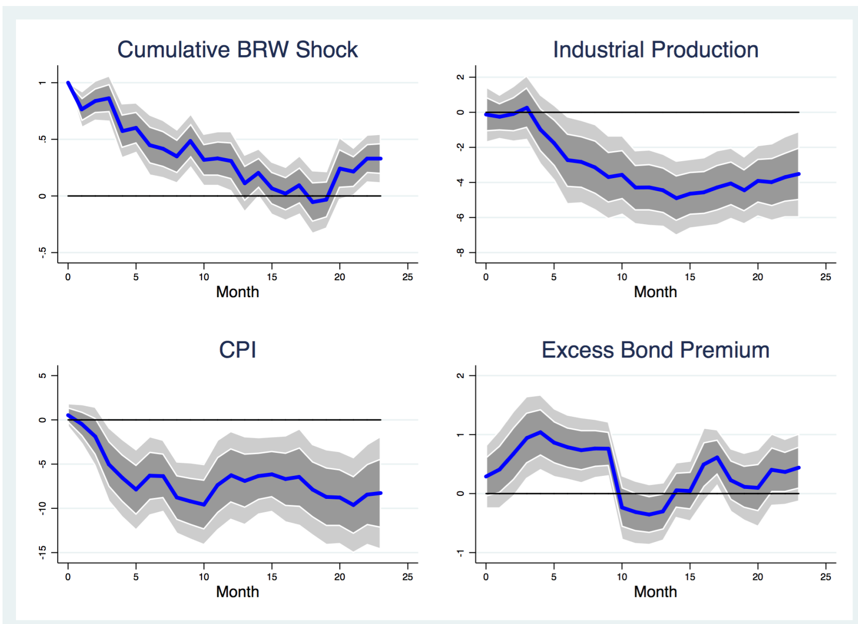
Note: Structural VAR with monthly data, 5 endogenous variables and 12 lags. Variables are ordered as follows: cumulative BRW shock series, log industrial production, log consumer price index (CPI), log commodity prices, and excess bond premium. Graphs show impulse responses estimated over different sample periods to a 100 basis point increase in the cumulative BRW shock series. Deep and shallow gray shaded areas are 68% and 90% confidence intervals produced by bootstrapping 100 times, respectively.

Figure 4: BRW Shock Series IRFs using Jorda (2005) Local Projections Method

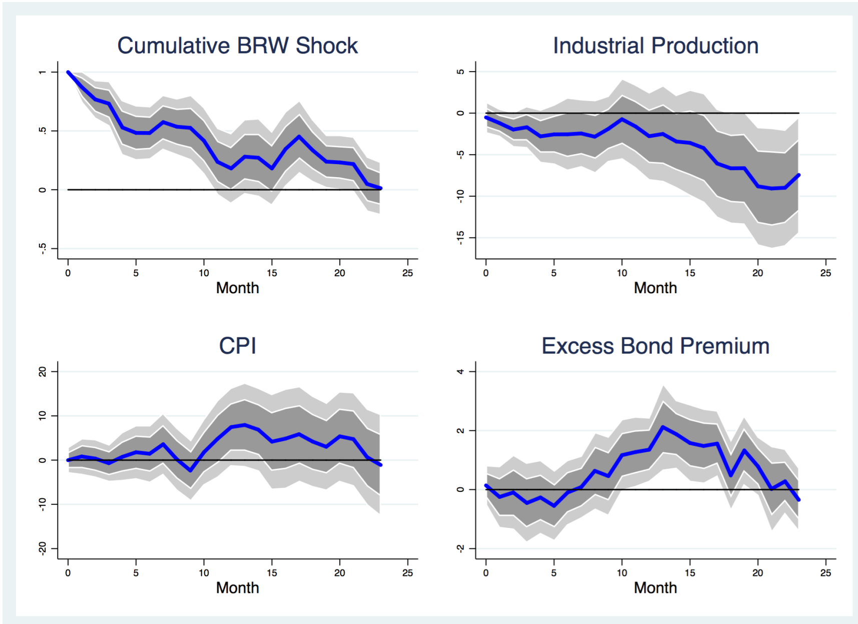
a. 1994m1-2017m12



b. 2008m1-2017m12



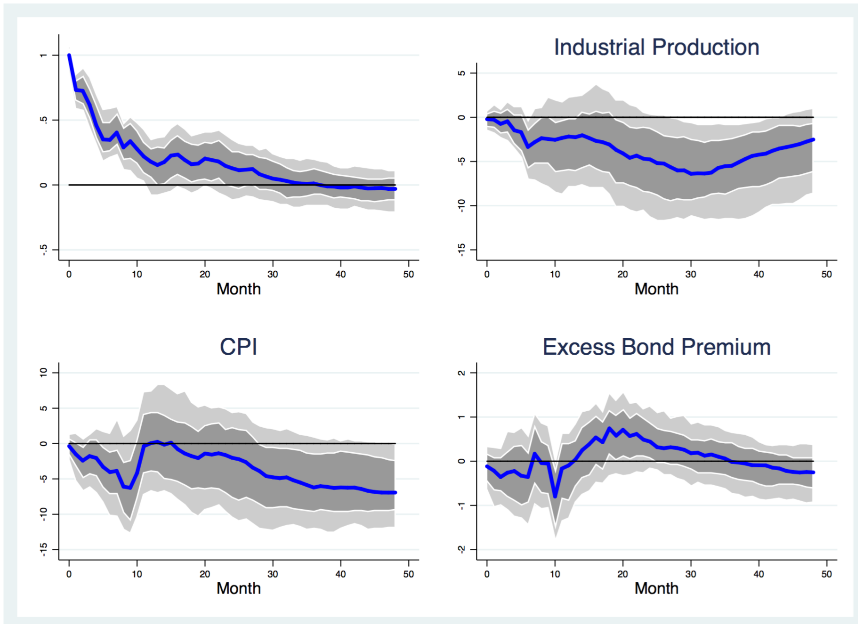
c. 1994m1-2007m12



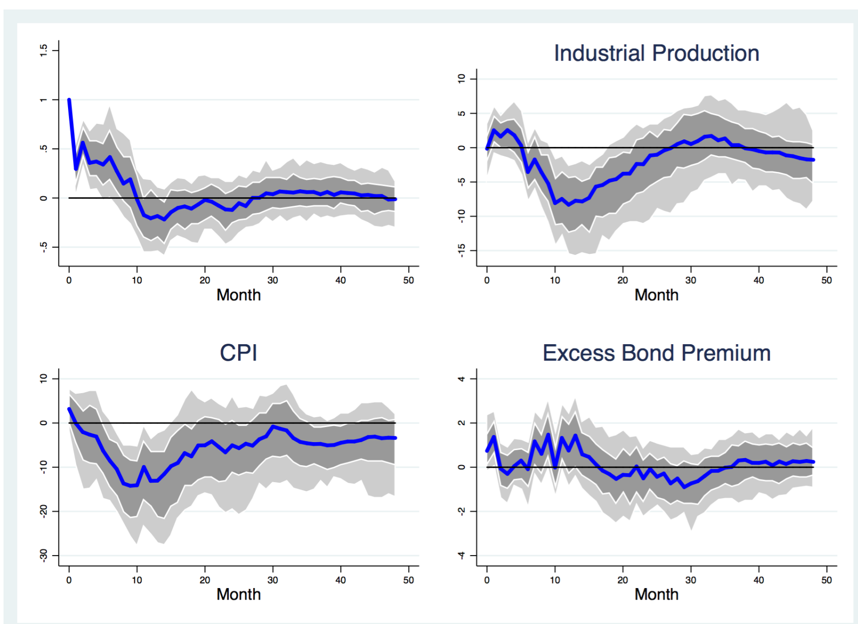
Note: The variables included are: cumulative BRW shock series, log industrial production, log consumer price index (CPI), log commodity prices, and excess bond premium. The deep and shallow gray shaded areas represent 68% and 90% confidence interval, respectively.

Figure 5: Robustness Check: Influence of the Term Premium

a. 1994m1-2017m12



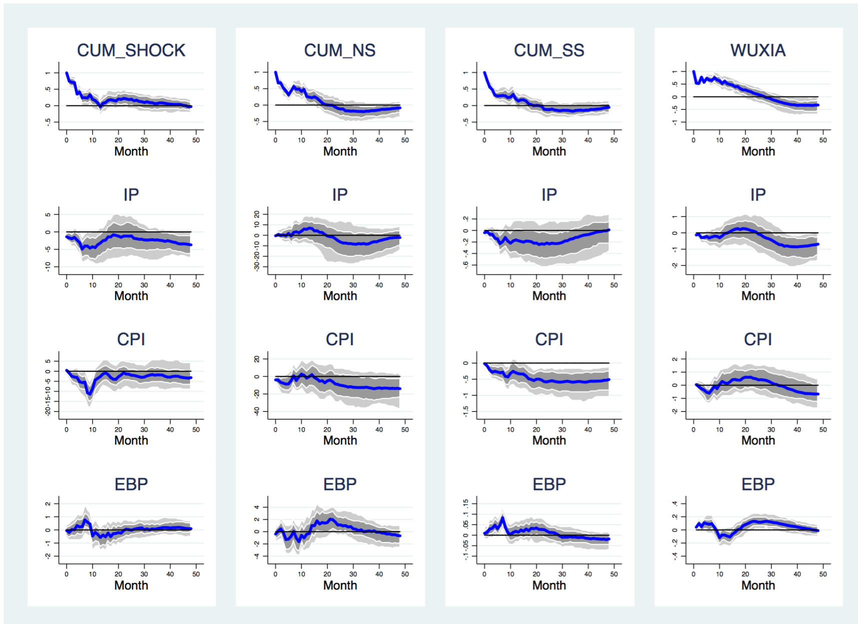
b. 2008m1-2017m12



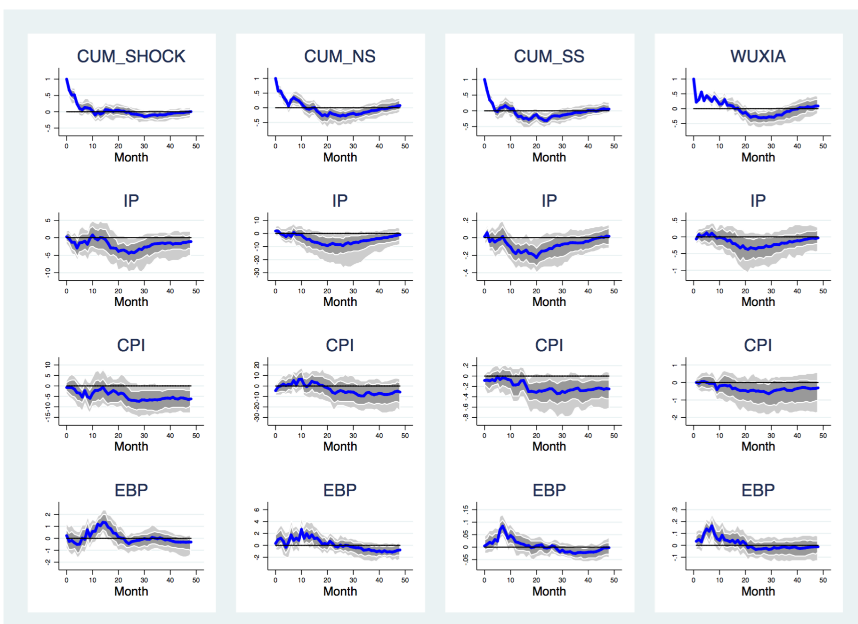
Note: Variables are ordered: the cumulative BRW shock series minus the term premium, log industrial production, log consumer price index (CPI), log commodity prices, and excess bond premium. Graphs show impulse responses to a 100 basis point increase in the cumulative BRW shock series. Deep and shallow gray shaded areas are 68% and 90% confidence intervals produced by bootstrapping 100 times, respectively.

Figure 6: SVARs with Alternative Shock Series

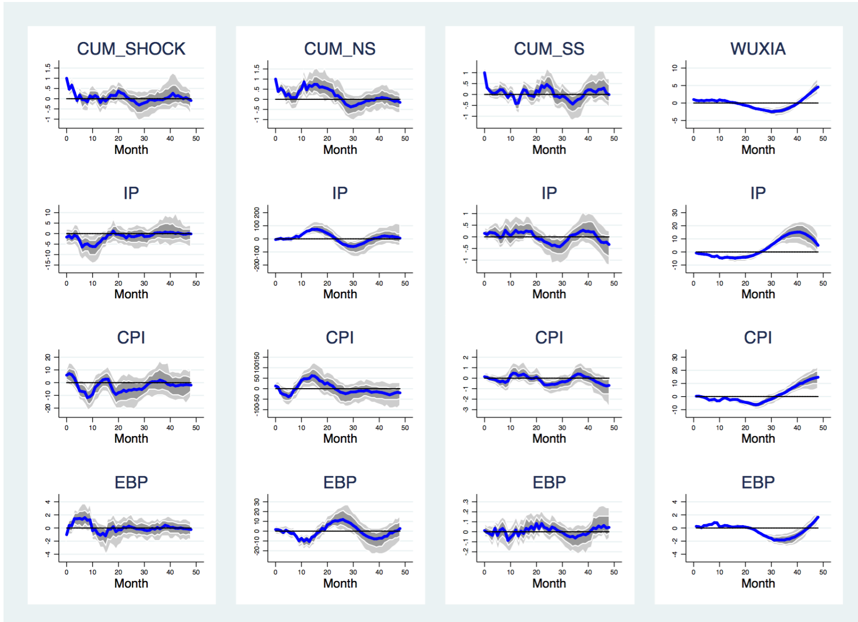
a. 1994m1-2015m12



b. 1994m1-2007m12

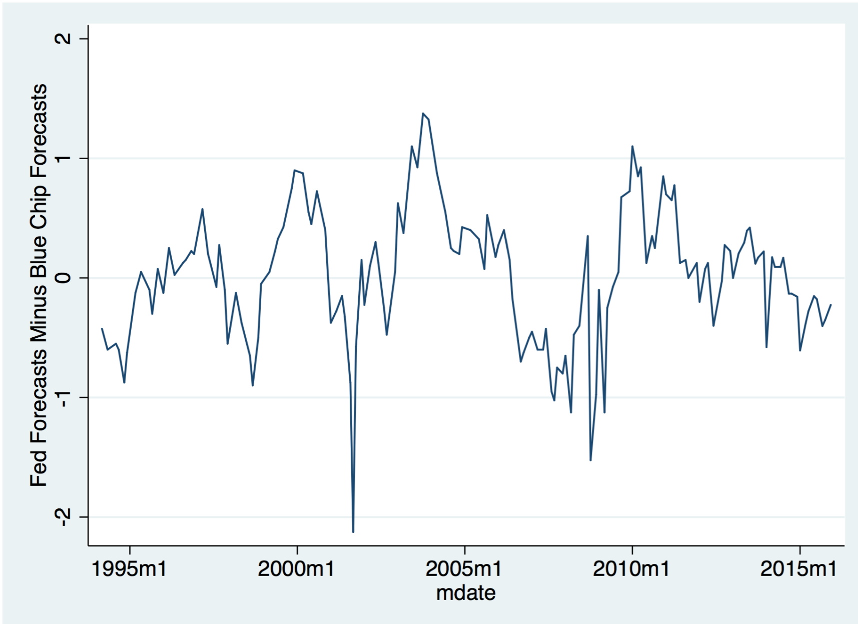


c. 2008m1-2015m12



Note: CUM_SHOCK, CUM_NS and CUM_SS refer to cumulative BRW shock series, Nakamura and Steinsson (2018) shock series, and Swanson (2017) shock series, respectively. For these cases, variables are ordered: the cumulative shock series, log industrial production, log consumer price index (CPI), log commodity prices, and excess bond premium. For the case with the Wu and Xia (2016) index, variables are ordered: log industrial production, log consumer price index (CPI), log commodity prices, excess bond premium, and the Wu-Xia index. Graphs show impulse response to a 100 basis point increase in the monetary policy indicator series. Deep and shallow gray shaded areas are 68% and 90% confidence intervals produced by bootstrapping 100 times, respectively.

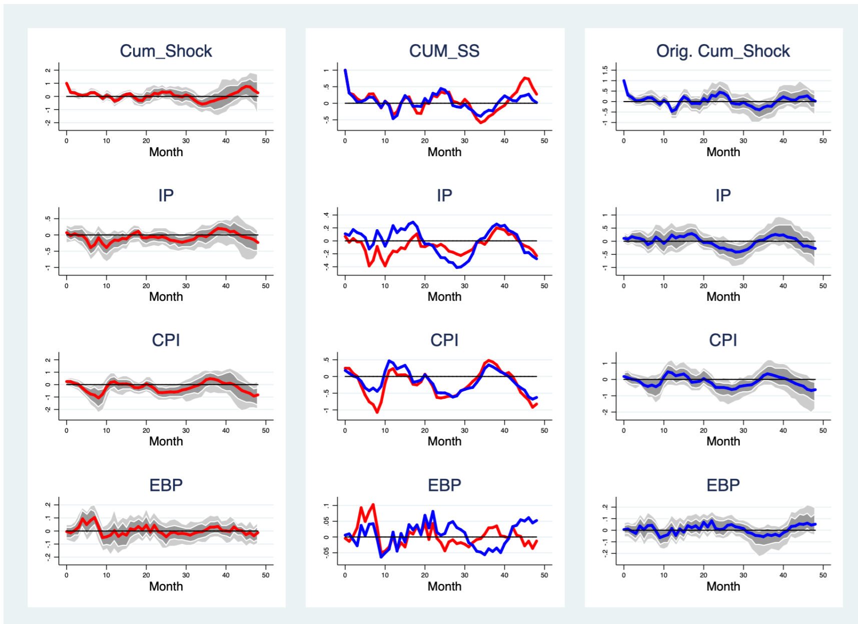
Figure 7: GDP Growth Forecasts, Fed Minus Blue Chip



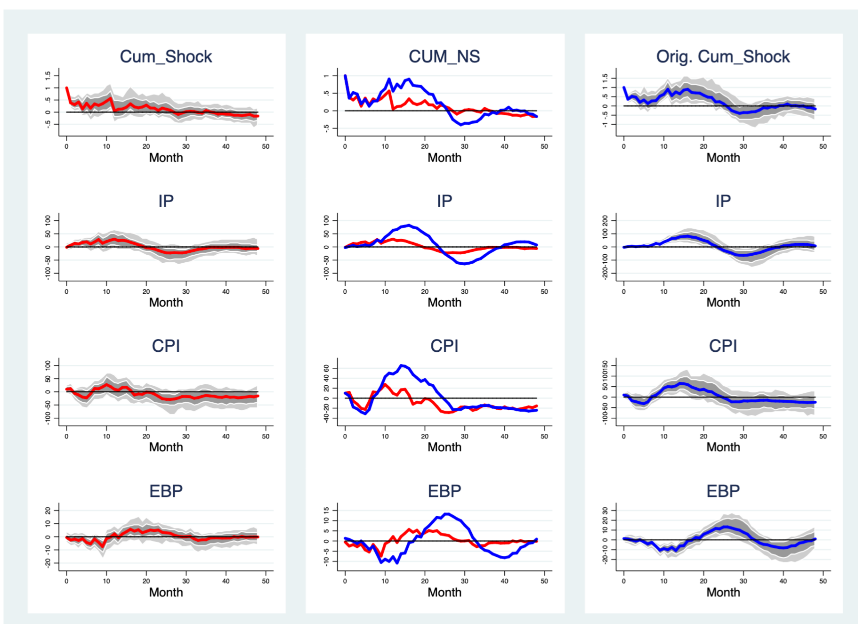
Note: Prior to December 2012, this is the average of the first four quarters ahead Greenbook forecasts less the corresponding Blue Chip forecasts. After January 2013, we use forecasts from the FOMC summary of economic projections (SEP) because the Greenbook data is not yet publicly available. The Fed SEP are available four times per year-in March, June, September, and December. For the other four FOMC meetings, we use the SEP from the previous FOMC meeting. We use the current year SEP forecast for real GDP growth rate if the FOMC meeting happens in the first quarter of the year. Otherwise, we use the next year SEP forecast for real GDP Growth.

Figure 8: Accounting for the Fed Information Effect: SVARs using Orthogonalized Shock Series (2009:1 - 2015:12)

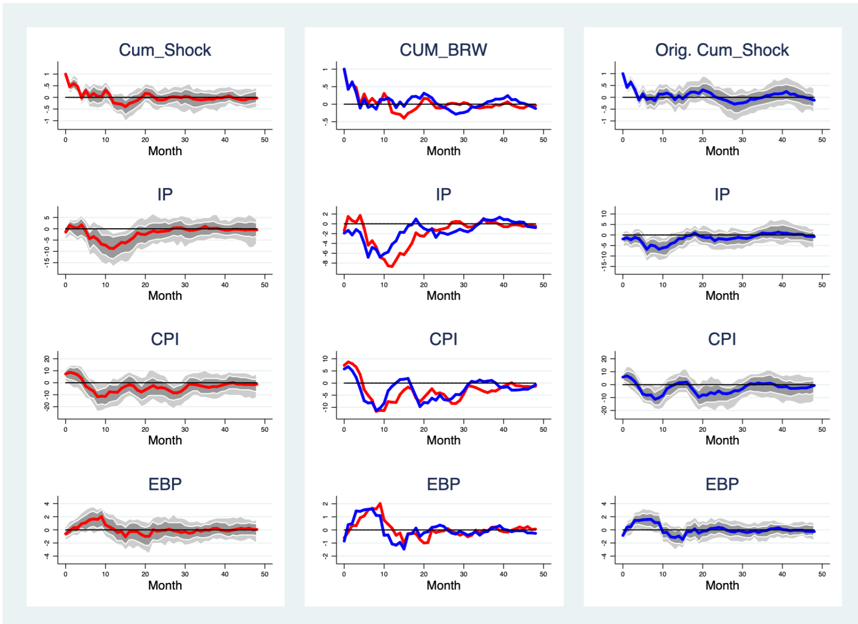
a. Swanson Shock: Original (blue) versus Orthogonalized (red) Shock Series



b. N&S Shock: Original (blue) versus Orthogonalized (red) Shock Series



c. BRW Shock: Original (blue) versus Orthogonalized (red) Shock Series



Note: The orthogonalized shock series are the residuals from the regressions reported in Table 4. We regress each shock series on the differences between the Fed and Blue Chip forecasts.

Table 1: **Correlation with BRW Shock Series**

	Full Sample	Pre-ZLB	ZLB
N&S Shock	0.4211	0.5754	0.5092
SS shock	0.6157	0.7098	0.6091
R&R Shock		0.1312	
Kuttner Shock		0.3083	
SS_FFR		0.3733	
SS_FG	0.4906	0.6046	0.6473
SS_LASP			0.3776

Note: The benchmark shock is our BRW shock series estimated from Equation (3) and (4). *N&S* Shock refers to the policy factor shock of Nakamura and Steinsson (2018), which we update to the present. *SS Shock* refers to the sum of the shock series of the federal funds rate, the forward guidance and the large asset purchases in Swanson (2018). *R&R Shock* refers to the estimated shock series in Romer and Romer (2004). *Kuttner Shock* refers to the 30-minute fed funds rate changes around FOMC announcement obtained from Nakamura and Steinsson (2018). *SS_FFR*, *SS_FG*, *SS_LASP* refers to the shock series of the federal funds rate, forward guidance and large asset purchases in Swanson (2018). Sample periods are: Full sample 1994m1-2017m12, Pre ZLB 1994m1-2008m12, ZLB 2009m1-2015m12.

Table 2: **Shock Series Robustness: Correlations with Baseline BRW Shock Series**

	Norm2	Norm10	BRW1969	R5	QE	Unscheduled	Day2	IV2	TP	OLS	PCA	Tight
BRW Shock	0.9753	0.9808	0.9844	0.9564	0.9181	0.8634	0.8383	0.9951	0.7908	0.9926	0.2487	0.4251
Observations	288	288	288	288	288	275	288	288	288	288	288	197

Note: *BRW Shock* refers to our BRW shock series estimated from Equation (3) and (4).
Norm2 refers to the BRW shock series aligned from using the 2-year Treasury Rate as policy indicator.
Norm10 refers to the BRW shock series aligned from using the 10-year Treasury Rate as policy indicator.
BRW1969 refers to our BRW shock series estimated from Equation (3) and (4) from 1969m1 to 2017m12.
R5 refers to the BRW shock series aligned using zero-coupon yields with only the 1, 2, 5, 10, 30-year maturities as outcome variables.
QE refers to the BRW shock series aligned ruling out the announcement of QE1 in March, 2009.
Unscheduled refers to the BRW shock series aligned including all the unscheduled FOMC meeting dates since 1995.
Day2 refers to the BRW shock series aligned using a 2-day event window around FOMC announcements days.
IV2 refers to the BRW shock series aligned using the daily movements in the policy indicator 1-day before FOMC announcement day rather than one week as the instrument variable.
TP refers to the BRW shock series generated as the baseline approach from Equation (3) and (4) but free of the estimated term premium.
OLS refers to the alternative BRW shock series aligned from the simple Fama-Macbeth method without the IDH instrument variable.
PCA refers to the shock series generated from extracting the first principal component of all outcome variables (daily changes of 1 to 30-year zero coupon rate around FOMC meeting).
Tight refers to the BRW shock series using the 30-minute change of the Federal Funds Rate around FOMC announcements as the policy indicator, aligned from the simple Fama-Macbeth method, rather than a two hours wide window.

Table 3: **Fed Information Effect**

	1995-2014	2000-2014	2000-2007	1995-1999
BRW Shock	0.12	0.06	0.25	0.02
	(0.19)	(0.21)	(0.37)	(0.46)
SS Shock	1.77*	1.87	1.84*	1.36
	(1.02)	(1.27)	(1.03)	(1.19)
N&S Shock	0.71**	0.80**	0.67**	0.39
	(0.33)	(0.40)	(0.32)	(0.41)
BRW Tight	0.08	-0.01	0.05	0.54**
	(0.17)	(0.20)	(0.21)	(0.25)
Observations	122	89	51	32

Note: Constant term not displayed. Robust standard error in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. *BRW Shock* refers to our BRW shock series estimated from Equation (3) and (4). *SS Shock* refers to the sum of the shock series of the Federal Funds rate, forward guidance and large scale asset purchases of Swanson (2018), scaled by 100. *N&S Shock* refers to the policy news shocks of Nakamura and Steinsson (2018). *BRW Tight* refers to the shock series using 30min tight-window change of Federal Funds Rate around FOMC annoucement as the policy indicator and aligned from the simple Fama-Macbeth method. We regress the monthly change (in the current month to next) in survey expectations of output growth over the next 3 quarters from Blue Chip Economic Indicators on the shock series in that month. Sample periods are: 1995m1-2014m4, 2000m1-2014m4, 2000m1-2007m12, and 1995m1-1999m12.

Table 4: **Shock Series Regressed on Fed minus Blue Chip GDP Growth Forecasts**

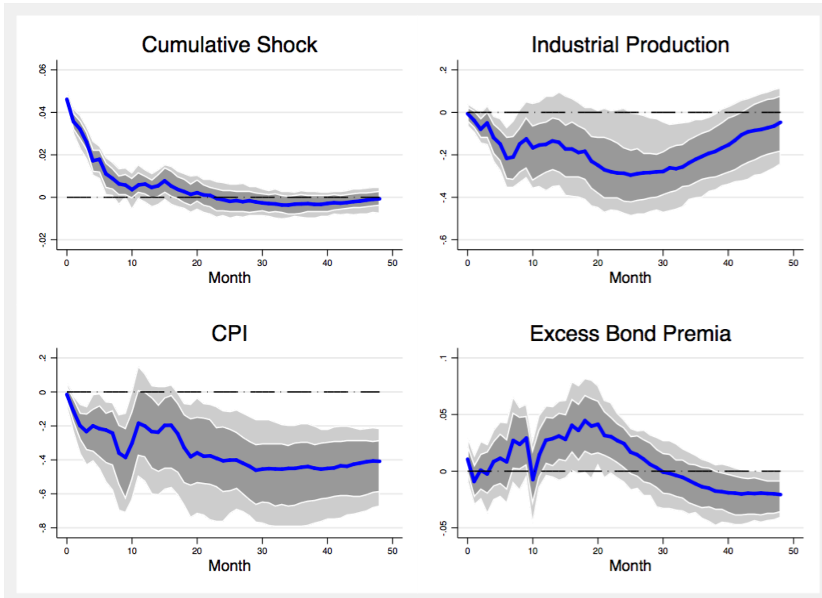
	(1) N&S Shock	(2) Updated N&S Shock	(3) BRW Shock	(4) Swanson's Shock
Fed - BC	2.00**	1.95***	2.00	0.67**
	(0.77)	(0.70)	(1.54)	(0.31)
Constant	0.23	0.23	-0.72	0.07
	(0.33)	(0.29)	(0.65)	(0.11)
Observations	131	150	150	150
R-squared	0.09	0.08	0.02	0.07

Note: Constant term not displayed. Robust standard error in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. *BRW Shock* refers to our BRW shock series estimated from Equation (3) and (4). *SS Shock* refers to the sum of the shock series of the federal funds rate, the forward guidance and the large asset purchases proposed by Swanson (2018). We scale the SS shock by 100. *N&S Shock* refers to the policy factor shocks from Nakamura and Steinsson (2018). The updated N&S Shock is the shock series updated to 2015m12 following the method in Nakamura and Steinsson (2018). *Fed - BC* is the difference between Fed and Blue Chip GDP growth Forecasts, constructed as described above. Sample periods are: 1995m1-2014m3, 1994m1-2015m12, 1994m1-2015m12, and 1994m1-2015m11 (Swanson's sample ends just before lift-off).

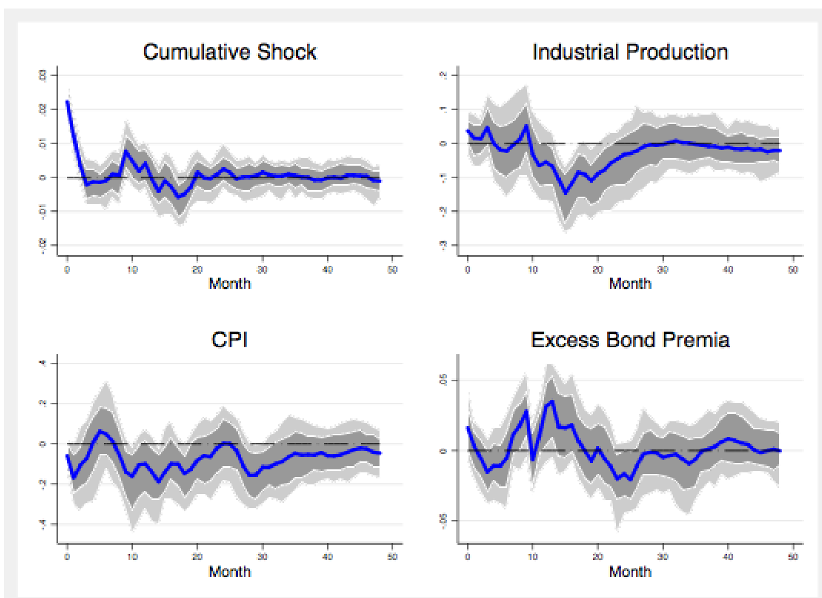
Appendix

Figure A1: Baseline SVAR Impulse Responses with Simple Daily Shock

a. Over Sample of 1994m1-2017m12

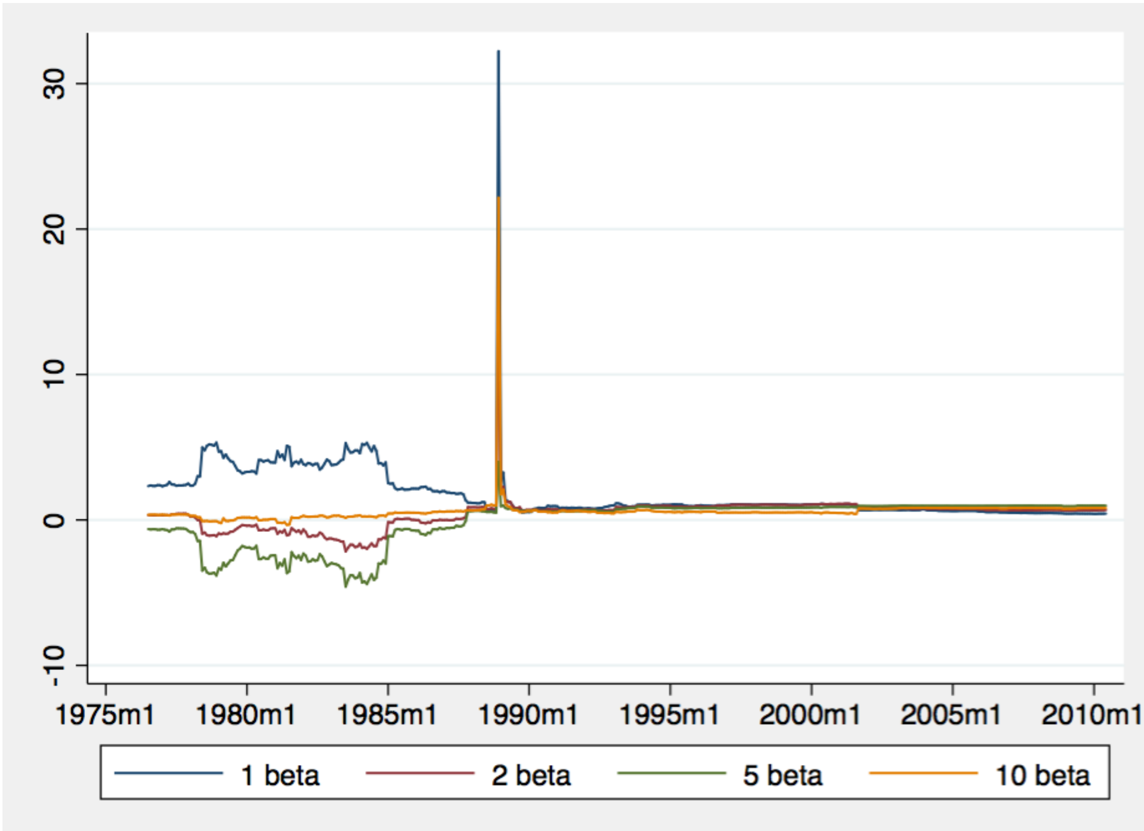


b. Over Sample of 2008m1-2017m12



Note: Structural VAR with monthly data, 5 endogenous variables and 12 lags. Variables are ordered as follows: the cumulative simple daily change of 5-year Treasury Rate around FOMC, the log industrial production, the log consumer price index (CPI), the log commodity prices and the excess bond premium. Graphs show impulse response with different sample periods to a 100 basis point increase in the cumulative BRW shock series. Deep and shallow gray shaded areas are 68% and 90% confidence intervals produced by bootstrapping 100 times, respectively.

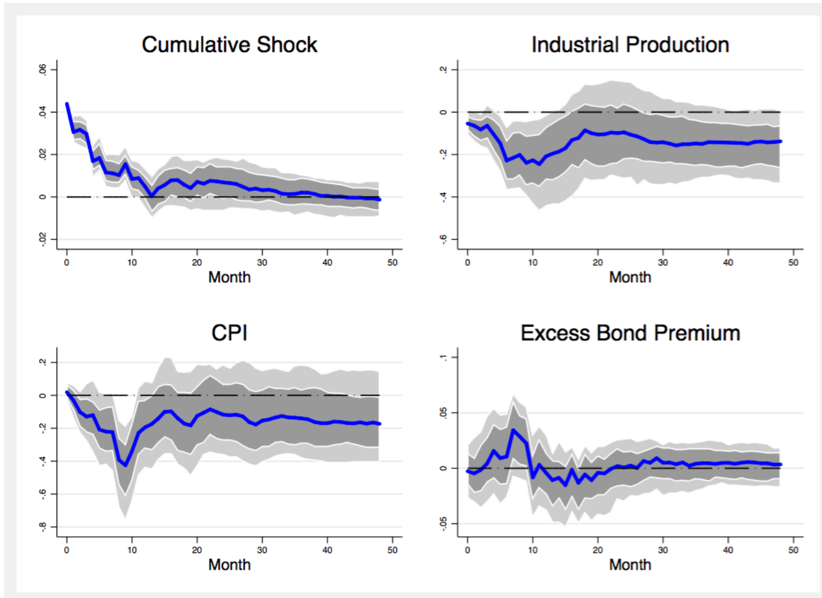
Figure A2: Rolling Sample 1969m1-2017m1



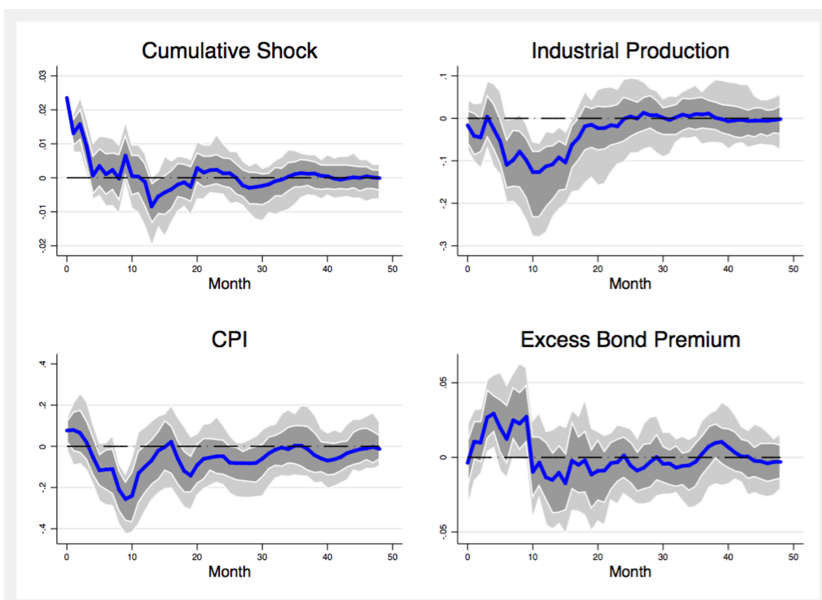
Note: rolling sample from 1969m1 to 2017m12 with each 15 years. *1 beta* refers to the estimate coefficient of using 1-year Treasury Rate as monetary policy indicator. *2 beta* refers to the estimate coefficient of using 2-year Treasury Rate as monetary policy indicator. *5 beta* refers to the estimate coefficient of using 5-year Treasury Rate as monetary policy indicator. *10 beta* refers to the estimate coefficient of using 10-year Treasury Rate as monetary policy indicator.

Figure A3: SVAR Impulse Responses with alternative IV

a. Over Sample of 1994m1-2017m12



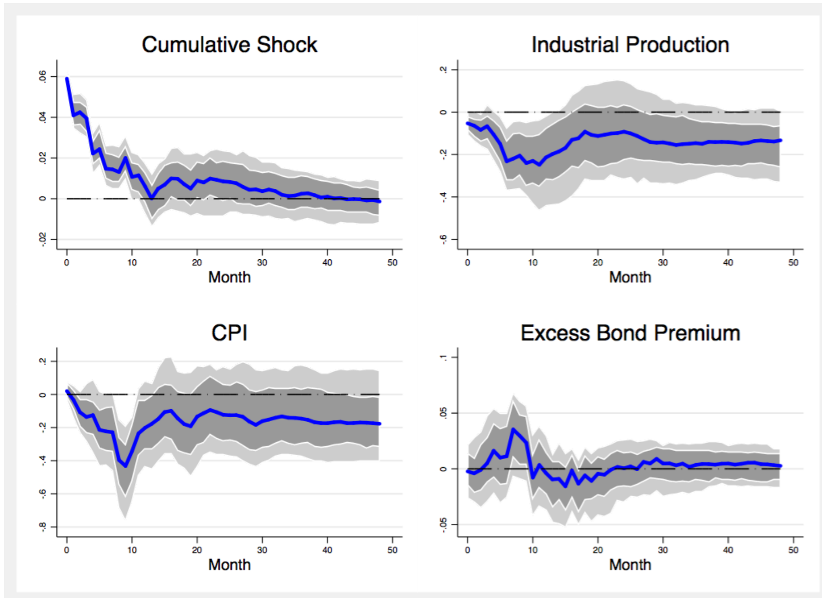
b. Over Sample of 2008m1-2017m12



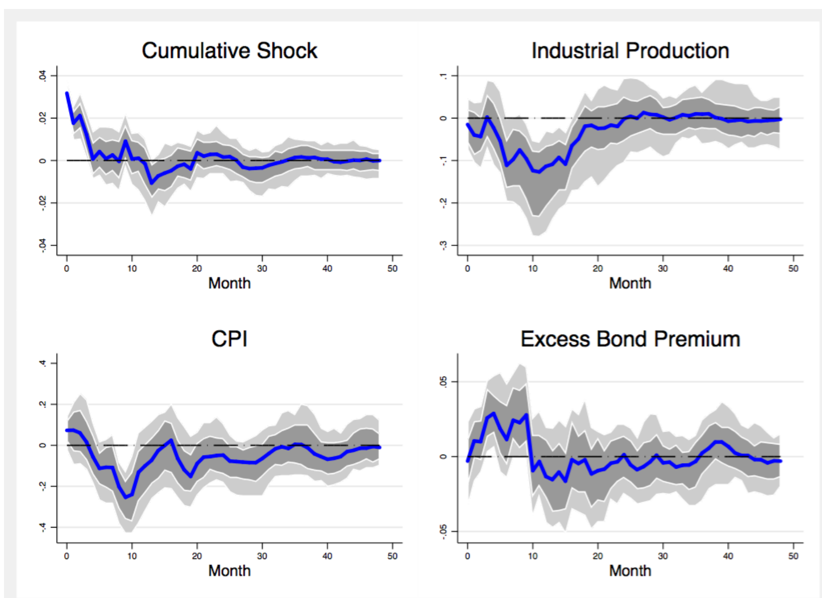
Note: Structural VAR with monthly data, 5 endogenous variables and 12 lags. Variables are ordered as follows: the cumulative aligned new shock series using daily movements in policy indicator 1-day before FOMC meeting as instrument variable, the log industrial production, the log consumer price index (CPI), the log commodity prices and the excess bond premium. Graphs show impulse response with different sample periods to a 100 basis point increase in the cumulative shock series. Deep and shallow gray shaded areas are 68% and 90% confidence intervals produced by bootstrapping 100 times, respectively.

Figure A4: SVAR Impulse Responses with Simple Fama-Macbeth Shock

a. Over Sample of 1994m1-2017m12



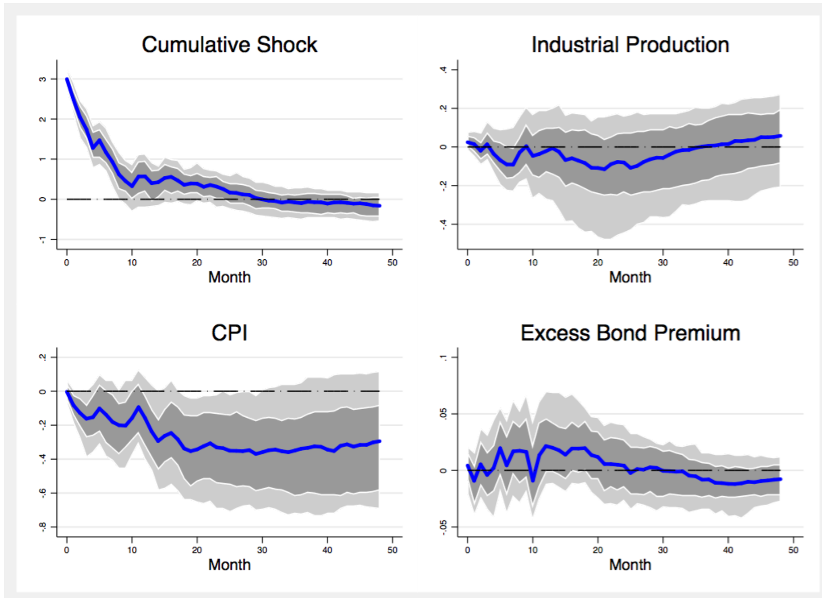
b. Over Sample of 2008m1-2017m12



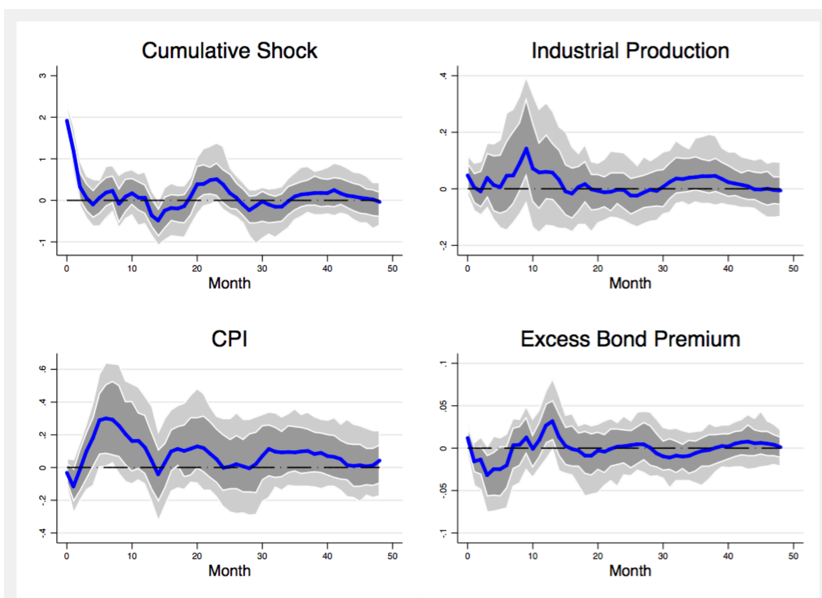
Note: Alternative BRW shock series is aligned from simple Fama-Macbeth method without IDH method. Structural VAR with monthly data, 5 endogenous variables and 12 lags. Variables are ordered as follows: the cumulative shock series, the log industrial production, the log consumer price index (CPI), the log commodity prices and the excess bond premium. Graphs show impulse response with different sample periods to a 100 basis point increase in the cumulative shock series. Deep and shallow gray shaded areas are 68% and 90% confidence intervals produced by bootstrapping 100 times, respectively.

Figure A5: SVAR Impulse Responses with PCA Shock

a. Over Sample of 1994m1-2017m12



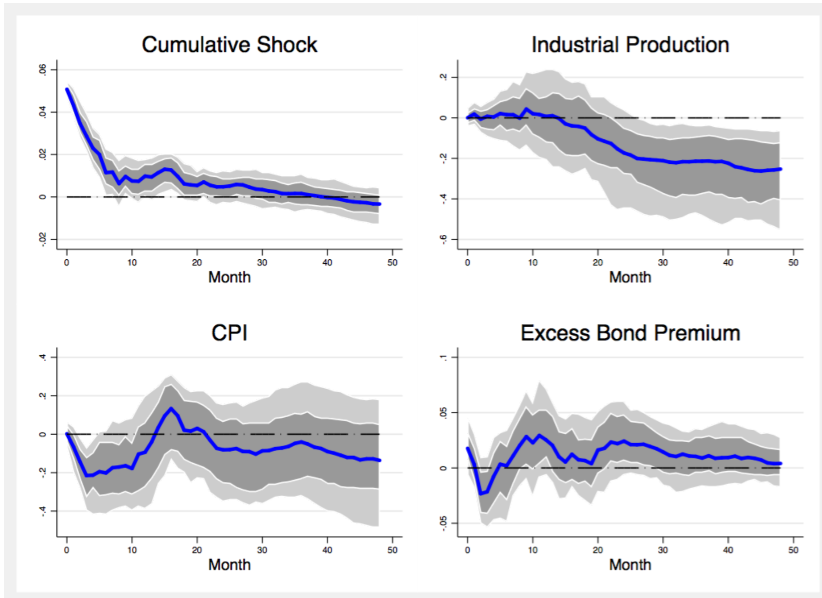
b. Over Sample of 2008m1-2017m12



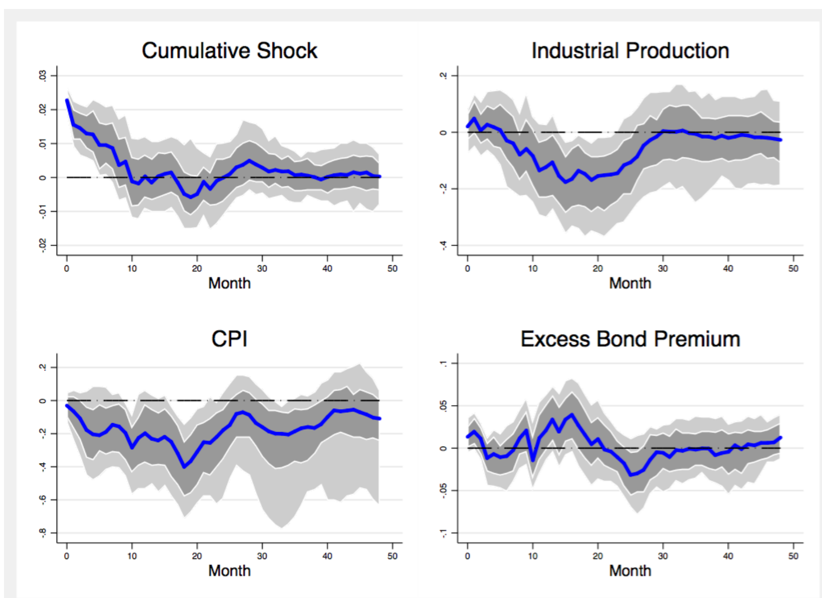
Note: Alternative BRW shock series is generated from extracting the first principal component of all the outcome variables (daily changes of 1 to 30-year zero coupon rate around FOMC meeting). Structural VAR with monthly data, 5 endogenous variables and 12 lags. Variables are ordered as follows: the cumulative shock series, the log industrial production, the log consumer price index (CPI), the log commodity prices and the excess bond premium. Graphs show impulse response with different sample periods to a 100 basis point increase in the cumulative shock series. Deep and shallow gray shaded areas are 68% and 90% confidence intervals produced by bootstrapping 100 times, respectively.

Figure A6: SVAR Impulse Responses with Tight-window Shock

a. Over Sample of 1994m1-2017m12



b. Over Sample of 2008m1-2017m12



Note: Tight-window shock uses 30min tight-window change of Federal Funds Rate around FOMC annoucement as the policy indicator and is aligned from simple Fama-Macbeth method. Structural VAR with monthly data, 5 endogenous variables and 12 lags. Variables are ordered as follows: the cumulative shock series, the log industrial production, the log consumer price index (CPI), the log commodity prices and the excess bond premium. Graphs show impulse response with different sample periods to a 100 basis point increase in the cumulative shock series. Deep and shallow gray shaded areas are 68% and 90% confidence intervals produced by bootstrapping 100 times, respectively.