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Abstract

We propose a recursive VAR model augmented with survey-based measures of future interest rates to identify the effects of forward guidance on the U.S. economy. Our results show that when interest rates are away from the zero lower bound (ZLB), an exogenous shift in the perception toward higher future interest rates leads to an increase in current economic activity. However, when policy rates fall to the ZLB, economic activity decreases following an upward revision to expected future interest rates. These findings are robust to alternative estimation frameworks, identification schemes, and data sources. We also provide a structural interpretation for our findings in the context of the workhorse New Keynesian model with news shocks about future monetary policy (forward guidance). In this setting, the monetary authority cannot accommodate the anticipatory effects from higher future interest rates while at the ZLB, which drags economic activity today. In turn, away from the ZLB, there is policy room to cut rates and revert the negative economic impacts of the anticipated policy. Similarly, announcing future lower interest rates while keeping interest rates at the ZLB today boosts current economic activity while the reverse can happen if, instead, policy rates are lifted above the ZLB to cool down the nascent expansion. Therefore, our empirical results and theoretical insights suggest that managing monetary policy expectations is a useful policy tool for stimulating economic activity, but its transmission mechanism is different at and away from the ZLB.

JEL Codes: E30, E32, E43, E52

Keywords: Monetary Policy Transmission Mechanism; Expectations Channel; Expectations-Driven Business Cycles; News Shocks; Survey-Based Forecasts.

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1. Introduction

A growing strand of the literature on expectations–driven business cycles has tried to empirically answer the question of how changes in expectations of future macroeconomic variables drive current macro aggregates. Leduc and Sill (2013), using survey-based forecasts of economic activity, are among the recent contributions showing that changes in expectations about the state of the macroeconomy are a significant driver of U.S. business cycles.[1] However, to our knowledge, the role of expectations of future interest rates—as a proxy for the expected future path of monetary policy—has received much less attention.

In this paper, unlike Leduc and Sill (2013) and the related expectations-driven business cycle literature, we empirically investigate the interest rate expectations' channel and its influence on the transmission mechanism of monetary policy and, therefore, on real economic activity and inflation. We use data on expectations about future short-term interest rates from the panel of private forecasters in the Survey of Professional Forecasters (SPF) and a VAR with sign restrictions motivated by theory as our benchmark empirical identification strategy. We consider a variety of data sources of interest rate expectations, as well as alternative estimation frameworks, including panel VAR, TVP-VAR, and FAVAR specifications for robustness.[2] We also explore the identification of the structural shocks using a more flexible, structured recursive scheme. In all cases, our results appear consistent and statistically and economically significant.

By segmenting the expectations dataset into the pre-2008 and post-2008 periods, we are able to differentiate between the effects of shocks to monetary policy expectations at the zero lower bound (henceforth, ZLB) and away from it. We find that monetary policy expectations shocks tend to explain more of the fluctuation in unemployment and inflation than the actual policy rate itself does. We also find evidence of a significant structural break in

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[1] Leduc and Sill (2013) use survey-based forecasts of economic activity for the U.S. up to 2008 (extended to 2010) to show that changes in expectations of future economic activity are a significant driver of real economic activity and inflation. Leduc and Sill (2013) find that "a perception that good times are ahead typically leads to a significant rise in current measures of economic activity and inflation" and a monetary policy tightening.

[2] We also explicitly consider that the fed funds rate became largely unresponsive near zero in the aftermath of the 2007-09 Global Financial Crisis, pushing the Federal Reserve to deploy a range of policies (not just forward guidance about the future path of the interest rate) as documented in Caldara *et al.* (2021), by using several monetary policy tool proxies in our empirical robustness checks.

the dynamic response of real economic activity to shocks to policy expectations at the ZLB. Away from the ZLB, a positive innovation to future expected interest rates causes a decrease in the unemployment rate and a slight decrease in inflation. However, at the ZLB, a positive innovation to policy expectations leads to a substantial increase in unemployment and a decrease in inflation. Hence, shocks to policy expectations can provide a significant lever for monetary policy even when the actual policy rate has been rendered ineffective—albeit a policy lever that operates differently when interest rates are stuck near zero than when they are not.

Our empirical work is also motivated, in part, by the theoretical literature on the expectations' channel of monetary policy. Krugman (2000), Eggertsson and Woodford (2003), Carlstrom *et al.* (2015), and Del Negro *et al.* (2015), among others, explain that the expected path of short-term interest rates influences private agents' current decisions and, more broadly, their perceptions about the future state of the economy. In this paper, we provide a novel approach to identify changes in the perception of the future path of the interest together with robust empirical evidence showing that the macroeconomic effects of these policy expectations shifts are significant, sizeable, and persistent but the responses at the ZLB can reverse sign relative to what we observe away from the ZLB given that away from the ZLB the central bank still has policy space to cut rates in order to provide further accommodation.

The Federal Reserve's management of monetary policy expectations (forward guidance) and use of other unconventional monetary policies became central to its response to the 2007-09 Global Financial Crisis shortly after the federal funds rate was rendered ineffective to provide further accommodation in the wake of the crisis. As documented in Contessi and Li (2013a, 2013b), forward guidance has played a significant role in the conduct of monetary policy in the U.S. and a number of other major advanced economies during this period. Bernanke *et al.* (2004) use event studies to uncover evidence that central bank communications can help to shape public expectations of future policy actions and have played an important role even before the 2007-09 Global Financial Crisis. Filardo and Hofmann (2014) also show that historically, forward guidance has had an influence on the economy through interest rate expectations. These historical experiences naturally raise the question of how effective such shocks to interest rate expectations have been to prop-up the economy and what mechanisms explain those macro effects.

The theoretical literature suggests that changes in the agents' perceptions about future interest rates can have significant effects, particularly when policy rates are stuck (such as at the ZLB), providing the rationale for policies that provide forward guidance in those instances (see, e.g., Carlstrom *et al.* (2015) and Del Negro *et al.* (2015)).[3] Our empirical work clarifies the shifting macroeconomic effects of changes in the expected path of future monetary policy and the role that forward guidance has played also away from the ZLB. In other words, we provide novel empirical findings supporting the view that the ZLB alters the expectations' channel in the transmission of monetary policy but does not negate the power that managing expectations has to stimulate the economy. We rationalize this evidence with a stylized New Keynesian model that illustrates how the empirical shift we observe in the U.S. data around 2008 can be connected to the transmission of news about future monetary policy (forward guidance) and how these news shocks propagate differently at the ZLB and away from it.

The rest of the paper is organized as follows: Section 2 outlines our theoretical model and the key insights about the propagation of forward guidance shocks at the ZLB and away from it; Section 3 briefly discusses the survey-based and macro data used in the empirical analysis; Section 4 describes the empirical methodologies and reports our main empirical results which are shown to be consistent with theory; and Section 5 summarizes our final conclusions. The Appendix outlines the derivations of the monetary policy transmission mechanism for the workhorse New Keynesian model and provides additional details on the data sources.[4]

[3] This has become an important consideration for policymakers not only due to the episode of near-zero policy rates that arose from the 2007-09 Global Financial Crisis, but also in the context of the historical downward trend in interest rates experienced over the past 40 years (see, e.g., Hamilton *et al.* (2016)). In an environment with low interest rates, episodes where policy rates hit the ZLB or simply become fixed at low levels for an extended period of time are likely to be more frequent as the COVID19 pandemic has poignantly reminded policymakers again.

[4] Supplementary materials with additional results from the estimated models are available on the web to accompany this paper (see Doehr and Martínez-García (2021)).

2. The Expectations' Channel of Monetary Policy

The workhorse New Keynesian model is summarized by the following equations which describe a short-run Phillips curve relationship, a dynamic IS equation, and the definition of the output gap of the economy (see, e.g., Woodford (2003)):

$$\pi_t = \beta E_t\left[\pi_{t+1}\right] + \kappa x_t, \quad (1)$$

$$x_t = E_t\left[x_{t+1}\right] - \sigma\left(i_{1,t} - E_t\left[\pi_{t+1}\right] - r_{1,t}^n\right), \quad (2)$$

$$y_t \equiv y_t^n + x_t. \quad (3)$$

Output y_t, output potential y_t^n, the output gap x_t, inflation π_t, the short-term nominal interest rate $i_{1,t}$, and the short-term natural (real) rate of interest $r_{1,t}^n$ are all expressed in log-deviations from the deterministic steady state. The intertemporal discount rate is denoted $0 < \beta < 1$, $\sigma > 0$ is the elasticity of intertemporal substitution, $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply, $0 < \theta < 1$ is the Calvo price stickiness parameter, and $\kappa \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}\left(\sigma + \varphi\right) > 0$ is the slope of the Phillips curve.

We close the workhorse model with a monetary policy rule along the lines of Del Negro *et al.* (2015), i.e., with:

$$i_{1,t} = \psi_\pi \pi_t + \psi_x x_t + \varepsilon_t, \quad (4)$$

$$\varepsilon_t = \varepsilon_t^m + \varepsilon_{t,t-l}^{news},\ l \geq 1, \quad (5)$$

where the policy parameters $\psi_\pi > 0$ and $\psi_x \geq 0$ measure the elasticity of the short-term nominal interest rate response to inflation and the output gap, respectively. A positive (negative) realization of the exogenous policy shock ε_t should be interpreted as a contractionary (expansionary) monetary policy shock and it arises from two distinct components: $\varepsilon_t^m \sim N\left(0, \sigma_m^2\right)$ which represents the unexpected component of the monetary policy shock (the monetary policy surprise innovation); and $\varepsilon_{t,t-l}^{news} \sim N\left(0, \sigma_{news}^{2}\right)$ which reflects the anticipated component of the policy shock known since time $t-l$ but realized only at time t (the monetary policy news innovation). The anticipated and unanticipated innovations of the monetary policy shock are assumed uncorrelated over time and with each other.

Given that monetary policy shocks—anticipated or unanticipated—do not affect the potential output and natural rate of interest rate of the economy in the frictionless case, we simply set them both to remain at their steady state values (i.e., $y_t^n = r_{1,t}^n = 0$). Hence, for any parameter values within the determinacy region of the parameter space, the solution of the workhorse New Keynesian model separating monetary policy shocks into unanticipated innovations and news about tomorrow's monetary policy (setting $l=1$ for simplicity) determines the aggregate dynamics of output y_t, inflation π_t, and the nominal short-term interest rates $i_{1,t}$ as follows:

$$
\begin{aligned}
y_t &= \underbrace{\left(-\frac{\sigma}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)}_{<0}\left(\varepsilon_t^m + \varepsilon_{t,t-1}^{news}\right) + \underbrace{\left(-\frac{\sigma\left(1+\sigma\kappa\left(1-\psi_\pi\beta\right)\right)}{\left(1+\sigma\psi_x+\sigma\psi_\pi\kappa\right)^2}\right)}_{?}\varepsilon_{t+1,t}^{news}, \\
\pi_t &= \underbrace{\left(-\frac{\sigma\kappa}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)}_{<0}\left(\varepsilon_t^m + \varepsilon_{t,t-1}^{news}\right) + \underbrace{\left(-\frac{\sigma\kappa\left(1+\beta\left(1+\sigma\psi_x\right)+\sigma\kappa\right)}{\left(1+\sigma\psi_x+\sigma\psi_\pi\kappa\right)^2}\right)}_{<0}\varepsilon_{t+1,t}^{news}, \qquad (6) \\
i_{1,t} &= \underbrace{\left(\frac{1}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)}_{>0}\left(\varepsilon_t^m + \varepsilon_{t,t-1}^{news}\right) + \underbrace{\left(-\sigma\frac{\psi_\pi\kappa\left(1+\beta+\sigma\kappa\right)+\psi_x\left(1+\kappa\sigma\right)}{\left(1+\sigma\psi_x+\sigma\psi_\pi\kappa\right)^2}\right)}_{<0}\varepsilon_{t+1,t}^{news}.
\end{aligned}
$$

The derivations of the analytical solution and the determinacy region follow the Blanchard and Kahn (1980) method and can be found in the Appendix.

2.1 Monetary Policy Shock Identification

The solution of the New Keynesian model in (6) illustrates that anticipated (news) shocks behave differently than unanticipated monetary shocks. Moreover, this solution also implies that private agents update their beliefs about the future based on the information that anticipated (news) shocks provide about the future policy path. To be more precise, rational forecasts of output and inflation naturally depend on expectations about the future path of monetary policy as follows:

$$E_t\left(y_{t+1}\right)=\underbrace{\left(-\sigma\right)}_{<0}E_t\left(i_{1,t+1}\right),$$
$$E_t\left(\pi_{t+1}\right)=\underbrace{\left(-\sigma\kappa\right)}_{<0}E_t\left(i_{1,t+1}\right), \tag{7}$$

and the rational forecast about next period's policy rate is driven solely by the anticipated (news) component of the monetary policy shock:

$$E_t\left(i_{1,t+1}\right)=\underbrace{\left(\tfrac{1}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)}_{>0}\varepsilon_{t+1,t}^{news}. \tag{8}$$

This provides a key theoretical motivation for our empirical VAR specification aimed at better capturing the dynamics of inflation and real economic activity in relation to monetary policy. We augment the standard three-variable VAR motivated by the New Keynesian model—which already includes inflation, a measure of economic activity, and the federal funds rate—with the addition of expectations about future monetary policy to help us with the identification of the anticipated and unanticipated components of the monetary policy shock.[5]

2.2 Forward Guidance and the Yield Curve

An expectations-based interpretation of the term structure posits that the log yield on an n-period nominal bond, $i_{n,t}$, can be represented as:

$$i_{n,t}=\tfrac{1}{n}\sum_{j=0}^{n-1}E_t\left(i_{1,t+j}\right)+\theta_{n,t}, \tag{9}$$

where $E_t\left(\cdot\right)$ denotes expectations at time t, $i_{1,t+j}$ is the short-term nominal rate j periods ahead, and $\theta_{n,t}$ is the risk premium required by investors to compensate them for holding longer-term bonds instead of rolling-over short-term debt. Movements along the yield curve

[5] A version of Okun's law relating the unemployment rate to the output gap can be added to translate the model predictions into observable labor market and inflation outcomes. With some additional work the workhorse New Keynesian model can be extended to account for unemployment in a richer, micro-founded setup along the lines of Blanchard and Galí (2010).

can result from changes in policy rate expectations or in the risk premium term $\theta_{n,t}$ which captures illiquidity, default, and duration risk.[6]

A credible promise of lower short-term interest rates will be incorporated into lower long-term interest rates today, signaling a shift in future monetary policy (a future monetary accommodation). But lower long-term rates today can also result from a shift in the risk premium $\theta_{n,t}$. Interestingly, the effect of increased uncertainty regarding the future monetary policy path is an important confounding factor that influences the risk premium $\theta_{n,t}$ itself. The key takeaway from this is that we prefer to use survey-based expectations rather than long-term yields in our empirical strategy to get around the difficulty posed by jointly modeling the risk premium and the long-term rates (that price monetary as well as non-monetary confounding risk factors).[7] Moreover, using survey-based expectations instead of long rates also allows us to exploit the temporal and cross-sectional dimension of the panel of forecasters to identify anticipated monetary shocks separately from unanticipated monetary shocks.

2.3 Forward Guidance when Monetary Policy is Unconstrained

The workhorse New Keynesian model shows that the efficacy of monetary policy in stimulating aggregate demand does not exclusively depend on the current policy rates, but depends also on the news about the future path of monetary policy (see, e.g., Bernanke and Blinder (1992) on this same point). A purely unexpected expansionary monetary policy shock $\left(\varepsilon_{t+1}=\varepsilon_{t+1}^{m},\ \varepsilon_{t}^{m}=-1,\ \varepsilon_{t,t-1}^{news}=0\right)$ generates a one-period increase in output and inflation, y_t and π_t, with a concurrent fall in the nominal short-term interest rate, $i_{1,t}$. Moreover, the short-term real rate, $r_{1,t}\equiv i_{1,t}-E_t\left[\pi_{t+1}\right]$, can be characterized generically as:

---

[6] We omit additional convexity terms in order to simplify the exposition. Those convexity terms could capture "tail risks" too—that is, rare events with large economic consequences but low probability of occurrence.

[7] Abstracting from the risk premium and retaining the assumption that $l=1$, it must be the case that $E_t\left(i_{1,t+j}\right)=0$ for any $j>1$ while $E_t\left(i_{1,t+1}\right)$ is given by (8). Hence, in this illustration, the longer-term yield $i_{2,t}$ contains the same information about the anticipated path of monetary policy as any yield with an even longer-maturity (i.e., than any $i_{n,t}$ for $n>2$). For longer lags between the time at which anticipated monetary shocks are known and the time they enter as part of the policy shock (i.e., for $l>1$), longer maturities across the yield curve would be affected as well.

$$
\begin{aligned}
r_{1,t} &\equiv i_{1,t} - E_t\left[\pi_{t+1}\right] \\
&= \underbrace{\left(\frac{1}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)}_{>0}\left(\varepsilon_t^m + \varepsilon_{t,t-1}^{news}\right) + \underbrace{\left(-\sigma\left(\frac{\kappa\left(\psi_\pi(1+\beta)-1\right)+\psi_x}{\left(1+\sigma\psi_x+\sigma\psi_\pi\kappa\right)^2}\right)\right)}_{<0}\varepsilon_{t+1,t}^{news},
\end{aligned} \tag{10}
$$

and also falls in response to this unexpected monetary policy shock. So long as the determinacy condition is satisfied, different monetary policy rules—as determined by the policy parameter vector $\left(\psi_\pi, \psi_x\right)$—can influence the magnitude of the macroeconomic responses to such unanticipated monetary policy shock innovation, but not the actual direction of the response.

The dynamics generated by a news shock innovation are different than those of an unexpected monetary policy shock innovation because they trigger a reaction on the part of private agents even before the policy change actually materializes through the interest rate and the expectations' channels. Under the assumption that the effects of nominal rigidities vanish asymptotically—i.e., $\lim_{T\to\infty} E_t\left[y_{t+T} - y_{t+T}^n\right] = \lim_{T\to\infty} E_t\left[y_{t+T}\right] = 0$—the dynamic IS equation can be solved forward to yield the following expression:[8]

$$
\begin{aligned}
y_t &= -\sigma\sum_{j=0}^{+\infty} E_t\left(r_{1,t+j}\right) \\
&= -\sigma\sum_{j=0}^{+\infty} E_t\left(i_{1,t+j} - \pi_{t+1+j}\right),
\end{aligned} \tag{11}
$$

which shows that output is proportional to the sum of the entire path of current and expected future real interest rates, $r_{1,t}$. Similarly, solving the Phillips curve forward we obtain that:

$$
\pi_t = \kappa\sum_{j=0}^{+\infty} \beta^j E_t\left[y_{t+j}\right], \tag{12}
$$

which indicates that the (discounted) cumulative sum of the entire path of current and expected future output determines the current inflation rate.

[8] Only if real interest rates are affected will consumption and investment respond (Lucas and Prescott (1971)). We make this connection explicit here in the context of the workhorse New Keynesian model with nominal rigidities breaking the neutrality of monetary policy in the short-run.

Since rational forecasts of output and inflation are related to forecasts about the future path of monetary policy (as shown in (7)), equations (11) and (12) can be re-written in terms of current short-term interest rates and expectations of future monetary policy as follows:

$$\begin{aligned} y_t &= -\sigma i_{1,t} - \sigma\left(1+\sigma\kappa\right)\sum_{j=0}^{+\infty} E_t\left(i_{1,t+1+j}\right), \\ \pi_t &= \kappa y_t - \sigma\kappa\sum_{j=0}^{+\infty} \beta^{j+1} E_t\left(i_{1,t+1+j}\right) \\ &= -\sigma\kappa i_{1,t} - \sigma\kappa\sum_{j=0}^{+\infty}\left(\beta^{j+1} + \left(1+\sigma\kappa\right)\right) E_t\left(i_{1,t+1+j}\right). \end{aligned} \tag{13}$$

While expectations about future monetary policy at different horizons have the same effect on output today, the same is not true for their impact on current inflation which diminishes with the time horizon. In other words, the workhorse model predicts that longer-term forward guidance announcements can produce the same real effects but with a more muted response on inflation. Hence, a non-trivial trade-off arises in regards to the duration of the forward guidance commitment that policymakers must take into account to balance their dual mandate goals set in terms of inflation and economic activity.

The current policy rate is driven by anticipated and unanticipated shocks to monetary policy as seen in (6), but expectations about future monetary policy only depend on anticipated policy shocks as seen in (8). Unexpected monetary policy shocks have no effect on expectations about future monetary policy, so they influence output and inflation in (13) only through the movements of the current nominal short-term interest rate. In turn, news shocks about future monetary policy operate through interest rate expectations after news of a future policy change become known and through the short-term interest rate feedback from the time the policy change is known to the time is set to take effect. In the illustrative case where news is anticipated with a one-period lead only ($l = 1$), the expectations of monetary policy two-periods forward or longer go back to zero implying that policy is expected to return to its steady state. Hence, aggregate output and inflation in (13) can be simplified and re-expressed as:

$$\begin{aligned} y_t &= -\sigma i_{1,t} - \sigma\left(1+\sigma\kappa\right) E_t\left(i_{1,t+1}\right), \\ \pi_t &= -\sigma\kappa i_{1,t} - \sigma\kappa\left(\beta + \left(1+\sigma\kappa\right)\right) E_t\left(i_{1,t+1}\right), \end{aligned} \tag{14}$$

which neatly decomposes the two channels of monetary policy transmission: the interest rate channel through $i_{1,t}$ and the expectations' channel through $E_t\left(i_{1,t+1}\right)$.

Hence, the workhorse New Keynesian model illustrates in (14) one of the fundamental concerns of our subsequent empirical investigation—that the distinction between anticipated and unanticipated monetary policy shocks is crucial because these shocks operate through very different monetary transmission channels. In particular, we clearly observe that news shocks about future monetary policy, unlike the unexpected policy shocks, activate the expectations' channel for the transmission of monetary policy.

We consider two possible scenarios to disentangle the effects due to the anticipation of future monetary policy changes from those that arise from changes in current policy: (scenario *i*) realized news about a future monetary policy expansion $\left(\varepsilon_{t+1}=\varepsilon_{t+1,t}^{news},\ \varepsilon_{t+1}^{m}=0,\ \varepsilon_{t+1,t}^{news}=-1\right)$; and (scenario *ii*) unrealized news about a future monetary policy expansion $\left(\varepsilon_{t+1}=0,\ \varepsilon_{t+1}^{m}=-\varepsilon_{t+1,t}^{news},\ \varepsilon_{t+1,t}^{news}=-1\right)$. An anticipated monetary policy shock one-period ahead affects the dynamics of output and inflation in two consecutive periods—at the time it is announced (t) and next period when it should take effect ($t+1$). At the time news about the future monetary policy arrives, the economy responds in anticipation of a future change in policy irrespective of whether the shock is realized (scenario *i*) or unrealized (scenario *ii*).

At time t, firms foresee a future expansion whenever news arrive of an expansionary change in monetary policy that would lower next period's short-term rate and, accordingly, increase their prices leading to higher inflation today. The response of the real variables arises from the nominal rigidities that feature so prominently in the New Keynesian model. Households' preferences for consumption smoothing stimulate current consumption today in anticipation of a future expansion which boosts output accordingly. However, anticipation effects operating through expectations are only one part of the story. Raising inflation and output today also provokes an increase in the current short-term interest rate under the terms of the monetary policy rule in (4). This feedback from policy raises real interest rates and counteracts the stimulative effects arising from the anticipation of a future monetary expansion. We find, in fact, that this feedback effect from policy can be so powerful that the impact of a news shock may look very different than that of an unexpected monetary policy shock.[9]

We summarize the decomposition of the effect that a news shock about a future monetary expansion has at time t through the anticipation effect that operates via expectations and through the policy feedback effect that operates via the interest rate channel in Table 1 below. We find that inflation (as well as the nominal short-term interest) increases in response to news about a future monetary expansion, but that such news can result instead in a temporary contraction of output whenever the policy coefficient that determines the strength of the response to inflation fluctuations ψ_π is sufficiently high (i.e., if $\psi_\pi > \frac{\sigma\kappa+1}{\sigma\kappa\beta}$). Hence, news shocks about monetary policy will boost current output only if the central bank is not too aggressively fighting inflation.

Table 1. Decomposition of the Response to a News Shock

	Anticipation Effect (Expectations' Channel) at t from $\varepsilon_{t+1,t}^{news}=-1$	Policy Feedback Effect at t from $\varepsilon_{t+1,t}^{news}=-1$	Total Effect at t from $\varepsilon_{t+1,t}^{news}=-1$
y_t	$\underbrace{\left(\frac{\sigma(1+\sigma\kappa)}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)}_{>0}$	$\underbrace{\left(-\sigma\left(\sigma\frac{\psi_\pi\kappa(1+\beta+\sigma\kappa)+\psi_x(1+\kappa\sigma)}{(1+\sigma\psi_x+\sigma\psi_\pi\kappa)^2}\right)\right)}_{<0}$	$\underbrace{\left(\frac{\sigma(1+\sigma\kappa(1-\psi_\pi\beta))}{(1+\sigma\psi_x+\sigma\psi_\pi\kappa)^2}\right)}_{?}$
π_t	$\underbrace{\left(\frac{\sigma\kappa(\beta+(1+\sigma\kappa))}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)}_{>0}$	$\underbrace{\left(-\sigma\kappa\left(\sigma\frac{\psi_\pi\kappa(1+\beta+\sigma\kappa)+\psi_x(1+\kappa\sigma)}{(1+\sigma\psi_x+\sigma\psi_\pi\kappa)^2}\right)\right)}_{<0}$	$\underbrace{\left(\frac{\sigma\kappa(1+\beta(1+\sigma\psi_x)+\sigma\kappa)}{(1+\sigma\psi_x+\sigma\psi_\pi\kappa)^2}\right)}_{>0}$
$i_{1,t}$	$\underbrace{\left(\sigma\frac{(1+\sigma\psi_x+\sigma\psi_\pi\kappa)(\psi_\pi\kappa(1+\beta+\sigma\kappa)+\psi_x(1+\sigma\kappa))}{(1+\sigma\psi_x+\sigma\psi_\pi\kappa)^2}\right)}_{>0}$	$\underbrace{-\left(\sigma\frac{(\sigma\psi_x+\sigma\psi_\pi\kappa)(\psi_\pi\kappa(1+\beta+\sigma\kappa)+\psi_x(1+\kappa\sigma))}{(1+\sigma\psi_x+\sigma\psi_\pi\kappa)^2}\right)}_{<0}$	$\underbrace{\left(\sigma\frac{\psi_\pi\kappa(1+\beta+\sigma\kappa)+\psi_x(1+\kappa\sigma)}{(1+\sigma\psi_x+\sigma\psi_\pi\kappa)^2}\right)}_{>0}$

The takeaway from this decomposition exercise is that, under plausible parameterizations and a conventional specification of the monetary policy rule, theory suggests

[9] In fact, in some respects it looks more like a supply shock (and can be confounded with it) when it drives inflation and output in opposite directions, as we show later.

that the response of output to news about future monetary policy can be weak or possibly negative due to the strength of the counteracting feedback from monetary policy (the second column of Table 1).[10] An expansionary news shock can result in a weaker output contraction when the anticipation of the shock is over a longer period of time ($l > 1$). This is because, in that case, the stimulative effect of the expected future lower interest rate not only raises the policy rate at the time the future policy change is announced, but also puts upward pressure on the interest rate path over all subsequent periods until the policy change is implemented; however, with $l > 1$ there is more time to respond to facilitate a smoother consumption path and a more tempered adjustment of production.

The responses of the realized and unrealized news shocks coincide until the period when the policy change must take effect. In our illustration, in period $t+1$, private agents must adjust their behavior to the actual policy shock—that is, they must adjust at $t+1$ according to whether the news they had anticipated is realized or not. If the news shock is realized (scenario *i*), the impact will be exactly the same as that of an unexpected monetary policy shock at that point in time (short-term interest rates will fall, and output and inflation will increase). In that scenario, the belief that triggered the response at time t is validated at time $t+1$. If the news shock is unrealized (scenario *ii*), the previous period belief of a policy change is reneged in practice and, without an actual policy change being implemented, private agents act rationally to keep output, inflation, and the short-term interest rate at their corresponding steady state values.[11]

[10] A standard parameterization of the New Keynesian model sets the intertemporal discount rate to $\beta = 0.99$, the elasticity of intertemporal substitution at $\sigma = 2$, and the inverse of the Frisch elasticity at $\varphi = 2$. The Calvo price stickiness is kept at $\theta = \frac{2}{3}$ which implies an average price duration of three quarters. From here it follows that the slope of the Phillips curve is $\kappa \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}\left(\sigma + \varphi\right) = 0.68$ and the threshold above which output contracts in response to a news shock is given by $\psi_{\pi} > 1.75$. Simply setting $\sigma = 3$, which is well within the range of reasonable values for the elasticity of intertemporal substitution, increases the Phillips curve slope to $\kappa = 0.85$ and lowers the threshold down to $\psi_{\pi} > 1.41$. Hence, assuming the policy rule coefficients are $\psi_{\pi} = 1.5$ and $\psi_{x} = \frac{0.5}{4}$ to be consistent with the experience during the Greenspan era, we can neither rule out positive but weak nor contractionary output responses to an anticipated future monetary expansion under plausible parameterizations of the (non-policy) structural parameters of the New Keynesian model.

[11] Forward guidance commitments that are announced but ultimately reneged can lead to a loss of credibility on the monetary policy that mitigates the efficacy of this policy tool. On this point, see Cole and Martínez-García (2021).

We should also highlight three additional takeaways from our analysis of the differences in the responses of output, inflation, and the interest rate to unexpected and news shocks about monetary policy:

First, news shocks strengthen the endogenous propagation of the New Keynesian model. News shocks are modeled as i.i.d. shocks, but the anticipation of a future change in monetary policy affects the path of these endogenous variables from the moment it becomes known. Therefore, the effects of an i.i.d. shock may extend over time and have persistent effects from what is otherwise a transitory shock innovation.

Second, news shocks can generate a dynamic response in the endogenous variables even if no actual policy change takes place (scenario *ii*). This last point in particular reinforces the importance of expectations in our subsequent empirical analysis, as the actual policy rate is then insufficient to identify the stance of monetary policy. For instance, a one-period ahead news shock unrealized at time $t+1$ but anticipated at time t could be confounded with an unexpected monetary policy innovation at time t if we disregard the accompanying change in the expectations about tomorrow's interest rate that we observe today only when the shock is anticipated, leading to possibly erroneous empirical inferences about the nature of the actual unexpected shocks. This is because otherwise unrealized news shocks and unexpected shocks would be misidentified and bundled together. Proper identification of expected and unexpected monetary policy shocks is crucial in assessing the efficacy of monetary policy—and this is precisely the key rationale for augmenting the standard three-variable VAR motivated by the New Keynesian model with expectations about future monetary policy.

Third, irrespective of whether monetary policy shocks are anticipated, unanticipated or a combination of both, we can combine the policy rule equation in (4) with the decomposition of output and inflation given by (14) to obtain:

$$i_{1,t} = -\left(\frac{\psi_\pi \sigma\kappa\left(\beta+\left(1+\sigma\kappa\right)\right)+\psi_x\sigma\left(1+\sigma\kappa\right)}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right) E_t\left(i_{1,t+1}\right) + \left(\frac{1}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)\varepsilon_t, \tag{15}$$

which expresses the current short-term policy rate in terms of next periods' expected interest rate $E_t\left(i_{1,t+1}\right)$ and the current monetary policy shock ε_t. The monetary policy shock can be decomposed in terms of an expected and an unexpected component as indicated in (5). Hence, combining the expression above with the equation that relates policy expectations to anticipated shocks in (8), the current policy rate can be further re-expressed as follows:

$$i_{1,t} - E_{t-1}\left(i_{1,t}\right) = -\left(\frac{\psi_\pi \sigma\kappa\left(\beta+\left(1+\sigma\kappa\right)\right)+\psi_x\sigma\left(1+\sigma\kappa\right)}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)E_t\left(i_{1,t+1}\right)+\left(\frac{1}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)\varepsilon_t^m, \tag{16}$$

indicating that the forecasting error for the short-term interest rate moves partly due to unexpected shocks and partly due to the anticipation of future monetary policy as captured in tomorrow's expectations (as reflected in the interest rate expectations equation in (8)).

2.4 Forward Guidance when Monetary Policy Is Constrained

When conventional monetary policy can no longer be implemented through rate cutes to provide monetary accommodation due to the ZLB, managing expectations through forward guidance (news about future policy) becomes central for the transmission of monetary policy. However, news shocks that anticipate a future monetary expansion behave differently at the ZLB than when monetary policy is unconstrained because the policy feedback effect that can potentially overturn the positive response of output to the anticipation of a future expansion induced by forward guidance is no longer happening when short-term interest rates are stuck at zero.

To illustrate this point, we simply assume that the ZLB on nominal short-term interest rates is enforced with a straightforward modification of the monetary policy rule in (4), i.e.,

$$i_{1,t} = \psi_\pi \pi_t + \psi_x x_t + \varepsilon_t^m + \varepsilon_{t,t-1}^{news}, \tag{17}$$

$$\overline{i}_{1,t} = \max\left\{i_{1,t}, -i_1^*\right\}, \tag{18}$$

where $i_1^* \equiv -\ln(\beta)$ is the steady state short-term interest rate (in logs).[12] We then assume that the ZLB becomes binding at time t as a result of an unexpected shock that lowers the natural interest rate $r_{1,t}^n$ sufficiently below zero (as, for instance, Eggertsson and Woodford (2003) and the subsequent literature on the ZLB does). With probability $0 < \alpha < 1$, the natural rate remains below zero and nominal short-term interest rates constrained the next period. With probability $1-\alpha$, the natural rate shock dissipates, nominal interest rates become unconstrained, and the economy reverts back to normal. For simplicity, we assume that private agents form their expectations about the future in this manner.

While it lasts, this natural rate shock prevents the conventional use of the policy rate to provide monetary accommodation. News of an impending monetary policy shift arriving one period in advance ($l = 1$), however, can still elicit stimulative effects. To understand the dynamic implications of news shocks in this situation, consider the implications of enforcing the ZLB in (14) as follows:

$$\begin{aligned} y_t &= -\sigma \overline{i}_{1,t} - \sigma(1+\sigma\kappa) E_t\left(\overline{i}_{1,t+1}\right), \\ \pi_t &= -\sigma\kappa \overline{i}_{1,t} - \sigma\kappa\left(\beta + (1+\sigma\kappa)\right) E_t\left(\overline{i}_{1,t+1}\right), \end{aligned} \tag{19}$$

while still distinguishing the anticipation effect (expectations' channel) and the policy feedback effect (interest rate channel) of monetary policy as we have done before. In this case, if the ZLB becomes binding at time t, the aggregate dynamics of output and inflation in (19) reduce to:

$$\begin{aligned} y_t &= \sigma i_1^* - \sigma(1+\sigma\kappa)\left[\alpha\left(-i_1^*\right) + (1-\alpha) E_t\left(i_{1,t+1}\right)\right], \\ \pi_t &= \sigma\kappa i_1^* - \sigma\kappa\left(\beta + (1+\sigma\kappa)\right)\left[\alpha\left(-i_1^*\right) + (1-\alpha) E_t\left(i_{1,t+1}\right)\right], \end{aligned} \tag{20}$$

where the expectations about future monetary policy when interest rates become unconstrained are given in equation (8) as if a return to the ZLB was no longer anticipated after interest rate lift above the ZLB.

[12] All variables are expressed in log-deviations from their deterministic steady state values. Hence, whenever $\overline{i}_{1,t} = -i_1^*$ in (18), the nominal short-term interest rate (the log of the one-period yield) becomes zero. It is in this sense that such a constraint imposes the ZLB on nominal short-term interest rates.

The feedback policy effect that played a key role in overturning the increase in current economic activity that arises from anticipating a future monetary expansion when short-term interest rates are unconstrained is negated at the ZLB by the fact that current short-term interest rates are stuck at zero. The anticipation effect through expectations is the only effect that remains and, similar to a conventional unexpected monetary policy shock, this drives inflation and output up (as summarized in Table 2 below). The strength of the stimulative effect will depend not just on the particular form of the monetary policy rule to be followed after lifting interest rates away from zero, but also on the likelihood associated with remaining at the ZLB next period. The more likely it is that the economy will remain at the ZLB tomorrow, the less effective news about a policy change will be at stimulating output today. However, while the strength of the output response to news may depend on these considerations, the sign of the response is unequivocal: news about a future monetary expansion contribute to boost economic activity today.

Accordingly, news about future monetary policy (and, more generally, the policy of forward guidance) can be effective in raising current output at the ZLB while unanticipated monetary shocks are by construction ineffective. Without the feedback policy effect that induces this result, we show that news shocks that signal a future monetary expansion will trigger positive output responses at the ZLB.[13] Hence, whether the shock is eventually realized or not, the response to a news shock can be very different whether interest rates are constrained or unconstrained—even to the point of inducing a full reversal in the response of real economic activity.

Allowing for longer periods of anticipation ($l > 1$), a contraction in economic activity in response to a news shock is likely to occur when interest rates are unconstrained too. News shocks are still expansionary when interest rates are constrained at the ZLB. Hence, our illustration of a reversal in the sign of the output response at the ZLB and away from it when

[13] The effect at time $t+1$ of the monetary expansion anticipated one-period-ahead at time t is analogous to the response we discussed before when characterizing the solution of the New Keynesian model under the assumption that interest rates are always unconstrained. If the interest rate remains constrained, there will be no difference in terms of output or inflation whether the shock materializes at time $t+1$ or not. If the news shock is realized and interest rates become unconstrained, that would induce output and inflation to raise; if it is unrealized, output and inflation will be kept at their steady state values.

$l=1$ would be retained in a model that incorporated news about future monetary policy $l>1$ periods ahead and also in the case where multiple news shocks with varying periods of anticipation are included simultaneously as in Del Negro *et al.* (2015).

Table 2. Decomposition of the Response to a News Shock When the ZLB Is Binding

	Anticipation Effect (Expectations' Channel) at t from $\varepsilon_{t+1,t}^{news}=-1$	Policy Feedback Effect at t from $\varepsilon_{t+1,t}^{news}=-1$	Total Effect at t from $\varepsilon_{t+1,t}^{news}=-1$
y_t	$\underbrace{(1-\alpha)\left(\frac{\sigma(1+\sigma\kappa)}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)}_{>0}$	--	$\underbrace{(1-\alpha)\left(\frac{\sigma(1+\sigma\kappa)}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)}_{>0}$
π_t	$\underbrace{(1-\alpha)\left(\frac{\sigma\kappa(\beta+(1+\sigma\kappa))}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)}_{>0}$	--	$\underbrace{(1-\alpha)\left(\frac{\sigma\kappa(\beta+(1+\sigma\kappa))}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)}_{>0}$
$i_{1,t}$	--	--	--

A key takeaway from the workhorse New Keynesian model, therefore, is that news shocks (and the policy of forward guidance) behave differently than unexpected monetary policy shocks and may be more powerful at the ZLB than away from it. Our empirical strategy is guided by these theoretical predictions and provides corroborating evidence that innovations to expectations of future interest rates tend to contribute more to fluctuations in economic activity and inflation at the ZLB than when interest rates are unconstrained. Most notably, we also find subsequent empirical confirmation for the reversal in sign in the response of economic activity to an expectations shock at the ZLB, consistent with that of monetary policy news shocks in the theoretical model. Hence, our paper provides a theoretical interpretation and novel empirical evidence highlighting the important differences between anticipated and unanticipated monetary policy shocks, the role of expectations for identification, and the shift in the transmission of monetary policy news shocks that occurs at the ZLB—while also showing the quantitative importance that forward guidance policies have based on the U.S. experience.

We recognize that there other potential confounding factors that have appeared, especially in the aftermath of the 2007-09 Global Financial Crisis—such as the deployment of quantitative easing and other unconventional monetary policies not necessarily targeted exclusively at managing policy expectations as is the case of forward guidance policies—so our empirical strategy accounts for those as well. Even after taking stock of all those considerations and a variety of related issues, the plausibility and quantitative importance of the expectations' channel of monetary policy—particularly in regards to the efficacy of expansionary monetary policy expectations' shocks on economic activity at the ZLB—remains a robust empirical and theoretical finding.

3. Data

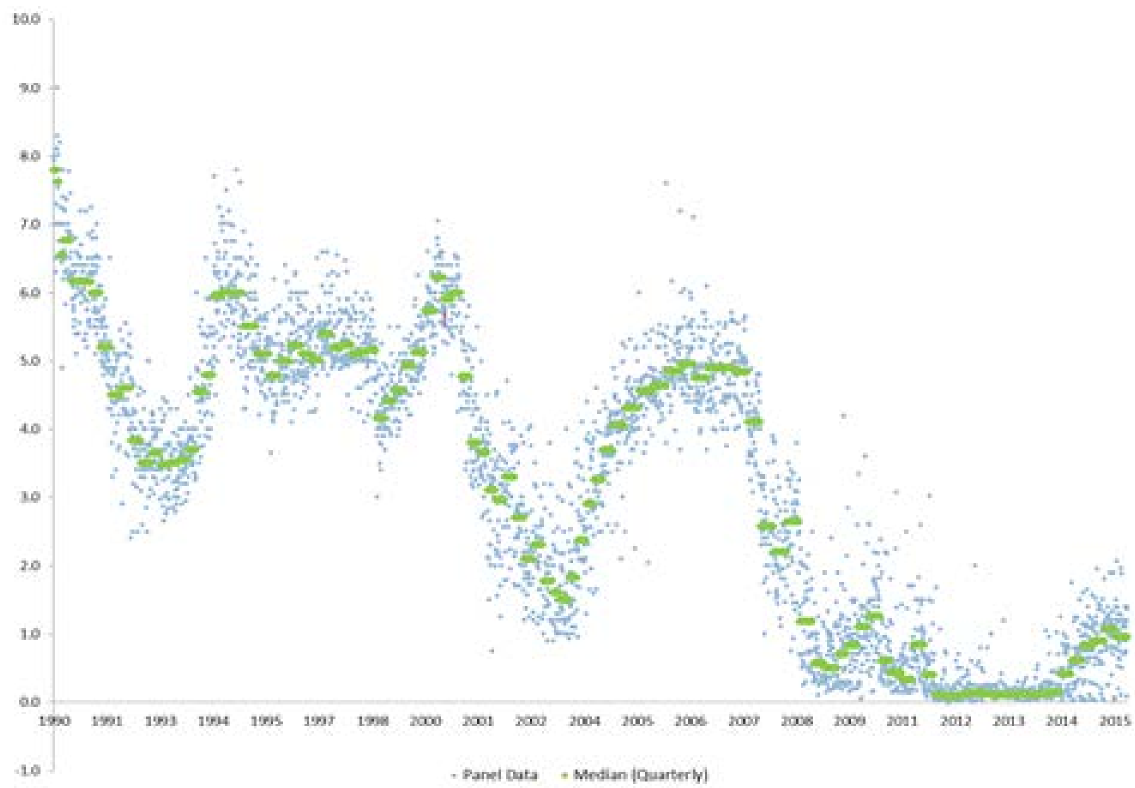
To explore the role of monetary policy expectations in the macroeconomy, we use interest rate forecasts from the Federal Reserve Bank of Philadelphia (2015a)'s Survey of Professional Forecasters (SPF) in our benchmark model. The SPF provides a panel of one quarter, two quarter, three quarter, four quarter, current fiscal year, and next fiscal year forecasts. We use the longest consistent forecast horizon available (four quarters ahead) for the three-month Treasury bill rate in our empirical benchmark. Figure 1 plots the expected four-quarter ahead forecast on the three-month Treasury bill rate for all panelists reporting each quarter, superimposed next to the corresponding quarterly median forecast of the panel. We utilize both the median and the full panel in our empirical strategy.

The SPF dataset of forecasts is taken at quarterly intervals from 1981:Q3 through 2015:Q2. However, we choose to use the sample beginning in 1990:Q1 through 2015:Q2 for our empirical analysis, due to two reasons, the regime shift that occurred at the end of Federal Reserve Chairman Paul Volcker's term in office (August 6, 1979 – August 11, 1987), and the end of a decade characterized by the Federal Reserve's efforts to bring inflation down after the stagflation of the 1970s.[14] The practice of using output and omitting the difficult-to-measure

[14] Our sample period does not include the Federal Reserve's gradual liftoff phase that began with a quarter-point increase in December 2015, raising the federal funds rate band to a range between 0.25 and 0.5 percent. In restricting our sample in this way, we aim to focus our attention only on how monetary policy (forward guidance, in particular) managed interest rate expectations (by signaling the path of future rates and/or reducing monetary policy uncertainty) as U.S. policymakers confronted the ZLB for the first time in the post-WWII period.

output gap in empirical analysis tends to spuriously produce evidence of price puzzles, even controlling for commodity prices which are rather apparent in the 1980's (see, e.g., Balke and Emery (1994) and Giordani (2004)). Removing the 1980's from our VARs therefore abstracts from this transition period and mitigates the issues posed by the price puzzle.

Figure 1. Expected Interest Rate on 3-month Treasury Bills Four Quarters Ahead



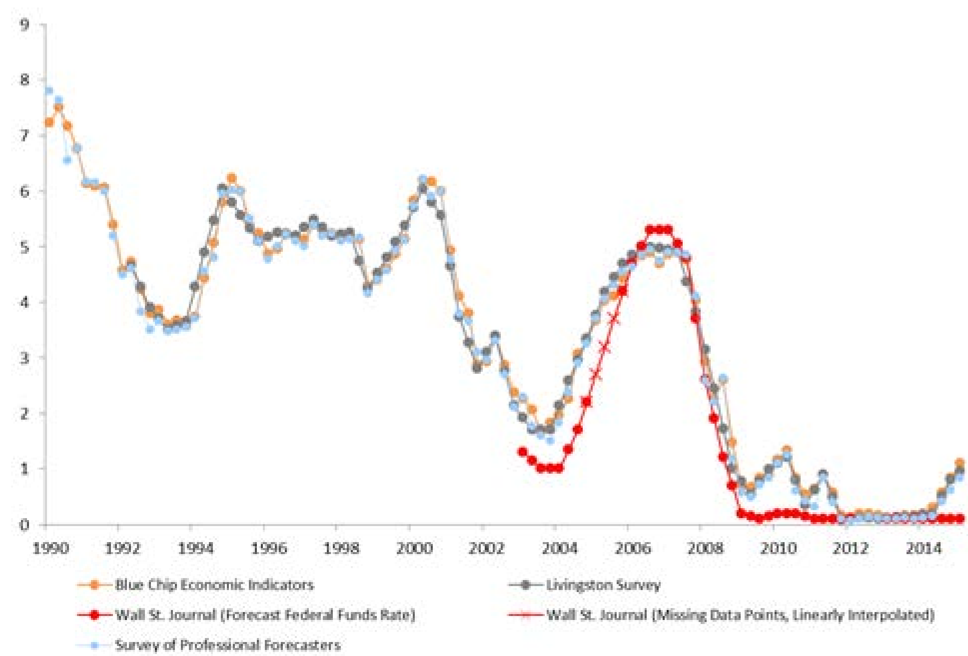
Note: All data plotted is at quarterly frequency and describes the entire panel of forecasts available each quarter from the SPF.

We also use forecasts from the Blue Chip Economic Indicators (BCEI) survey (Aspen Publishers (2015)), the Livingston Survey from Federal Reserve Bank of Philadelphia (2015b), and survey-based interest rate expectations obtained from the Wall Street Journal (2015) as alternative policy expectations sources for robustness check (see Figure 2).[15] Forecasters of the BCEI survey provide forecasts of the expected interest rate on the three-month Treasury bill rate for the current fiscal year, next fiscal year, the current quarter, the next quarter ahead, two

[15] We extend our thanks to Ben Leubsdorf at the Wall St. Journal for assisting in providing the Wall Street Journal (2015)'s dataset.

quarters ahead, three quarters ahead, and four quarters ahead. To maintain consistency with the benchmark based on SPF data, we use the longest available horizon, the expected yield four quarters in the future. The survey provides the median forecast of the panel every month, so we use simple averaging to find the quarterly forecast, and use the same sample length as with the SPF data (1990:Q1 – 2015:Q2). Similarly, forecasters of the Livingston Survey provide six months ahead, twelve months ahead, current fiscal year, and next fiscal year forecasts of the three-month Treasury bill rate. We use the twelve months ahead forecast to maintain consistency and use the longest horizon possible. This panel of forecasts is taken at semiannual intervals from 1992:S1 through 2015:S1. Given that, we use simple linearization to interpolate quarterly forecasts, and use the quarterly median in our models. Finally, the Wall Street Journal (2015) dataset provides the six months ahead and twelve months ahead forecast of the federal funds rate at semiannual intervals from 2003:S1 – 2015:S2. Treating the data in the same way as the Livingston semiannual data, we use linear interpolation to create quarterly forecasts, and extract the quarterly median forecast of the expected federal funds rate twelve months ahead.

Figure 2. Alternative Expectations Data



Note: All data plotted is at quarterly frequency and describes the median forecast. The Livingston survey and the Wall Street Journal data are semi-annual and therefore linearly interpolated. The BCEI survey is monthly and averaged to quarterly frequency.

Regarding non-expectations data, the shadow federal funds rate is obtained from the Center for Quantitative Economic Research at Federal Reserve Bank of Atlanta (2015), and was originally developed by Wu and Xia (2016) to back out a price-based indicator of the stance of monetary policy when operating through a variety of monetary policy tools in terms of a counterfactual federal funds rate "unconstrained" by the ZLB. All other variables used in our benchmark and alternative empirical models, outside of the FAVAR model—the core inflation rate, the civilian unemployment rate, the federal funds rate, total non-borrowed reserves, and the slope of the yield curve—were all obtained from FRED's database at Federal Reserve Bank of St. Louis (2015).

The FAVAR model incorporates a much wider array of 40 variables, described in detail in the Appendix, also from FRED's database at Federal Reserve Bank of St. Louis (2015), as well as some of the financial market data constructed by Shiller (2016) (cyclically adjusted price-to-earnings ratio and dividend yields), and the house price and exchange rate data from Mack and Martínez-García (2011) and Grossman *et al.* (2014). This richer dataset includes measures of real economic activity (such as manufacturing and production levels), financial conditions, volatility indices, usage of various commodities, government expenditures, exchange rates, and a variety of inflation measures, among other nominal and real economic indicators.

All non-expectations data is also expressed at quarterly frequency from 1990:Q1 through 2015:Q2 to match the sample size of the benchmark SPF forecasts, except for the data used in the FAVAR, which, due to the limitations inherent in finding consistently available quarterly data for all 40 economic indicators, begins in 2000:Q1.

4. Main Empirical Findings

4.1 Benchmark VAR Model

The specification of our benchmark VAR model is motivated by the workhorse New Keynesian model, augmented with survey-based expectations of future monetary policy. As shown in our theoretical discussion in Section 2, news shocks about future monetary policy can generate an immediate response in macroeconomic variables even if no policy change takes effect. This theoretical insight highlights the importance of the expectations term in modeling the transmission mechanism of monetary policy, as simply using the federal funds rate would otherwise be insufficient to identify the monetary policy stance of the Federal Reserve.

Furthermore, with interest rate expectations, we can differentiate between unexpected monetary policy shocks (surprise shocks) and anticipated monetary policy innovations (news shocks). This allows us to assess the transmission mechanism of monetary policy without mixing the effects of simultaneous news shocks and unexpected policy innovations, unlike what happens in the existing empirical literature on monetary policy shocks (see, e.g., Sims (1992)). Using survey-based short-term interest rate forecasts to proxy monetary policy expectations in the VAR, rather than backing out implied expectations from financial data or from long-term interest rates, allows us also to consider the direct impact of shocks to private agents' policy expectations without confounding them with the varied risk factors that are priced in the financial data.

4.1.1 Empirical Methodology

We use data from the SPF, which provides us the entire panel of forecasts of the expected three-month Treasury bill rate four quarters ahead, at a quarterly frequency, of which we employ the median forecast. The rest of variables in the benchmark model includes the realized core inflation rate, the realized unemployment rate, and the effective federal funds rate. Using core inflation rather than headline helps to mitigate the possibility of a price puzzle arising from exogenous energy price shocks. Using unemployment in the benchmark specification, rather than real GDP, eschews the difficult issues that frequently arise from data revisions. Finally, the federal funds rate is a key policy tool of the central bank.[16]

Sign and zero restrictions are our main strategy for identifying structural shocks. Essentially, by imposing *ex post* sign (or zero) restrictions on the set of moments generated in each iteration of the impulse response simulations to any given shock in the system, we can

[16] Both the choice to use unemployment rather than a different output proxy and the choice to use the federal funds rate, which became constrained at the ZLB in the aftermath of the 2007-09 Global Financial Crisis—and thus unable to describe properly the overall stance of monetary policy—are relaxed in subsequent robustness checks, which nonetheless yield consistent results with those of this benchmark specification.

cleanly identify the system and compare relative magnitudes and duration of the responses to expectations and monetary policy shocks. If the signs of the impulse responses to the candidate shock satisfy the restrictions, the draw and its corresponding responses are retained; if not, they are unused. Our empirical VAR model follows a slightly modified version of that of Binning (2013), an algorithm that acts as a unifying framework for short-run, long-run, zero and sign restrictions.[17]

Following Binning (2013), we estimate the VAR in the following manner:

$$
\begin{aligned}
&A(L)Y_t = u_t,\ E\left(u_t u_t^T\right) = \Sigma, \\
&A(L) \equiv \left(I_m - A_1 L - A_2 L^2 - \ldots - A_p L^P\right),
\end{aligned}
\tag{21}
$$

where Y_t is the $m \times 1$ vector that contains m observable variables at time $t+1$, u_t is the $m \times 1$ vector of forecast errors, p is the number of lags, L is the lag operator, $A_1, A_2, \ldots, A_p$ are $m \times m$ matrices of parameters, I_m is the $m \times m$ identity matrix that takes values of one in the diagonal and zero elsewhere, and Σ is the $m \times m$ covariance matrix of the forecast errors. We also make the following assumptions about the relationship between the structural and reduced form shocks:

$$
u_{t+1} = Z\varepsilon_{t+1},\ E_t\left(\varepsilon_{t+1}\varepsilon_{t+1}^T\right) = I_m,\ ZZ^T = \Sigma,
\tag{22}
$$

where ε_{t+1} are the structural shocks and Z is the short-run impact matrix, of which there are many that satisfy $ZZ^T = \Sigma$. We then use sign and zero restrictions to isolate the Z's that are consistent with theory. Using the lower Cholesky decomposition of the covariance matrix Σ, or simply put, $C = chol(\Sigma)^T$ where $CC^T = \Sigma$, as the candidate for the initial impact matrix Z, we concurrently define the short-run impact matrix we want to satisfy as L_0^*. The algorithm then proceeds by randomly drawing an $m \times m$ matrix from a normal distribution, from which we produce a randomly drawn orthogonal matrix Q^*. Finally, the algorithm generates draws of Z by multiplying the initial impact matrix by the random orthogonal draw. Impulse response

[17] See Binning (2013) for a full description of the algorithm and estimation procedure.

functions are thus created, and if they satisfy the restrictions specified in matrix L_0^*, they are retained, and if not, they are discarded.

While Binning (2013)'s algorithm for sign restrictions detailed above allows for either positive, negative, or unrestricted elements in the desired impact matrix L_0^*, we extend the zero restrictions to also allow for "nearly zero" responses.[18] Rather than only checking the sign of the contemporaneous response, for the particular restrictions we specify, the algorithm checks if the absolute value of the desired elements in Z are less than a predetermined cut-off value, close to zero. This gives the data a certain degree of flexibility, while still imposing some desired structure. All other restrictions are either sign restrictions (positive or negative) or simply left unspecified.

Guided by economic theory, we split the sample into a pre-ZLB period (1990:Q1 – 2008:Q3) and a ZLB period (2008:Q4 – 2015:Q2), and specify separate initial impact matrices, $L_{0,\text{Pre-ZLB}}^*$ and $L_{0,\text{ZLB}}^*$, for the respective samples, identifying four shocks to the system: an aggregate demand shock (AD), an aggregate supply shock (AS), a monetary policy shock (MP), and a monetary policy expectations (forward guidance) shock (FG). We split the benchmark VAR model into these two sub-samples to allow for the possibility of a structural break in the data. We split our sample after 2008:Q3 for two reasons. First, policy rates were already near the ZLB and quickly moving towards it by then. Second, given the worsening economic conditions (at the beginning of the recession) and the expected monetary policy response, policymakers, consumers, and investors were already anticipating that the degree of monetary accommodation required to deal with the crisis over the upcoming years could not be accommodated with conventional policies—that is, with further and deeper cuts of the federal funds rate—and would possibly require the extensive use of other policy tools (including forward guidance) instead. In other words, we choose to split the sample around 2008:Q3 (three-quarters ahead of the actual point in time at which the federal funds rate effectively hit the ZLB) because by that time private agents had already incorporated into their

[18] Notice that while Binning (2013)'s algorithm allows for short-run restrictions, long-run restrictions, zero restrictions, sign restrictions, and combinations of the above, we only use the option to identify structural shocks using sign restrictions here.

expectations the prospect that policy rates would become constrained at the ZLB shortly in the near future.[19]

Given that the model includes four variables, interest rate expectations four quarter ahead ($i_{e,t+4}$), unemployment (UR_t), core inflation (π_t), and the federal funds rate (FFR_t), we impose the following restrictions on the initial impact matrices for the two sub-samples:

$$
\begin{aligned}
L^*_{0,\text{Pre-ZLB}} &= \left[\begin{array}{cccc|c} MP & FG & AS & AD & \\ \hline +1 & \text{NaN} & \text{NaN} & -1 & FFR_t \\ 0 & +1 & 0 & 0 & i_{e,t+4} \\ -1 & -1 & +1 & -1 & \pi_t \\ +1 & -1 & +1 & +1 & UR_t \end{array}\right], \\
L^*_{0,\text{ZLB}} &= \left[\begin{array}{cccc|c} MP & FG & AS & AD & \\ \hline +1 & \text{NaN} & \text{NaN} & -1 & FFR_t \\ 0 & +1 & 0 & 0 & i_{e,t+4} \\ -1 & -1 & +1 & -1 & \pi_t \\ +1 & +1 & +1 & +1 & UR_t \end{array}\right],
\end{aligned} \tag{23}
$$

where the columns of the 4×4 matrices correspond to the shocks (labeled as such), and the rows correspond to the contemporaneous reactions of the variables in the VAR. For the restrictions labeled as "0", the cut-off value is set to 0.6, while restrictions labeled as "NaN" are left unrestricted. The theoretical motivation for the flexible-zero restrictions is that we wish to isolate exogenous news shocks to monetary policy expectations, which implies that news about future monetary policy (forward guidance)—i.e., not aggregate demand, aggregate supply, or monetary policy surprises—convey information to which future interest rate expectations ought to strongly respond on impact. Thus, shocks to other variables in the system are restricted to have a statistically negligible effect on the interest rate expectations. Other notable restrictions include those imposed on the macro variable responses to the news shock itself, the FG shock. These restrictions directly flow from the theory laid out earlier, and

[19] The robustness of this specific break-point is further explored later on where we use a Time-Varying Parameter VAR (TVP-VAR) to extract the quarterly impulse-response functions during every quarter in the sample, allowing for the parameters to change each period, and find that our results are again consistent with the benchmark, and that this particular time period, at the end of 2008, was indeed the point at which a significant structural shift in the underlying data-generating process occurred.

contain the sign restriction that reverses the response of unemployment to a news shock at the ZLB. All other restrictions remain the same across the two sub-samples, pre-ZLB and ZLB. The remaining restrictions on conventional monetary policy, aggregate demand and aggregate supply shocks in these matrices follow conventional New Keynesian macroeconomic theory. We leave the response of the monetary authority to an adverse aggregate supply shock unspecified, due to the opposing dynamics of unemployment and inflation triggered by this shock since this trade-off can result in higher or lower interest rates depending on the sensitivity of the Taylor rule to both dual mandate objectives.

One could argue that the optimal sign restrictions of the central bank's response to other shocks to the system in the ZLB sample should, by definition, also be restricted to zero, due to the binding constraint on interest rates. However, as seen in the previous empirical analysis, the federal funds rate does indeed have room to move in positive and to a certain degree in negative directions near the ZLB—albeit asymmetrically since the margin of the policy rate to fall further is very limited due to its proximity to the ZLB constraint. At any rate, we later consider not just different identification strategies that are less restrictive (such as using a Cholesky identification strategy to identify only the structural expectations shocks) but also alternative monetary policy tool proxies in the VAR to better capture the monetary policy stance of the Federal Reserve in the post-2007-09 Global Financial Crisis years.

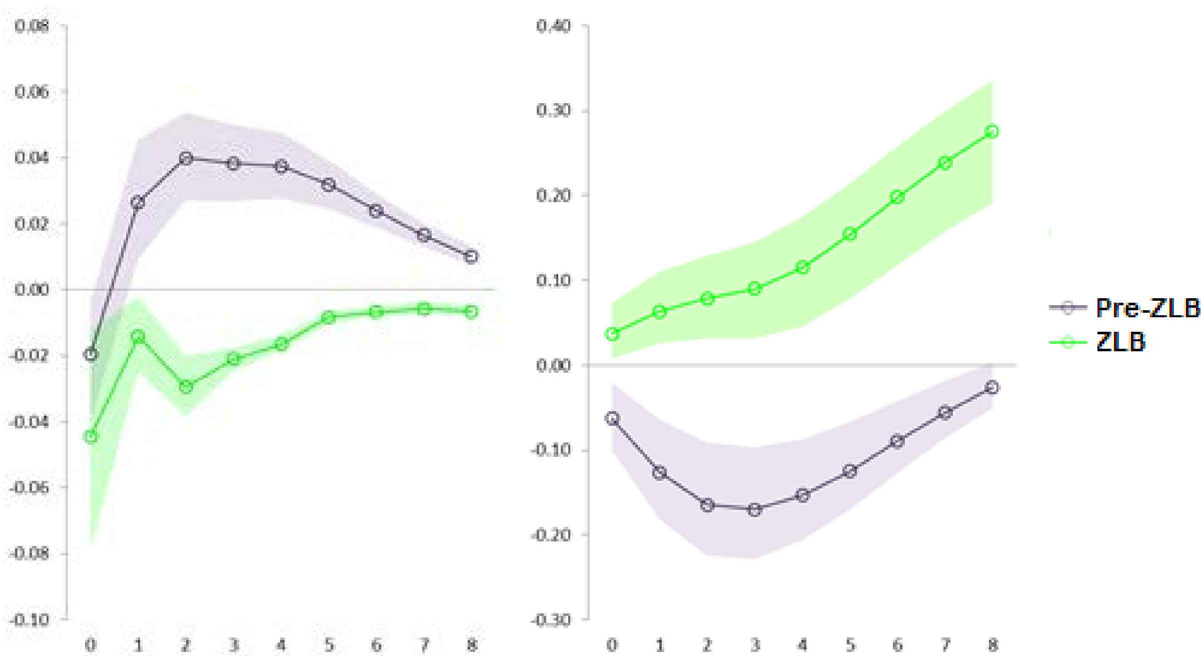
4.1.2 Key Results

The lag order selection analysis, run on the entire sample (1990:Q1 – 2015:Q2), yielded an optimal lag length of two lags, which minimized all reported measures of model fit, including Hansen's J-statistic, the Aikake information criterion, and the Schwarz criterion. To maintain consistency, our benchmark and all alternative model specifications—even when estimated on the pre-ZLB and ZLB subsamples—are also run using two lags ($p=2$). We start examining the propagation of expectations' shocks on the benchmark model with the impulse response functions. Figure 3 details the striking responses of inflation and unemployment to a one-standard-deviation increase in short term interest rate expectations.

Away from the ZLB, a one standard deviation increase in the expected rate on the three month Treasury bill rate four quarters ahead, equivalent to approximately a 2.4 percentage point increase which anticipates tighter future monetary policy, leads to a small on-impact dip in core inflation that remains tiny but turns positive over the forecast horizon, and a significant drop in unemployment on impact above 0.05%, which steadily grows to a negative impact of close to 0.2% after three quarters, before gradually trending back toward zero. Over the forecast horizon of 8 quarters (2 years), after which the unemployment response becomes statistically insignificant, the cumulative effect of the positive 2.4 percentage point increase in short-term interest rate expectations is a nearly 1.2 percentage points decrease in the unemployment rate. This is not only consistent with the theory laid out in Subsection 2.3, but of quantitative importance empirically.

Figure 3. Impulse Response Functions for the Expectations' Shock:
Benchmark Model with Sign Restrictions

Core Inflation (Left) | Unemployment (Right)



Note: Impulse response functions over eight quarters based on the benchmark VAR model using median SPF forecasts and sign restrictions motivated by theory. The pre-ZLB period corresponds to 1990:Q1 – 2008:Q3 while the ZLB refers to 2008:Q4 – 2015:Q2.

The rationale for this is that news shocks cause private agents to raise their future interest rate expectations, and accordingly they immediately reduce production capacity by hiring less today in order to effectively smooth consumption over time. Their response places upward pressure on unemployment and downward pressure on inflation today—before the central bank even takes any action—but the Federal Reserve would respond to those pressures by lowering interest rates under a fairly standard Taylor-type policy rule on inflation and unemployment. This, in turn, stimulates economic activity enough to offset the initial negative response from the news shock, pushing unemployment downward, lifting inflation upward, and yielding the impulse responses we see here.

The story dramatically changes once we turn to the ZLB. In the ZLB sub-sample, a one standard deviation increase in interest rate expectations, equivalent to a 0.4 percentage point rise in short term expectations four quarters ahead, again leads to a small dip in inflation of 0.04% on impact, that trends back toward zero over the 8-quarter forecast horizon. The response of unemployment, however, is of the opposite sign than away from the ZLB, with an on-impact increase of a bit less than 0.05%, which gradually trends upward to a maximum response of 0.28% at horizon $s = 8$. Cumulatively, over the eight-quarter forecast horizon, this totals approximately a 1.1% increase in the unemployment rate, simply from a 0.4% rise in future interest rate expectations today. This striking response is of the opposite sign than the response away from the ZLB.

This evidence of reversal would point again to the explanation articulated in theory earlier as a likely explanation for the U.S. experience. Put differently, at the ZLB, a rise in interest rate expectations would still cause private agents to expect lower future production and aim at smoothing their consumption levels starting today, but the monetary authority is no longer able to respond to that fall in output by subsequently lowering current interest rates to boost the economy. Thus, at the ZLB, we find a negative output response in the impulse responses as predicted by theory.

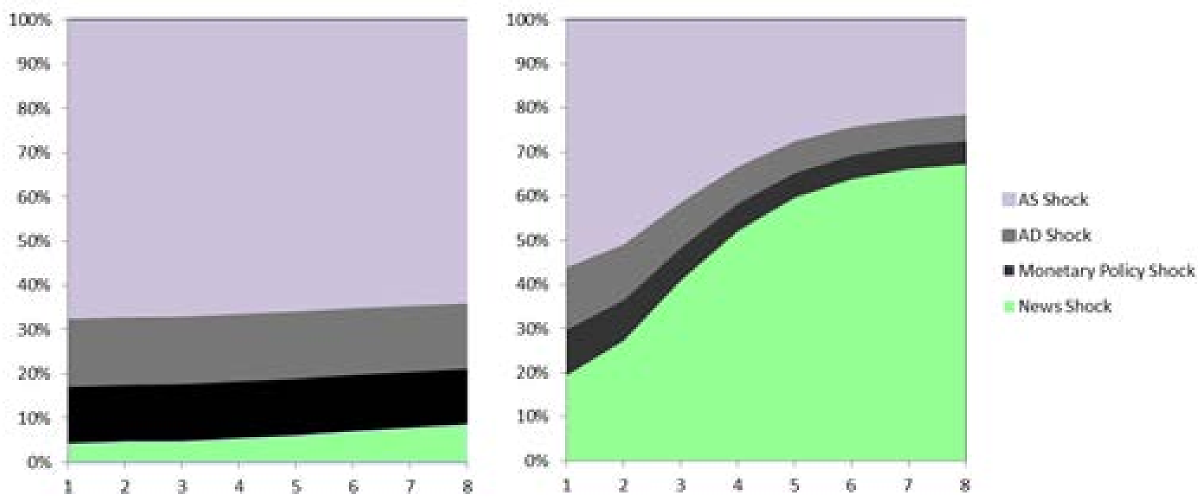
The forecast error variance decompositions, like the impulse-response functions, yield economically-relevant insights too. Indeed, the variance decompositions demonstrate the significant quantitative importance of monetary policy expectations—at and away from the ZLB. Figure 4 depicts the percentage of variation of core inflation and unemployment explained by interest rate expectations shocks relative to those of other structural shock innovations. At horizon $s=1$, away from the ZLB, approximately 5% of the fluctuations in core inflation and 20% of the fluctuations in unemployment are directly explained by movements in interest rate expectations, which then grow as the horizon lengthens. *A*t the ZLB, at horizon $s=1$, roughly 15% of the fluctuations in core inflation and 10% of the fluctuations in unemployment are explained by policy expectations. In this way, we say that failing to account for monetary policy expectations significantly understates the ability with which the central bank's forward guidance communications can affect the macroeconomy even at the ZLB, going well beyond what actual monetary policy shocks (surprises) alone accounts for.

The historical decompositions of core inflation and unemployment, shown in Figure 5, confirm the importance of policy news shocks. In any given quarter—at or away from the ZLB—news shocks often contribute up to or slightly more than 1 percentage points to the movements in the unemployment rate. The behavior of news in the decomposition at the ZLB is particularly intriguing, as we find that policy news shocks led to increases in the unemployment rate for much of the period, through 2013, suggesting that the Federal Reserve's forward guidance was not used effectively to lower unemployment during the worst of the 2007-09 Global Financial Crisis and the early part of the recovery until policymakers learned how to better deploy forward guidance to provide monetary accommodation at the ZLB (as noted, for instance, in Caldara *et al.* (2021)).

Figure 4. Forecast Error Variance Decompositions: Benchmark Model with Sign Restrictions

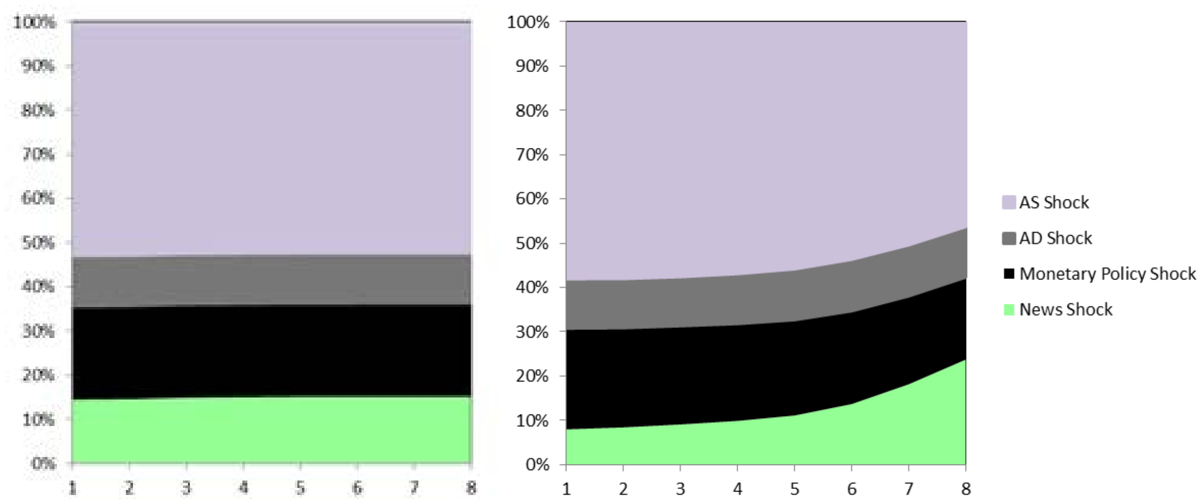
Pre-ZLB (1990:Q1 – 2008:Q3)

Core Inflation (Left) | Unemployment (Right)



ZLB (2008:Q4 – 2015:Q2)

Core Inflation (Left) | Unemployment (Right)

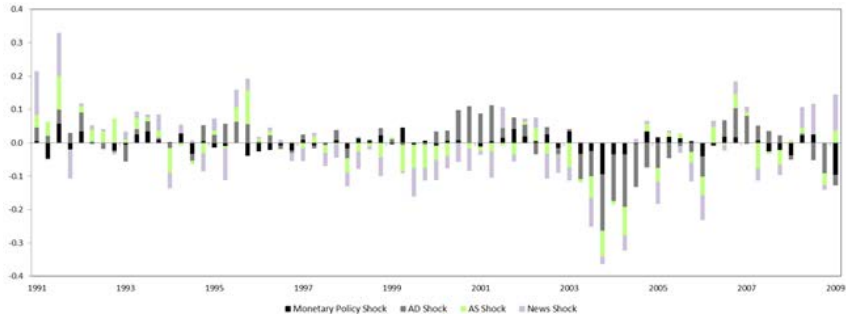


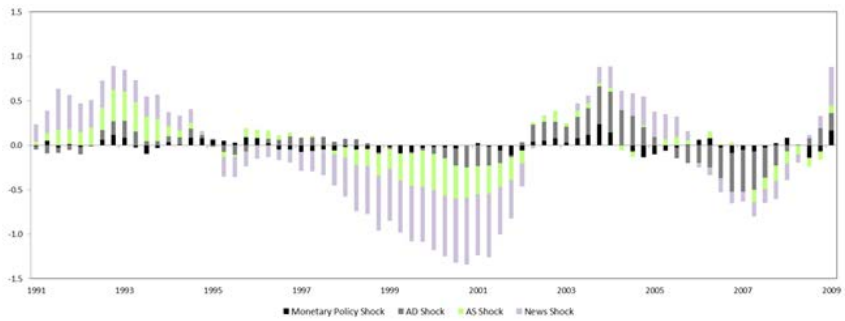
Note: Forecast error variance decomposition over eight quarters based on the benchmark VAR model using median SPF forecasts and sign restrictions.

Figure 5. Historical Decompositions: Benchmark Model with Sign Restrictions

Pre-ZLB (1990:Q1 – 2008:Q3)

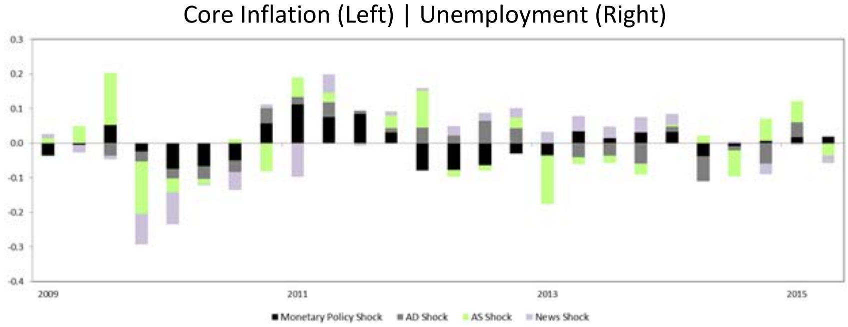
Core Inflation (Top) | Unemployment (Bottom)

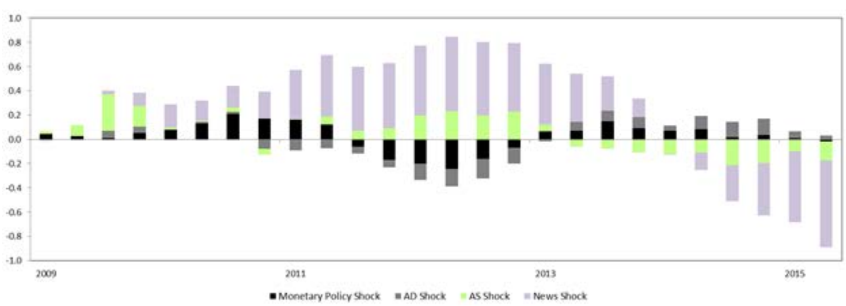




ZLB (2008:Q4 – 2015:Q2)

Core Inflation (Left) | Unemployment (Right)





Note: Forecast error variance decomposition over eight quarters based on the benchmark VAR model using median SPF forecasts and sign restrictions.

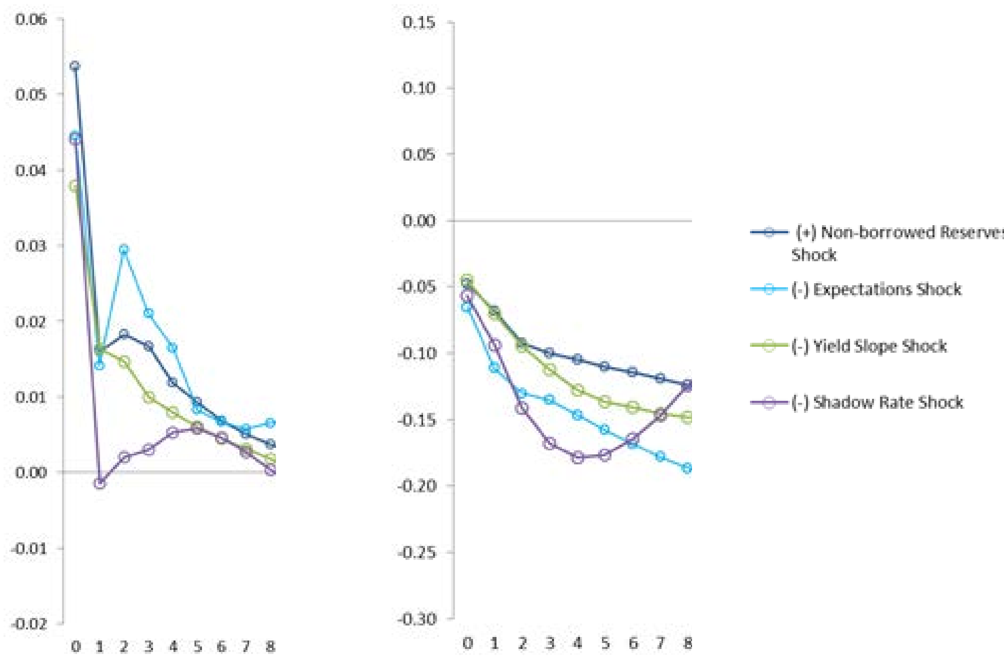
4.1.3 Other Monetary Policy Proxies

We explore alternative monetary policy tool proxies together with the effective federal funds rate, and perform a comparison of the responses to their corresponding shocks during the ZLB period. Figure 6 depicts the responses of core inflation and unemployment to a one standard deviation expansionary monetary policy shock using the effective federal funds rate together with either the growth rate of non-borrowed reserves, the Wu and Xia (2016) shadow rate, the slope of the yield curve (a known financial leading indicator according to Estrella and Mishkin (1998) and Rudebusch and Williams (2009)), or simply the interest rate expectations as we do in our benchmark model. At the ZLB, we find that a monetary policy news shock is the single most effective at driving a response of unemployment, in terms of maximum response as well as persistence. The shadow rate has a similarly large maximum response that peaks earlier (four quarters into the future), but we should note that this variable is a proxy for the monetary policy stance of the Federal Reserve, and not an implementable policy tool that the Federal Reserve directly controls. Depressing short term interest rate expectations four quarters ahead by only 0.4% (one standard deviation, at the ZLB), leads to a sustained decrease in the unemployment rate of 0.18% at horizon $s=8$. Similarly, a one-standard deviation expansionary shock to the slope of the yield curve leads to a maximum response of 0.14%, at $s=8$. The slope of the yield curve captures the expected path of future interest rate as implied by our discussion on long-term yields in Subsection 2.2 above, but it can be confounded by other unmodelled risk factors. A one-standard deviation expansionary shock to the growth rate of non-borrowed reserves (of which, the standard deviation is inherently a much larger value due to the unprecedented actions taken by the monetary authority in recent years), leads to a maximum decrease in the unemployment rate of about 0.12% at $s=8$.

In any event, these estimates are not too dissimilar from those obtained with interest rate expectations in the benchmark model. In no small part, this reflects that forward guidance and balance sheet policies have been most effective at providing monetary accommodation since the onset of the 2007-09 Global Financial Crisis when they have come hand in hand, reinforcing each other and anchoring the Federal Reserve's current and expected policy commitments.

Figure 6. Impulse Response Functions for the Monetary Policy Variable Proxies: Alternative Models with Sign Restrictions

Core Inflation (Left) | Unemployment (Right)



Note: Impulse response functions over eight quarters based on the benchmark VAR model using median SPF forecasts and sign restrictions motivated by theory for expectations shocks but unspecified for all other monetary policy tool proxies. The ZLB period refers to 2008:Q4 – 2015:Q2. Only the median response, not the confidence bands are plotted. Furthermore, we plot the response to a negative expectations shock, yield slope shock, and shadow rate shock together with the response to a positive non-borrowed reserve shock.

4.2 Robustness Checks

The reversal in the response of unemployment to monetary policy expectations' shocks we noted earlier is consistent with theory, empirically significant, and economically relevant. We now begin to explore various ways in which this could simply be, in colloquial terms, a fluke. This includes using different data sources, as well as considering alternative empirical models and other identification strategies. Here we explore, in particular, what a recursive scheme affords us. This will help us evaluate how consistent are our empirical findings with theory when using an alternative and somewhat less restrictive identification assumption, guiding us to uncover the robust relationships that exist between monetary policy expectations and the macroeconomy on its own.

4.2.1 VAR Model with Recursive Identification

The benchmark VAR is structured recursively, in a Cholesky ordering scheme, analogous to what Leduc and Sill (2013) do. As before, the structural VAR incorporates m macroeconomic variables contained in the vector Y_t as follows:

$$\widetilde{A}\left(I_m - A_1 L - A_2 L^2 - \ldots - A_p L^P\right) Y_t \equiv \widetilde{B} e_t, \tag{24}$$

where e_t is an $m \times 1$ vector of orthogonalized disturbances where $e_t \sim WN\left(0, I_m\right)$. The Cholesky restrictions are imposed on the above system by applying the following structural restrictions:

$\widetilde{A} \equiv \begin{bmatrix} 1 & 0 & 0 & 0 \\ . & 1 & 0 & 0 \\ . & . & 1 & 0 \\ . & . & . & 1 \end{bmatrix}$ is a lower triangular matrix with ones on the diagonal and

$\widetilde{B} \equiv \begin{bmatrix} . & 0 & 0 & 0 \\ 0 & . & 0 & 0 \\ 0 & 0 & . & 0 \\ 0 & 0 & 0 & . \end{bmatrix}$ is a diagonal matrix. Accordingly, we can then compute the Cholesky decomposition from the estimates of $\widetilde{A}$ and $\widetilde{B}$.

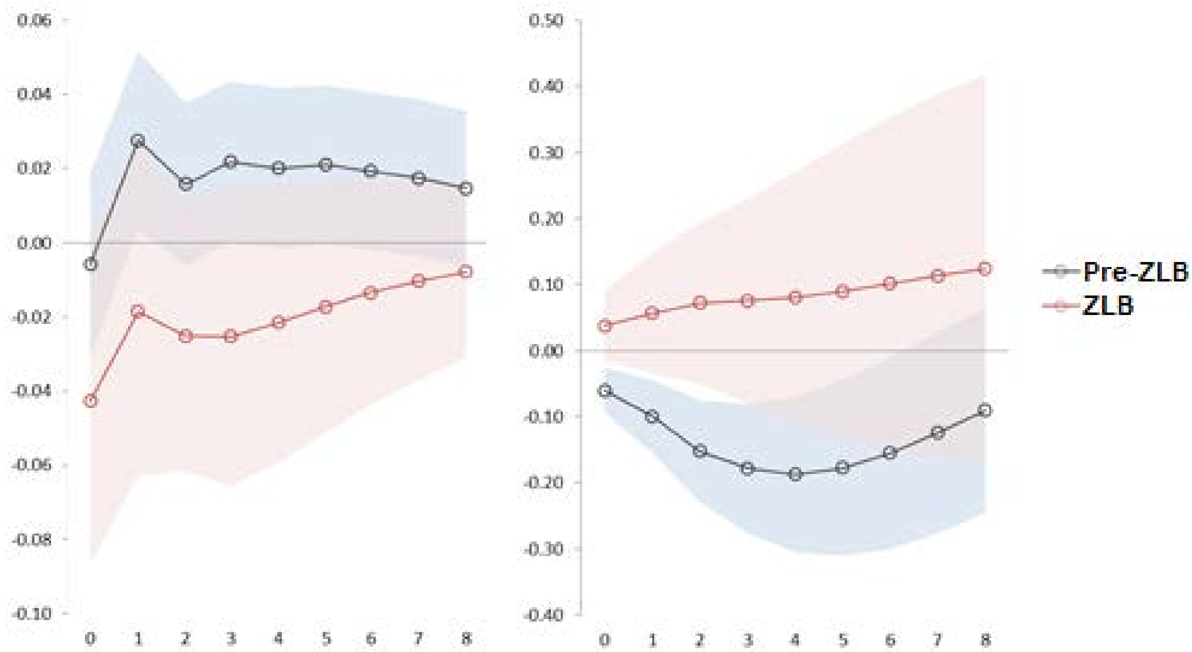
The Cholesky ordering can help us correctly isolate expectations' shocks in the VAR. For that, we place short-term interest rate expectations first in the scheme, such that the variable is not contemporaneously affected by shocks to other variables in the system, equivalent to the first row of matrix $\widetilde{A}$, while shocks to the variable itself contemporaneously affect all other variables. This ordering is also motivated by the timing of the forecast data. Forecasters, when forming their expectations, only have previous historical data with which to make their projections, given that they are asked to fill out the questionnaires at the start of each quarter—hence, they are, truly, not able to incorporate current fluctuations in core inflation, unemployment, or the federal funds rate that occur during the quarter, only historical movements. At the same time, the realized variables in the VAR, core inflation, unemployment, and interest rates, are all able to respond contemporaneously to shocks to expectations. Of these three realized variables, the federal funds rate is placed last in the scheme, consistent with a standard interpretation of the Taylor rule, in which the central bank responds to current economic conditions under a dual mandate that sets its goals in terms of inflation and the unemployment rate. The unemployment rate is placed immediately before the federal funds rate.[20] In summary, the benchmark model is ordered as interest rate expectations, core inflation, the unemployment rate, followed last by the federal funds rate. We focus our analysis here only on shocks to expectations, as the previous literature has already explored the issues and limitations that may arise from using the Cholesky scheme to examine shocks to other variables in the system, particularly traditional monetary policy shocks that tend not to be well-identified in this recursive scheme (see Carlstrom *et al.* (2009)).

Even when identifying the system with this recursive scheme instead of using sign restrictions, we still find results consistent with those of the benchmark model. Comparing the impulse-response functions from a shock to monetary policy expectations, we find dynamics for the expectations shocks in Figure 7 under Cholesky identification similar to those in Figure 3 derived with sign restrictions. The magnitude of the responses is slightly larger in the sign restrictions VAR, with a one standard deviation increase in interest rate expectations, at the ZLB, associated with a maximum increase in the unemployment rate of 0.28%, at horizon $s = 8$, compared to the recursive benchmark model with Cholesky identification where it is around 0.12% with a lower level of statistical confidence. Away from the ZLB, a one standard deviation shock to monetary policy expectations leads to a maximum decrease in the unemployment rate of 0.18% with sign restrictions, nearly the same as the response found in the recursive benchmark with Cholesky identification.

[20] To explore the robustness of our results, we also tried different orderings of the variables, in which the federal funds rate responded to lagged values of inflation and output, given that it sometimes takes time for data to become available for policymakers to respond to, and again found consistent results with those of the benchmark scheme.

Figure 7. Impulse Response Functions for the Expectations' Shock: Benchmark Model with Cholesky Identification

Core Inflation (Left) | Unemployment (Right)



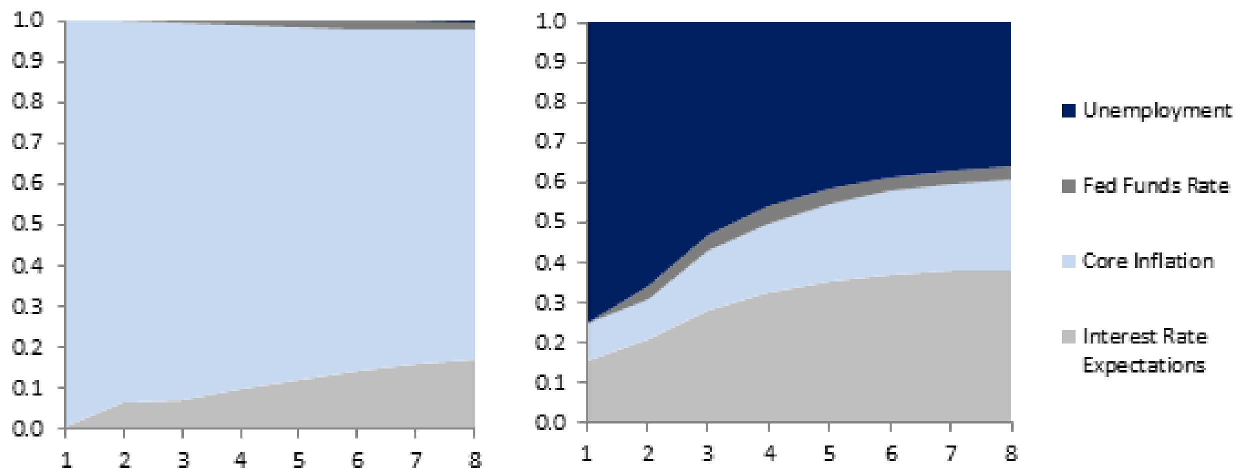
Note: Impulse response functions over eight quarters based on the benchmark VAR model using median SPF forecasts and Cholesky identification. Pre-ZLB corresponds to 1990:Q1 – 2008:Q3, ZLB refers to 2008:Q4 – 2015:Q2.

Identifying the model using a recursive scheme also yields similar results in regards to the quantitative importance of news shocks. The forecast error variance decompositions of unemployment and core inflation attribute significant amounts of the fluctuations in those variables to news, although slightly more with sign restrictions (Figure 4) than in the recursive model (Figure 8). Even with the recursive scheme under Cholesky identification, Figure 8 shows that, at horizon $s = 8$, away from the ZLB, approximately 12% of the fluctuations in core inflation and 32% of the fluctuations in unemployment are directly explained by movements in interest rate expectations. Similarly, at the ZLB, at $s = 8$, roughly 21% of the fluctuations in core inflation and 11% of the fluctuations in unemployment are explained by policy expectations. Hence, once again, failing to account for monetary policy expectations significantly understates the ability with which the Federal Reserve can affect the macroeconomy even at the ZLB.

Figure 8. Forecast Error Variance Decompositions:
Benchmark Model with Cholesky Identification

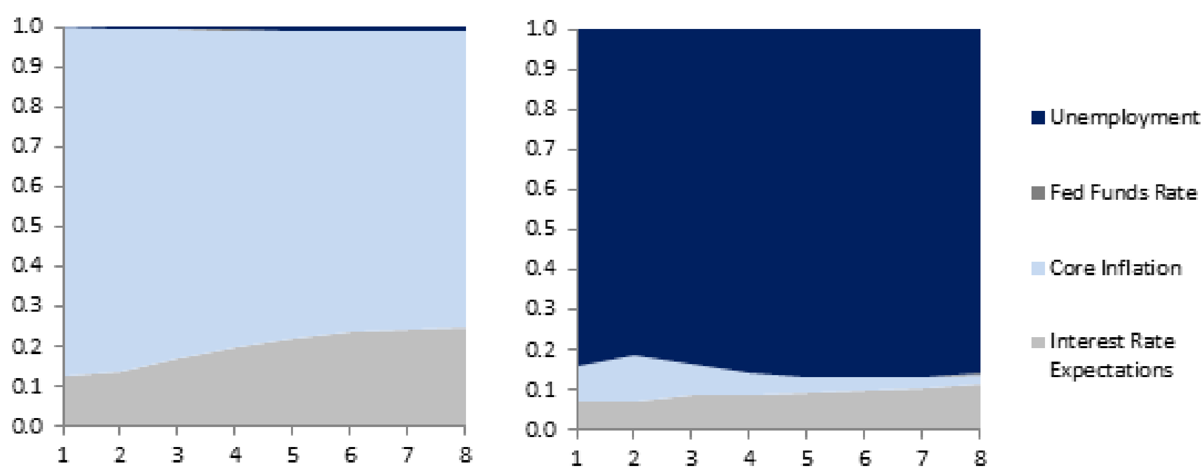
Pre-ZLB (1990:Q1 – 2008:Q3)

Core Inflation (Left) | Unemployment (Right)



ZLB (2008:Q4 – 2015:Q2)

Core Inflation (Left) | Unemployment (Right)



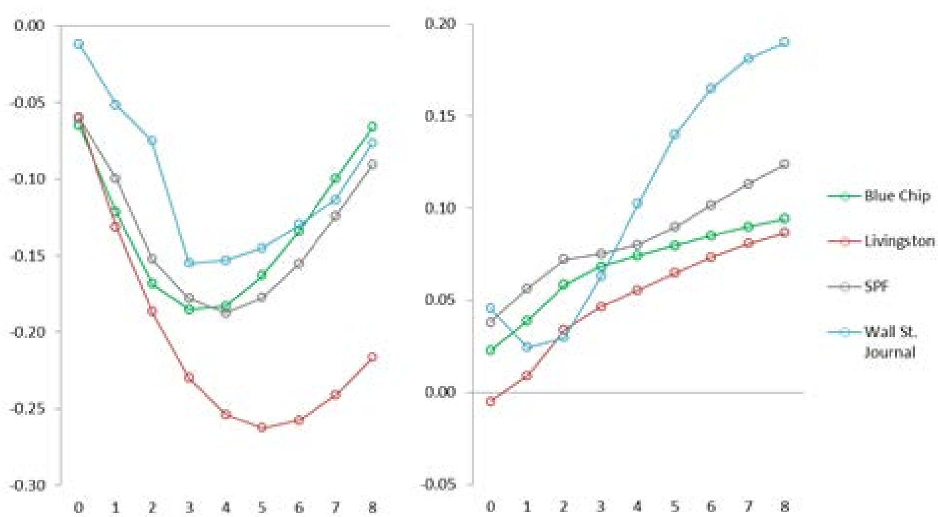
Note: Forecast error variance decomposition over eight quarters based on the benchmark VAR model using median SPF forecasts and Cholesky identification.

4.2.2 VAR Model with Alternative Survey-Based Expectations

We consider whether our previous results are simply a byproduct of the specific dataset used, the SPF. Accordingly, we re-estimate the same recursive model specification using alternative data sources, the Livingston Survey from Federal Reserve Bank of Philadelphia (2015b), the BCEI survey from Aspen Publishers (2015), and the survey-based federal funds rate expectations obtained from Wall Street Journal (2015). In each case, the data was transformed to be at quarterly intervals, to maintain consistency with our baseline specification, and ordered in the same recursive scheme, split into pre-ZLB and ZLB sub-samples. Figure 9 depicts the same impulse response functions, the reaction of the unemployment rate to a one standard deviation increase in short-term interest rate expectations, four quarters ahead, for all different survey sources. The reversal appears in all three alternative datasets, of varying magnitudes. For example, the response of the Livingston Survey is of an even higher order than the response with the SPF data at the ZLB, while the Wall Street Journal response has the largest impact at the ZLB. Nevertheless, the reversal is unequivocally present, across all datasets.

Figure 9. Unemployment Impulse Response Function for the Expectations' Shock: Benchmark Model with Cholesky Identification and Alternative Data Sources

Pre-ZLB (Left) | ZLB (Right)



Note: Unemployment impulse response functions over eight quarters based on the benchmark VAR model using median forecasts from SPF and Cholesky identification. Pre-ZLB corresponds to 1990:Q1 – 2008:Q3, ZLB refers to 2008:Q4 – 2015:Q2.

4.2.3 Factor-Augmented VAR (FAVAR) Model

Given that the benchmark VAR incorporates only four variables, we may be subject to model misspecification and omitted variable bias. Using survey expectations mitigates this to some extent, given that private agents are able to incorporate information other than core inflation, the unemployment rate, and interest rates, into their expectations. To account for the possibility of misspecification and omitted variable bias that still remain in expectations-augmented, small-scale VAR models like our benchmark model, we next follow Bernanke *et al.* (2005) in using a factor-augmented VAR (FAVAR), thus explicitly accounting for other potential transmission channels of monetary policy, as well as incorporating alternative policy tools like the unprecedented quantitative easing and fiscal policy actions seen in the aftermath of the 2007-09 Global Financial Crisis.

Our benchmark model after all, as with many standard VARs, faces limitations on how many variables we can immediately incorporate before running into over parameterization issues—often one includes a maximum of six to eight variables. Even if expanded, such a small set of variables is likely not representative of the hundreds of data series the central bank truly tracks. Similarly, a richer setting like that of the FAVAR model seems also particularly appropriate for modeling shocks to monetary policy expectations, as the forecasters in our survey data also incorporate a fuller information set when forming their interest rate expectations, inclusive of everything from general economic activity and nominal price measures to financial conditions and government expenditures.

Our approach for the FAVAR model closely follows that of Bernanke *et al.* (2005). Y_t is a 1×1 vector of the observed interest rate expectations, the same median SPF forecast series used in the recursive benchmark model. The full information set of other variables relevant to our empirical analysis is summarized by a $k \times 1$ vector of unobserved factors F_t. The dynamics of the factors F_t and monetary policy expectations Y_t are given by:

$$\begin{bmatrix} F_t \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1} \\ Y_{t-1} \end{bmatrix} + \nu_t, \qquad (25)$$

where $\Phi(L)$ is a conformable lag polynomial of finite order p, and the error term v_t has a mean of zero and covariance matrix Q. Because the factors are, by construction, unobservable, this system cannot be directly estimated. Thus, we take a wide set of informational time series, the $n \times 1$ vector X_t, and assume it is related to the unobservable factors F_t and the observed interest rate expectations Y_t by the following equation:

$$X_t = \Lambda^f F_t + \Lambda^y Y_t + e_t, \tag{26}$$

where Λ^f is an $n \times k$ matrix of factor loadings, Λ^y is $n \times m$, and the $n \times 1$ vector of error terms e_t are mean zero and uncorrelated. In this way, the large set of variables X_t is driven by the forces of both Y_t and F_t. To maintain consistency with the recursive benchmark model, we use two lags and the monetary policy expectations innovations are identified recursively, again split into the pre-ZLB and ZLB period.[21] Bernanke *et al.* (2005) divides the blocks of variables X_t into either "fast-moving" time series, which can respond contemporaneously to shocks to monetary policy expectations, or "slow-moving" time series, which cannot. To maintain the same recursive scheme as the recursive benchmark, we allow all variables in X_t to respond contemporaneously to shocks to monetary policy expectations Y_t, a particularly appropriate choice due also to the timing of the surveys—the very beginning of every quarter, leaving a full three months for the rest of the economy to adjust to any news shock. The one exception to this is the measure of fiscal policy, government expenditures, which we leave as a "slow-moving" variable, given the lengthy time it takes for legislation to pass (one would not expect it to be less than a mere three months, let alone the time required to implement it). A full list of the 40 variables included in the FAVAR is detailed in the Appendix.[22]

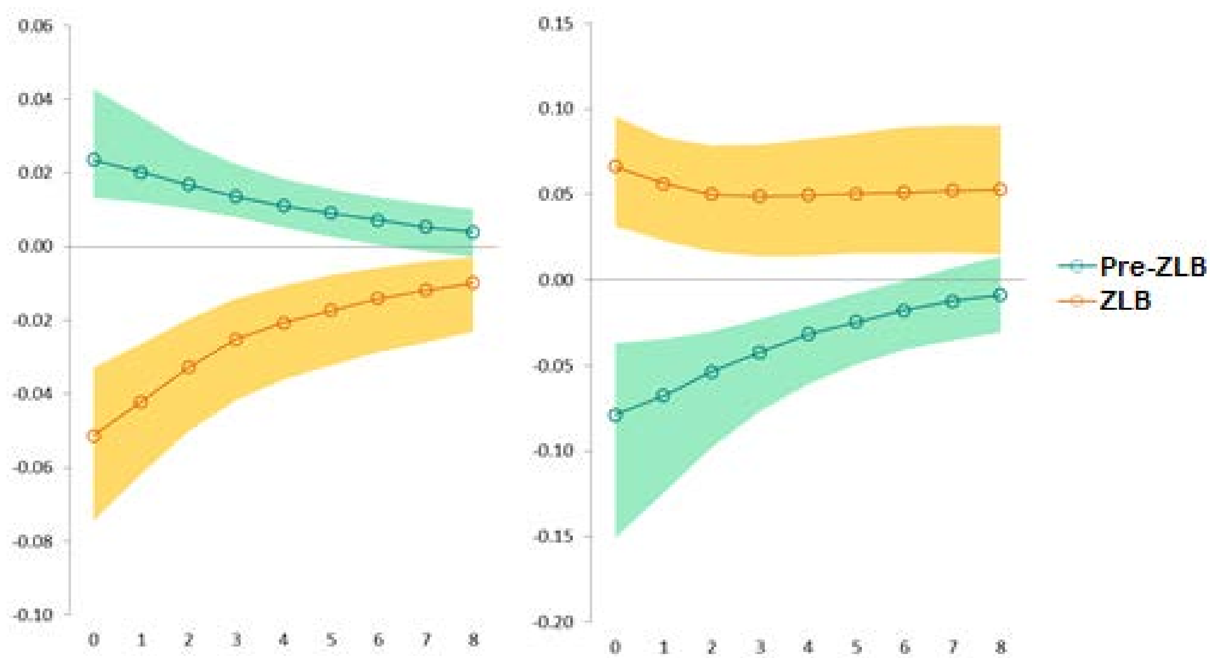
Even when incorporating the additional information set into the FAVAR model in this manner, we find dynamics largely consistent with the results of the benchmark model,

[21] We refer the reader to Bernanke *et al.* (2005) for an in-depth discussion of the FAVAR model, particularly the estimation methodology based on the Bayesian Gibbs sampling procedure.
[22] It also becomes necessary to shorten the pre-ZLB data sample to 2000:Q1 onward, rather than 1990, due to the difficulties with finding the desired data for this much broader set of variables, some of which were not available prior to 2000.

particularly in regard to the reversal in unemployment. As seen in the impulse responses in Figure 10, away from the ZLB, a rise in interest rate expectations leads to an immediate fall in unemployment, while at the ZLB, the same increasae leads to a significant and persistent rise in unemployment. The negative on-impact response of core inflation holds at the ZLB as well, although we find that something different happens away from the ZLB, as core inflation responds with a small rise on impact, albeit of a tiny magnitude. Put succinctly, the behavior of unemployment found in the benchmark model—the significant reversal in the unemployment response at and away from the ZLB—is seen here to not be simply a function of the highly stylized specification of the original empirical analysis. Rather, even when accounting for a wide range of potential omitted variables, this unique finding (the reversal of unemployment to a monetary policy expectations' shock) continues to hold.

Figure 10. Impulse Response Functions for the Expectations' Shock:
FAVAR Model with Cholesky Identification

Core Inflation (Left) | Unemployment (Right)



Note: Impulse response functions over eight quarters based on the FAVAR model using median SPF forecasts and Cholesky identification, together with 40 additional variables. The pre-ZLB period corresponds to 2000:Q1 – 2008:Q3 while the ZLB refers to 2008:Q4 – 2015:Q2.

4.2.4 Panel VAR (PVAR) Model

Although the economy stood at the ZLB in the aftermath of the 2007-09 Global Financial Crisis for, arguably, much longer than many thought it would, the ZLB data sample has nevertheless relatively few observations, only containing slightly under seven years of quarterly data points in it. This poses an issue that can potentially affect our benchmark model inferences—and many of the alternative specifications we explore in this paper, as switching out the monetary policy tool or data source does not mitigate this small sample issue. To further illuminate the dynamics surrounding monetary policy expectations and gain additional certainty about the robustness of our findings, we next exploit the panel nature of the SPF, rather than extracting the median forecast, by using a panel VAR to re-estimate the recursive benchmark model. In this way, we somewhat mitigate the small sample issue at the ZLB, by outwardly building out the cross-sectional dimension of the data sample and fully exploring the panel dynamics of the forecasts.

As in the traditional VAR approach, the panel VAR methodology treats all the variables in the system as endogenous; however, the panel-data approach also allows for unobserved individual heterogeneity which arises in our context across individual forecasters. A useful discussion of the panel VAR methodology can be found in Holtz *et al.* (1988), Love and Zicchino (2006), and Love and Abrigo (2016). Our panel VAR process incorporates q different variables as follows:

$$\begin{aligned} z_{jt} &= \Gamma_{0,t} + \Gamma_{1,t} z_{jt-1} + \ldots + \Gamma_{p,t} z_{jt-p} + f_{j,t} + Q_t \varepsilon_t, \\ \varepsilon_t &\sim N\left(0, I_{n_t^z}\right), \end{aligned} \tag{27}$$

where z_{jt} is the $n_t^z \times 1$ vector of endogenous variables at time t for forecaster j, p is the number of lags in the specification, and ε_t is the corresponding $n_t^z \times 1$ vector of exogenous shocks. We allow the dimension of z_{jt} to potentially change over time so long as $n_t^z \leq q$. $\Gamma_{0,t}, \Gamma_{1,t}, \ldots, \Gamma_{p,t}$ and Q_t are the conformable matrices containing the unknown VAR parameters to be estimated. The likelihood of the model is invariant to orthonormal transformations of Q_t.

We parameterize the likelihood function in terms of $\Sigma_t = Q_t^T Q_t$ and estimate this reduced-form representation. Only in a second step, we identify Q_t based on a Cholesky decomposition, consistent with the recursive benchmark.

We allow for "individual heterogeneity" in the levels of the variables by introducing fixed effects across forecasters, with the term $f_{j,t}$ in the specification above. Mean-differencing to eliminate the fixed effects creates biased coefficients because of correlated regressors in the model specification due to the lags of the dependent variables. Hence, instead we follow the Helmert procedure proposed by Arellano and Bover (1995) of forward mean-differencing to deal with this problem.[23] The Helmert transformation preserves the orthogonality between transformed variables and lagged regressors, so it should not affect the estimates of the coefficients by system GMM, and allows us to use lagged regressors in the panel VAR specification.

Consistent with the benchmark model, we also allow the parameters to change when the interest rate hits or stays away from the ZLB. Thus, we define for the lags $l = 1, \ldots, p$ the following coefficients $\Gamma_{l,1} = \Gamma_{l,t\in\{\text{Pre-ZLB}\}}$, $\Gamma_{l,2} = \Gamma_{l,t\in\{\text{ZLB}\}}$, $\Sigma_{l,1} = \Sigma_{l,t\in\{\text{Pre-ZLB}\}}$, $\Sigma_{l,2} = \Sigma_{l,t\in\{\text{ZLB}\}}$, with sample-specific fixed effects $f_{j,1} = f_{j,t\in\{\text{Pre-ZLB}\}}$ and $f_{j,2} = f_{j,t\in\{\text{ZLB}\}}$. Since the variance-covariance matrix of the errors Q_t is generally not diagonal, we need to decompose the residuals so that they become orthogonal. We adopt the ordering of the recursive benchmark and impose a Cholesky decomposition that allocates any correlation between the residuals to the variable that comes first in the preset ordering. We again focus the analysis of our results on the shock to interest rate expectations, the first variable in the Cholesky system.

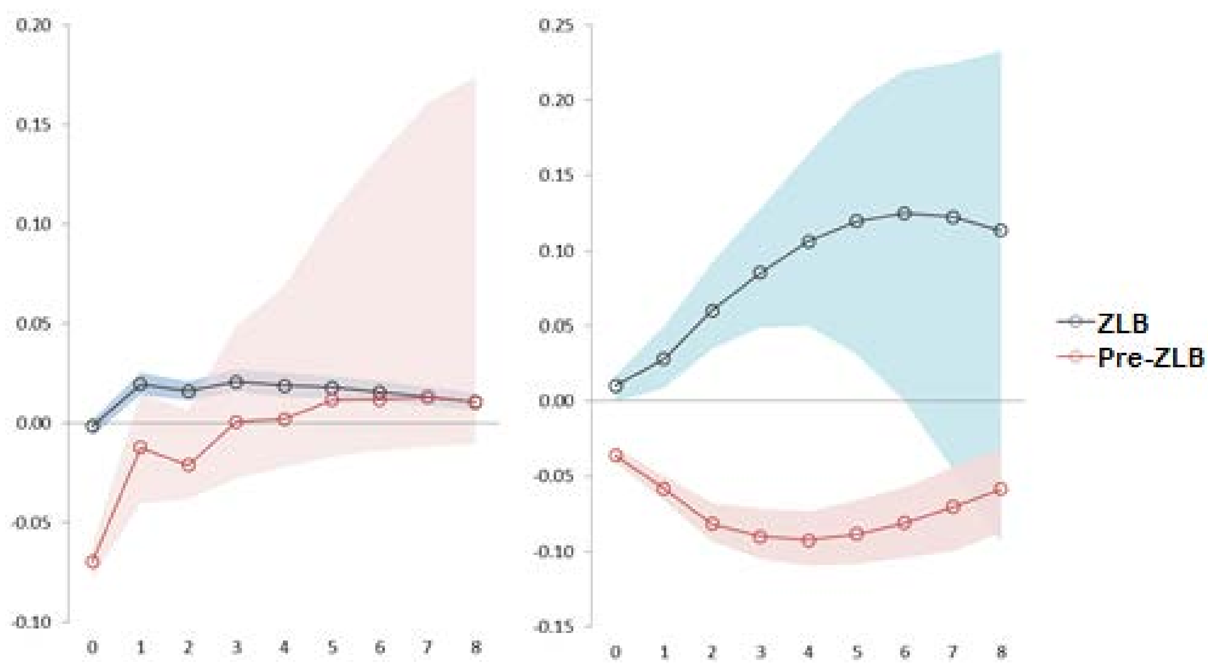
The impulse response functions recovered from the model estimated using this panel VAR methodology with the same split sample and quarterly SPF data not only confirm the

[23] Controlling for individual fixed effects with the Helmert transformation or forward mean differencing removes the mean of all future observations for each individual forecasters-time pair. Gives larger weight to observations closer to the beginning of the series (and assumes observations have equal variances). It is computed as follows: $z_{jt}^{H} = \sqrt{\frac{T-t}{T-t+1}}\left(z_{jt} - \frac{1}{T-t}\sum_{z=t+1}^{T} z_{jz}\right)$.

original point estimates, but provide additional confidence surrounding those estimates. As seen in Figure 11, the same one standard deviation positive shock to interest rate expectations leads to a small dip in inflation both at and away from the ZLB, as well as to the reversal dynamics in unemployment. Away from the ZLB, the shock to expectations leads to a maximum fall in unemployment of around 0.10%, while at the ZLB the same shock leads to a maximum rise in unemployment of around 0.13%. Thus, the notable difference between these estimates and those of the recursive benchmark model is that the confidence bands surrounding these point estimates are somewhat tighter than those obtained with the SPF median forecast. This extension of the recursive model verifies that not only were the original results found in the ZLB sub-sample robust to expanding the dataset laterally to include the entire panel of forecasts, but that we can be more confident in the statistical significance of the direction and magnitude of the unemployment response reversal than if we had not considered the full cross-section of the panel of forecasters.

Figure 11. Impulse Response Functions for the Expectations' Shock: Panel VAR Model with Cholesky Identification

Core Inflation (Left) | Unemployment (Right)



Note: Impulse response functions over eight quarters based on the panel VAR model using median SPF forecasts and Cholesky identification. The pre-ZLB period corresponds to 1990:Q1 – 2008:Q3 while the ZLB refers to 2008:Q4 – 2015:Q2.

4.2.5 Time-Varying Parameter VAR (TVP-VAR) Model

Finally, to further explore whether the reversal found in the data is simply due to the specific break point we chose, we next implement a Time-Varying Parameter VAR (TVP-VAR), allowing the parameters to change every quarter of the sample, to "let the data speak" as whether we truly have a break point as monetary policy encounters the ZLB—or if a clear reversal truly even exists without forcing a split sample. Maintaining all else consistent with the recursive benchmark—data source, lag selection, frequency, and Cholesky ordering—this framework also allows us to incorporate the role of stochastic volatility into the model. This may be of importance, due to the effects of a binding ZLB on interest rates, which effectively truncate possible innovations to the federal funds rate, as well as downward movements in interest rate expectations themselves.

The following model and estimation approach closely follows Primiceri (2005)'s multivariate time series framework with varying coefficients that captures nonlinearities and time-variation in the parameters, while also accounting for possible heteroscedasticity of the disturbances.[24] We estimate the pth-order TVP-VAR model with stochastic volatility as:

$$\begin{aligned} Y_t &= X_t^T \beta_t + A_t^{-1}\Sigma_t \varepsilon_t, \\ X_t^T &= I_{n\times n} \otimes \left[1, y_{t-1}^T, \ldots, y_{t-p}^T\right], \ \forall t = p+1, \ldots, \overline{T}, \end{aligned} \tag{28}$$

where Y_t is an $n\times 1$ column-vector of n different endogenous variables, X_t is a Kronecker product of the $n\times n$ identity matrix, β_t is an $n(np+1)\times 1$ column-vector of the effects of the p lags of the endogenous variables plus a constant intercept, and $\overline{T}$ is the sample size. The error term ε_t is a column-vector of size $n\times 1$, the matrix of standard deviations Σ_t is diagonal and time-varying:

$$\Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{n,t} \end{bmatrix}, \tag{29}$$

[24] See Primiceri (2005) for a more in-depth analysis of the model specification, assumptions, and estimation technique, as well as Nakajima (2011) for a more extensive discussion of the role of stochastic volatility.

and the matrix A_t that captures the contemporaneous relationships is lower triangular and also time-varying:

$$A_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ \alpha_{2,1,t} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ \alpha_{n,1,t} & \cdots & \alpha_{n,n-1,t} & 1 \end{bmatrix}. \tag{30}$$

The reduced form to be estimated takes the form described in (28)-(30) above where all the time-varying coefficients follow random walks without drift and all the time-varying standard deviations follow geometric random walks without drift:

$$\begin{aligned} &\beta_{j,t} = \beta_{j,t-1} + u_t^j,\ j = 1,\ldots,n(np+1), \\ &\alpha_{j,t} = \alpha_{j,t-1} + v_t^j,\ j = 1,\ldots,\frac{(n^2-n)}{2}, \\ &\ln(\sigma_{j,t}) = \ln(\sigma_{j,t-1}) + w_t^j,\ j = 1,\ldots,n. \end{aligned} \tag{31}$$

The vector of innovations is assumed to be jointly normally distributed as follows:

$$\begin{bmatrix} \varepsilon_t \\ u_t \\ v_t \\ w_t \end{bmatrix} \sim N\left(0, \begin{bmatrix} I_{n\times n} & 0 & 0 & 0 \\ 0 & U_{n(np+1)\times n(np+1)} & 0 & 0 \\ 0 & 0 & V_{\frac{(n^2-n)}{2}\times\frac{(n^2-n)}{2}} & 0 \\ 0 & 0 & 0 & W_{n\times n} \end{bmatrix}\right), \tag{32}$$

where ε_t is the matrix of errors terms and $u_t = (\ldots, u_t^j, \ldots)'$, $v_t = (\ldots, v_t^j, \ldots)'$, and $w_t = (\ldots, w_t^j, \ldots)'$ consist of the innovations introduced in (31) and (32) above. The conforming matrices U, V, and W are positive definite. Moreover, V is assumed to be block diagonal implying that innovations to contemporaneous effects are uncorrelated across equations.

Consistent with the Bayesian approach, a Gibbs sampler is used to evaluate the posterior distribution of the unobservable states $\beta_{j,t}$, $\alpha_{j,t}$, and $\ln(\sigma_{j,t})$ together with the hyperparameters U, V, and W. In order to evaluate the posterior, we first specify the prior distributions of the parameters. The hyperparameters U, V, and W follow the independent inverse Wishart distribution while the priors for the initial states of the coefficients $\alpha_{i,t}$, $\beta_{j,t}$, and $\ln\left(\sigma_{j,t}\right)$ are normally distributed. The hyperparameters and initial states are assumed to be independent. The priors are chosen to be largely consistent with those of Primiceri (2005), and a bit tighter than those used by Nakajima (2011), attributing more of the time variation to the volatility of the disturbances ($\ln\left(\sigma_{j,t}\right)$) rather than to the coefficients ($\beta_{j,t}$) themselves. Primiceri (2005)'s tighter priors are meant to negate the possibility of erroneously attributing additional time variation to the parameters when they are truly closer to time invariant. We use a subset of the data set estimated through OLS to form estimations used in the specification of the prior distributions—specifically, the first 40 quarters of the time series are used for this purpose. The Gibbs sampler provides us with draws from the conditional posteriors over subsets of the parameter set and the data. From those, the sampler iteratively produces a numerical evaluation of the posterior.[25]

To recover the impulse response functions after the initial model estimation, we identify the key shock of interest, shocks to monetary policy expectations, by using zero restrictions on the contemporaneous reactions of the expectations variable to other variables in the system. These zero restrictions are essentially used to identify the model in a consistent fashion as in the recursive benchmark, ultimately implementing a Cholesky ordering scheme. The model estimation and additional procedures were performed in Matlab using two lags of the endogenous variables ($p = 2$).[26] A sample of 10,000 iterations of the Gibbs sampler is used, discarding the first 2,000 for convergence.

Allowing for stochastic volatility and constantly shifting parameters turns out to not only provide corroborating evidence for the predicted reversal in the unemployment response, it also sheds additional light on the dynamics at play as the economy transitioned into the ZLB. Figure 12 plots the on-impact response of the unemployment rate to a one standard deviation positive shock in interest rate expectations estimated at each quarter in the TVP-VAR, as well as the cumulative response of unemployment over the entire 8-quarter (2 year) forecast horizon

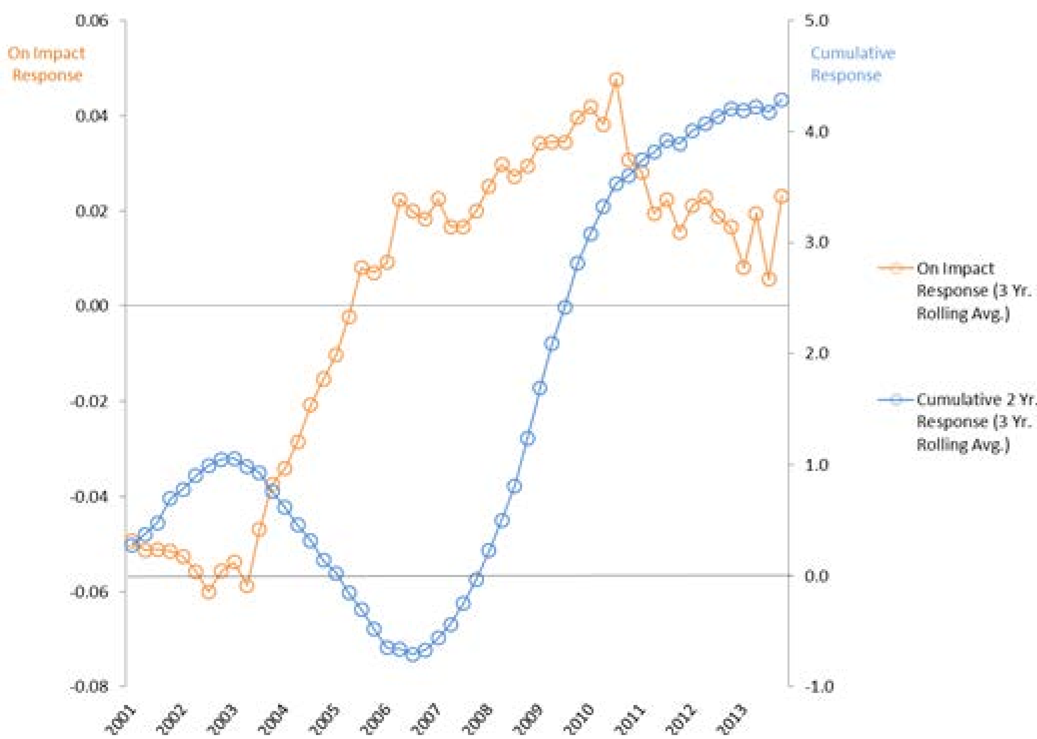
[25] See Blake and Mumtaz (2017) for a detailed explanation of the implementation and Bayesian estimation of TVP-VARs with stochastic volatility.

[26] The model uses code for a TVP-VAR with stochastic volatility and sign restrictions, made publicly available by Haroon Mumtaz at: https://sites.google.com/site/hmumtaz77/.

of the impulse response function, again estimated at each quarter in the VAR. The plot starts at a later date than the beginning of our chosen sample (the early 2000's rather than 1990) due to the use of the first segment of the time series to initialize the parameters.

First focusing on the on-impact response, one can clearly see the reversal. Interestingly, while the on-impact response switches from negative to positive around 2007, the upward trend begins much sooner. We believe this is due to the historical downward trend that has characterized interest rates in the U.S. Looking at Figure 1, for instance, interest rates had a "nearly" ZLB episode around 2003, the same year in which the data begins to show signs of trending toward the estimated sign reversal. Thus, the dynamics of the switch may not be due to factors associated purely with the 2007-09 Global Financial Crisis and the subsequent recovery, but indeed due to the unique dynamics of a binding ZLB.

Figure 12. Unemployment Impulse Response Functions for the Expectations' Shock: TVP-VAR with Cholesky Identification



Note: On-impact and cumulative unemployment impulse response functions based on the panel VAR model using median SPF forecasts and Cholesky identification. The estimates plotted cover the period 2001:Q1 – 2015:Q2.

Second, the plot of the cumulative response in Figure 12 is also striking due to the relatively extreme reaction we find at the ZLB. While, unlike the on-impact response, the cumulative response turns positive only in 2008, allowing it to vary each quarter illuminates the fact that the reversal effect has become much stronger in recent years. Rather than blending this with the weaker reaction at the onset of the ZLB in 2008, we can extract the most recent impulse response function, that of 2015:Q2, and extrapolate that one standard deviation positive increase in interest rate expectations at that point would have led to a cumulative increase in the unemployment rate of 4.2 percentage points, a highly significant effect, especially when viewed in light of the often-heard claim that the central bank has little power to stimulate real economic activity when the rates fall to the ZLB.

5. Concluding Remarks

The intriguing shift in the dynamic responses to shocks to expectations about future monetary policy is indicative of how the transmission mechanism of forward guidance changes when interest rates edge toward the ZLB. Our empirical investigation of the transmission mechanism of monetary policy and expectations using multiple VAR models that build on the approach of Leduc and Sill (2013) to assess expectations-driven business cycles. We find that future short-term interest rate expectations are a highly significant driver of variability in economic activity and inflation. In this paper we propose a theoretical model that provides an intuitive rationale for these results. As the policy rates become stuck at the ZLB, the behavior of the monetary transmission mechanism itself changes—shocks to expectations themselves, rather than the policy tool, are what influence economic activity (and inflation), as the monetary authority can no longer respond through the short-term interest rate channel to the current effects that arise from anticipating news shocks about future policy (innovations to anticipated monetary policy). Consistent with this, we find strong evidence that downward revisions to expected future monetary policy one-year ahead can have large and opposing effects on economic activity when policy rates approach zero in theory as well as empirically.

However, even at the ZLB, the central bank can still use forward guidance to provide additional stimulus. Although shocks to monetary policy expectations are shown to have effects on economic activity during “normal policy” times away from the ZLB, due to the lack of policy space for the central bank to accommodate the anticipatory effects of interest rate news at the ZLB, the importance, sign and dynamic effects of these news shocks changes significantly. Hence, while policy expectations remain crucial for stimulating the economy, deploying forward guidance at the ZLB based on our understanding of the propagation of interest rate news shocks from empirical evidence gathered solely when policy was away from the ZLB can lead to significant policy errors. Managing policy expectations provides a significant opportunity for guiding an economy when conventional monetary policy is no longer a realistic option at the ZLB, but policymakers must be aware that forward guidance operates differently when policy rates are constrained in order to make the best of it and avoid unintended policy errors.

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Appendix

A. Data Sources

Table A1. Data (all models excluding FAVAR)

Notation	Variable	Notes	Source(s)
$E_t^j\left(i_{t+4}\right)$	Interest rate expectations	Expected yield on the 3-month Treasury Bill rate, 4 quarters ahead (annualized rates, %), for a varying sample of j forecasters each quarter	• Survey of Professional Forecasters: "tbill6" (FRB.P)
$E_t\left(i_{t+4}\right)$	Interest rate expectations	Panel-level median expected yield on the 3-month Treasury Bill, 4 quarters ahead (annualized rates, %)	• Survey of Professional Forecasters: "tbill6" (FRB.P) • Blue Chip Economic Indicators: "tbill6bc" • Livingston Survey: "tbill6livingston" (FRB.P)
$E_t\left(FFR_{t+4}\right)$	Interest rate expectations	Panel-level median expected federal funds rate, 4 quarters ahead (annualized, %)	• Wall St. Journal Survey: "ffr12"
π_t	Inflation	Core inflation rate (CPI), quarter-over-quarter (annualized rate, %), seasonally-adjusted	• FRB.SL: "cpilfesl_pch"
UR_t	Unemployment	Seasonally-adjusted civilian unemployment rate (%)	• FRB.S: "unrate"
FFR_t	Federal Funds Rate	Effective overnight Federal Funds Rate (annualized rate, %)	• FRB.SL: "fedfunds"
SR_t	Shadow Rate	Wu and Xia (2016) Shadow Rate (annualized rate, %)	• FRB.A: "shadowrate"
NBR_t	Non-borrowed Reserves	Growth rate of non-borrowed reserves of depository institutions, quarter-over-quarter (%)	• FRB.SL: "nonborres"
$Slope_t$	Yield Curve Slope	(Yield on 10-Year Treasury – yield on 3-Month Treasury)	• FRB.SL: "t10yffm"

Note: All data calculated by the authors are available upon request. This data or a subset is included in the vector of observable variables used in the estimation. The acronym SPF stands for the Survey of Professional Forecasters (Federal Reserve Bank of Philadelphia (2015a)); FRB.P stands for Federal Reserve Bank of Philadelphia who apart from the SPF also produces the Livingston Survey (Federal Reserve Bank of Philadelphia (2015b)); and FRB.A stands for Federal Reserve Bank of Atlanta (Federal Reserve Bank of Atlanta (2015)). FRB.SL stands for Federal Reserve Economic Database (FRED) of the Federal Reserve Bank of St. Louis (2015); Blue Chip Economic Indicators (BCEI) is a monthly survey from Aspen (2015); and Wall Street Journal refers to the forecast data from Wall Street Journal (2015).

Table A2. Data (FAVAR model)

Notation	Variable	Notes	Source(s)
$E_t\left(i_{t+4}\right)$	Interest rate expectations	Panel-level median expected yield on the 3-month Treasury Bill, 4 quarters ahead (annualized rates, %)	• Survey of Professional Forecasters: "tbill6" (FRB.P)
FFR_t	Federal funds rate	Effective overnight federal funds rate, Annualized Rate	FRB.SL
UR_t	Unemployment	Civilian Unemployment Rate, Percent, Quarterly, Seasonally Adjusted	FRB.SL
$\pi_t^{Core\_CPI}$	Core CPI	Consumer Price Index for All Urban Consumers: All Items Less Food and Energy, Index 1982-1984=100, Quarterly, Seasonally Adjusted	FRB.SL
π_t^{CPI}	CPI	Consumer Price Index for All Urban Consumers: All Items, Index 1982-1984=100, Quarterly, Seasonally Adjusted	FRB.SL
$\pi_t^{Food\_PPI}$	Food PPI	Producer Price Index by Commodity for Processed Foods and Feeds, Index 1982=100, Quarterly, Not Seasonally Adjusted	FRB.SL
$\pi_t^{Core\_PPI}$	Core PPI	Producer Price Index by Commodity for Final Demand: Finished Goods Less Foods and Energy, Index 1982=100, Quarterly, Seasonally Adjusted	FRB.SL
π_t^{PPI}	PPI	Producer Price Index for All Commodities, Index 1982=100, Quarterly, Seasonally Adjusted	FRB.SL
$\pi_t^{GDP\_Defl}$	GDP Deflator	Gross Domestic Product: Implicit Price Deflator, Index 2009=100, Quarterly, Seasonally Adjusted	FRB.SL
ω_t	Wages	Gross domestic income: Compensation of employees, paid: Wages and salaries, Billions of Dollars, Quarterly, Seasonally Adjusted Annual Rate	FRB.SL
GDP_t	GDP	Real Gross Domestic Product, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate	FRB.SL
φ_t	Productivity	Business Sector: Real Output Per Hour of All Persons, Index 2009=100, Quarterly, Seasonally Adjusted	FRB.SL
λ_t	Capacity Utilization	Capacity Utilization: Total index, Percent of Capacity, Quarterly, Seasonally Adjusted	FRB.SL
M_t	Capacity Utilization: Manufacturing	Capacity Utilization: Manufacturing (NAICS), Percent of Capacity, Quarterly, Seasonally Adjusted	FRB.SL
E_t	Capacity Utilization: Electricity & Gas	Capacity Utilization: Electric and gas utilities, Percent of Capacity, Quarterly, Seasonally Adjusted	FRB.SL
C_t	Consumption	Real Personal Consumption Expenditures, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate	FRB.SL
G_t	Government Expenditures	Federal government current expenditures, Billions of Dollars, Quarterly, Seasonally Adjusted	FRB.SL

EX_t	Exports	Real Exports of Goods and Services, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate	FRB.SL
IM_t	Imports	Real imports of goods and services, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate	FRB.SL
ς_t	Inventories	Total Business Inventories, Millions of Dollars, End of Period, Quarterly, Seasonally Adjusted	FRB.SL
χ_t	Construction	Total Construction Expenditures, Index 2007:Q4=100, Quarterly, Seasonally Adjusted Annual Rate	FRB.SL
$\perp_t$	Transportation	Total Transportation Services Index, Chain-type Index 2000=100, Quarterly, Seasonally Adjusted	FRB.SL
$TRN_t^{freight}$	Freight Transportation	Freight Transportation Services Index, Chain-type Index 2000=100, Quarterly, Seasonally Adjusted	FRB.SL
η_t	Industrial Production: Food, Beverage & Tobacco	Industrial Production: Nondurable manufacturing: Food, beverage, and tobacco, Index 2012=100, Quarterly, Seasonally Adjusted	FRB.SL
ρ_t	Industrial Production: Petroleum & Coal	Industrial Production: Nondurable manufacturing: Petroleum and coal products, Index 2012=100, Quarterly, Seasonally Adjusted	FRB.SL
ξ_t	Industrial Production: Chemicals	Industrial Production: Nondurable manufacturing: Chemical, Index 2012=100, Quarterly, Seasonally Adjusted	FRB.SL
M_t^1	M1	M1 Money Stock, Billions of Dollars, Quarterly, Seasonally Adjusted	FRB.SL
M_t^2	M2	M2 Money Stock, Billions of Dollars, Quarterly, Seasonally Adjusted	FRB.SL
M_t^{Base}	Monetary Base	St. Louis Adjusted Monetary Base, Billions of Dollars, Quarterly, Seasonally Adjusted	FRB.SL
$\mathrm{M}_t^{Currency}$	Currency	Currency Component of M1, Billions of Dollars, Quarterly, Seasonally Adjusted	FRB.SL
κ_t	Reserves	Total Reserve Balances Maintained with Federal Reserve Banks, Billions of Dollars, Quarterly, Seasonally Adjusted	FRB.SL
Γ_t	Lending	Loans and Leases in Bank Credit, All Commercial Banks, Billions of U.S. Dollars, Quarterly, Seasonally Adjusted	FRB.SL
$\Gamma_t^{HH\_NP}$	Household & Nonprofit Lending	Households and Nonprofit Organizations; Credit Market Instruments; Liability, Level, Billions of Dollars, Quarterly, Seasonally Adjusted	FRB.SL
Γ_t^{CC}	Credit Card Lending	Consumer Loans: Credit Cards and Other Revolving Plans, All Commercial Banks, Billions of U.S. Dollars, Quarterly, Seasonally Adjusted	FRB.SL
$House_t$	House Prices	All-Transactions House Price Index for the United States, Index 1980:Q1=100, Quarterly, Seasonally Adjusted	Mack and Martínez-García (2011)
$\mathrm{P}_t^{Shiller}$	P/E Ratio	Cyclically-adjusted price to earnings ratio for the S&P 500 index	Shiller (2016)

$\Psi_t^{Shiller}$	Dividend Yield	Ratio of dividends over stock price for the S&P 500 index	Shiller (2016)
Ω_t	Market Capitalization	Russell 2000 Price Index, Seasonally Adjusted	FRB.SL
γ_t	VIX Equity Volatility	CBOE Volatility Index, Seasonally Adjusted	FRB.SL
e_t^{Broad}	Nominal Exchange Rate: Broad	Trade-Weighted U.S. Dollar Index against broad group of U.S. trading partners, Seasonally Adjusted	Grossman *et al.* (2014)
e_t^{Major}	Nominal Exchange Rate: Major Partners	Trade-Weighted U.S. Dollar Index against group of U.S. major trading partners, Seasonally Adjusted	FRB.SL

Note: All data calculated by the authors are available upon request. This data is used to estimate the FAVAR model. The acronym SPF stands for the Survey of Professional Forecasters (Federal Reserve Bank of Philadelphia (2015a)); FRB.P stands for Federal Reserve Bank of Philadelphia; and FRB.SL stands for Federal Reserve Economic Database (FRED) of the Federal Reserve Bank of St. Louis (2015). All data was transformed to be stationary where necessary.

B. Analytical Solution to the New Keynesian Model with Anticipated and Unanticipated Monetary Policy Innovations

The workhorse New Keynesian model discussed in the paper can be summarized as follows:

$$\begin{array}{ccc} \text{Dynamic IS} & : & y_t = E_t\left[y_{t+1}\right] - \sigma\left(i_{1,t} - E_t\left[\pi_{t+1}\right]\right), \\ \text{Phillips Curve} & : & \pi_t = \beta E_t\left[\pi_{t+1}\right] + \kappa y_t, \\ \text{Monetary Policy Rule} & : & i_{1,t} = \psi_\pi \pi_t + \psi_x y_t + \varepsilon_t, \\ \text{Monetary Policy Shock} & : & \varepsilon_t = \varepsilon_t^m + \varepsilon_{t,t-1}^{news}. \end{array} \tag{S1}$$

Substituting the monetary policy rule into the dynamics IS equation leads to the following two-dimensional expectational difference system:

$$\begin{array}{c} E_t\left[y_{t+1}\right] + \sigma E_t\left[\pi_{t+1}\right] = \left(1+\sigma\psi_x\right) y_t + \sigma\psi_\pi \pi_t + \sigma\varepsilon_t, \\ \beta E_t\left[\pi_{t+1}\right] = \pi_t - \kappa y_t. \end{array} \tag{S2}$$

We can cast the equilibrium conditions by means of the following system of expectational difference equations:

$$\begin{bmatrix} y_t \\ \pi_t \end{bmatrix} = A \begin{bmatrix} E_t\left[y_{t+1}\right] \\ E_t\left[\pi_{t+1}\right] \end{bmatrix} - B\varepsilon_t, \tag{S3}$$

where the conforming matrices A and B are:

$$A = \frac{1}{1+\sigma\left(\psi_x + \kappa\psi_\pi\right)} \begin{pmatrix} 1 & \sigma\left(1-\beta\psi_\pi\right) \\ \kappa & \sigma\kappa + \left(1-\sigma\psi_x\right)\beta \end{pmatrix}; \quad B = \frac{1}{1+\sigma\left(\psi_x + \kappa\psi_\pi\right)} \begin{pmatrix} \sigma \\ \sigma\kappa \end{pmatrix}. \tag{S4}$$

Given that both output and inflation are non-predetermined variables, the solution to this expectational difference system is locally unique if and only if A has both eigenvalues within the unit circle (see Blanchard and Kahn (1980)). The eigenvalues are identical to the ones in the model without anticipated (news) shocks, so the stability properties of the model are not affected by the addition of news to the specification of the monetary policy shock. Therefore, it can be shown that a necessary and sufficient condition for determinacy (uniqueness) with or without news shocks is that:

$$\kappa\left(\psi_\pi - 1\right) + \left(1-\beta\right)\psi_x > 0, \tag{S5}$$

so long as the policy parameters $\left(\psi_\pi, \psi_x\right)$ are non-negative.

We assume that the condition that ensures determinacy given in (S5) is satisfied and conjecture that the solution takes the following form:

$$\begin{aligned} y_t &= \phi_{y,1}\varepsilon_t + \phi_{y,2}E_t\varepsilon_{t+1} = \phi_{y,1}\varepsilon_t + \phi_{y,2}\varepsilon_{t+1,t}^{news}, \\ \pi_t &= \phi_{\pi,1}\varepsilon_t + \phi_{\pi,2}E_t\varepsilon_{t+1} = \phi_{\pi,1}\varepsilon_t + \phi_{\pi,2}\varepsilon_{t+1,t}^{news}, \end{aligned} \tag{S6}$$

where $\left(\phi_{y,1}, \phi_{y,2}\right)$ and $\left(\phi_{\pi,1}, \phi_{\pi,2}\right)$ are coefficients to be determined. This solution indicates that current output and inflation depend not just on the current monetary policy shock ε_t but also on the anticipated component of tomorrow's monetary policy shock. Imposing the guessed solution on the two-dimensional expectational difference system, we find that:

$$\begin{aligned} &\phi_{y,1} = -\tfrac{\sigma}{1+\sigma\psi_x+\sigma\psi_\pi\kappa} < 0; \quad \phi_{y,2} = -\tfrac{\sigma}{\left(1+\sigma\psi_x+\sigma\psi_\pi\kappa\right)^2}\left(1+\sigma\kappa\left(1-\psi_\pi\beta\right)\right) \begin{cases} < 0 \text{ if } \psi_\pi < \left(1+\frac{1}{\sigma\kappa}\right)\beta^{-1} \\ > 0 \text{ otherwise} \end{cases}; \\ &\phi_{\pi,1} = -\tfrac{\sigma\kappa}{1+\sigma\psi_x+\sigma\psi_\pi\kappa} < 0; \qquad \phi_{\pi,2} = -\tfrac{\sigma\kappa}{\left(1+\sigma\psi_x+\sigma\psi_\pi\kappa\right)^2}\left(1+\beta\left(1+\sigma\psi_x\right)+\sigma\kappa\right) < 0. \end{aligned} \tag{S7}$$

The short-term nominal interest rate (which is the policy instrument) is then equal to:

$$i_{1,t} = \psi_\pi\pi_t + \psi_x y_t + \varepsilon_t = \phi_{i,1}\varepsilon_t + \phi_{i,2}\varepsilon_{t+1,t}^{news}, \tag{S8}$$

where

$$\phi_{i,1} = \left(\tfrac{1}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right) > 0; \quad \phi_{i,2} = -\sigma\left(\tfrac{\psi_\pi\kappa\left(1+\beta+\sigma\kappa\right)+\psi_x\left(1+\kappa\sigma\right)}{\left(1+\sigma\psi_x+\sigma\psi_\pi\kappa\right)^2}\right) < 0. \tag{S9}$$

Hence, output, inflation and the short-term interest rates are linked to the anticipated and unanticipated components of the monetary policy shock. However, anticipated monetary policy shock innovations behave differently than unanticipated shock innovations.

Next period expectations of output, inflation and the short-term nominal interest rate are naturally related to the anticipated component to next period's monetary policy shock as follows:

$$E_t\left(y_{t+1}\right)=\phi_{y,1}\varepsilon_{t+1,t}^{news};\ E_t\left(\pi_{t+1}\right)=\phi_{\pi,1}\varepsilon_{t+1,t}^{news};\ E_t\left(i_{1,t+1}\right)=\phi_{i,1}\varepsilon_{t+1,t}^{news}. \tag{S10}$$

Hence, the short-term real rate for the economy can be inferred as:

$$r_{1,t}\equiv i_{1,t}-E_t\left[\pi_{t+1}\right]=\phi_{r,1}\varepsilon_t+\phi_{r,2}\varepsilon_{t+1,t}^{news}, \tag{S11}$$

Where

$$\phi_{r,1}=\left(\frac{1}{1+\sigma\psi_x+\sigma\psi_\pi\kappa}\right)>0;\quad \phi_{r,2}=-\sigma\left(\frac{\kappa\left(\psi_\pi\left(1+\beta\right)-1\right)+\psi_x}{\left(1+\sigma\psi_x+\sigma\psi_\pi\kappa\right)^2}\right)<0. \tag{S12}$$

Notice that the sign of the coefficient $\phi_{r,2}$ requires that we invoke the determinacy condition in (S5) to show that:

$$\begin{aligned}\kappa\left(\psi_\pi\left(1+\beta\right)-1\right)+\psi_x &= \kappa\left(\psi_\pi-1\right)+\psi_\pi\kappa\beta+\psi_x\\ &>-\left(1-\beta\right)\psi_x+\psi_\pi\kappa\beta+\psi_x\\ &=\beta\left(\psi_x+\psi_\pi\kappa\right)>0.\end{aligned} \tag{S12}$$

Accordingly, under determinacy the sign of the response to today's news about tomorrow's monetary policy is unequivocal.