What Does Anticipated Monetary Policy Do?

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Abstract

Forward rate guidance, which has been used with increasing regularity by monetary policymakers, relies on the manipulation of expectations of future short-term interest rates. We identify shocks to these expectations at short and long horizons since the early 1980s and examine their effects on contemporaneous macroeconomic outcomes. Our identification uses sign restrictions on survey forecasts incorporated in a structural VAR model to isolate expected deviations from the monetary-policy rule. We find that expectations of future policy easing that materialize over the subsequent four quarters—similar to those generated by credible forward guidance—have immediate and persistent stimulative effects on output, inflation, and employment. The effects are larger than those produced by an identical shift in the policy path that is not anticipated. Our results are broadly consistent with the mechanism underlying forward guidance in New Keynesian models, but they suggest that those models overstate the persistence of the inflation response. Further, we find that changes in short-rate expectations farther in the future have weaker macroeconomic effects, the opposite of what most New Keynesian models predict.

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1 Introduction

Since short-term nominal interest rates in the United States and abroad reached their effective lower bound, monetary policy has increasingly utilized forward rate guidance as a means to stimulate the economy. For example, from 2011 onward, the FOMC provided calendar dates through which it expected the policy to be maintained, economic thresholds that it believed would warrant maintaining the same policy, and statements signaling potential upcoming deviations from the conventional policy rule. While the active use of explicit communication about the future path of the policy rate is novel for most central banks, its potency relies on a mechanism that, in principle, should always be present—namely, agents' current behavior should depend on their expectations about the future state of the economy, which in turn depend on the expected configuration of future interest rates. This paper attempts to measure the effects of changes in short-rate expectations on the macroeconomy and thereby assess the potential quantitative impact of forward-guidance policies.

The idea that expectations of future monetary policy can affect today's economy is not new, and authors beginning with Krugman (1999) and Eggertsson and Woodford (2003) have argued that central banks can stimulate the economy by committing to maintain a high level of policy accommodation in the future. While this theory has been most explored in the context of New Keynesian models (also see, e.g., Laseen and Svensson, 2011, and Werning, 2011), the central mechanism is common to a broad class of models in which agents are forward looking and monetary policy is not neutral. Yet the quantitative importance of this monetary-policy-expectations channel remains an open question. Even within the context of New Keynesian models, alternative variations, such as those explored in Levin et al. (2010), McKay et al. (2014), and Werning (2015), can cause the impact of forward guidance to differ substantially, and standard versions of such models deliver macroeconomic effects that are generally viewed as implausibly large (Carlstrom et al., 2012; Del Negro et al., 2013).

But what *is* a plausible effect of monetary-policy expectations? To date, the most direct, model-free estimates come from Campbell et al. (2012), who used data from surveys and interest-rate futures to examine how expectations about the economy change when expectations about short-term rates change. But those authors found the opposite of what theory predicts: when the Federal Reserve signals that lower rates are coming, survey expectations of GDP and inflation decline. As they argued, this result likely reflects agents interpreting accommodative signals by the Fed as conveying negative information about the prospects for the economy ("Delphic" forward guidance), rather than as commitments to future stimulative deviations from the historical policy rule ("Odyssean" forward guidance). This same underlying phenomenon extends beyond cases of explicit guidance by the Fed—*any* shock that lowers short-rate expectations is good news if it reflects exogenously looser future policy but bad news if it reflects an anticipated endogenous policy response to a weaker economy. The presence of these two types of short-rate expectations shocks with potentially opposite impacts also creates an identification problem for other studies, such as Gurkaynak et al. (2005) and Gertler and Karadi (2014), that examine how economic and financial variables respond to shifts in monetary-policy expectations without making the distinction.

The absence of clear evidence on the macroeconomic effects of monetary-policy expectations leaves researchers with no benchmark for calibrating and assessing their models of forward guidance, and it leaves policymakers with little to go on when considering what type of forward guidance to articulate. We fill this gap by developing new measures of shocks to short-rate expectations and examining their dynamic effects on macroeconomic variables. As in Campbell et al. (2012), we use survey forecasts to capture the anticipated path of short-term rates and the economy in a model-free way.[1] However, as just discussed, the surveys are not by themselves sufficient to distinguish whether the expectations shocks are good news or bad news for the economy. We therefore embed them in a structural VAR model that separates the sources of forecast fluctuations. In particular, we use sign restrictions to ensure that we have isolated shocks to anticipated future monetary policy: the expected short rate must move in the *opposite* direction of expected inflation and expected GDP. In nearly all theoretical models, this directional pattern of changes in macro variables is unique to monetary policy shocks. For example, changes in short-rate expectations that arise from the anticipated endogenous response of policymakers to economic shocks (such as those associated with Delphic forward guidance) cause expected short rates to move in the *same* direction as expected inflation or expected GDP, so our identification scheme strips out these systematic policy responses.[2]

We find that when survey respondents anticipate a monetary policy easing over the subsequent year (controlling for past macro data and the current policy stance), this leads to an immediate and persistent increase in both prices

[1] Indeed, if theories of forward guidance are correct, there is little hope of measuring its effect *without* direct measures of expectations, since, when economic agents' anticipations matter and are not included in the econometrician's information set, structural policy shocks cannot generally be recovered by econometricians (Leeper et al., 2013; Milani and Treadwell, 2012).

[2] The title of our paper is a homage to Leeper et al. (1996), which was among the first studies to use a VAR to grapple with an analagous identification problem—how to separate the response of monetary policy to the economy from the response of the economy to monetary policy.

and output. For example, a decrease of 25 basis points in expectations for the average short-term rate over the next year, holding all else constant, results in a short-run increase in both GDP and the price level of about 1 percent. These effects occur much faster than those of a conventional monetary-policy shock, which we identify in the same VAR. After about two years, a given shock to policy expectations has about the same effect on output as a conventional policy shock of the same size and an effect on inflation that is 2 to 3 times as large. Shocks to expectations beyond the one-year horizon still have effects in the same direction, but they are smaller, less persistent, and not always statistically significant.

Forward rate guidance can be viewed as a combination of an immediate shock to the expected short rate and subsequent shocks to the actual short rate. This is because, after a future deviation from the policy rule is successfully communicated to agents, the central bank must introduce a series of innovations to the short rate in order to keep it at its promised level. We therefore use our results to build a policy experiment that simulates credible, Odyssean forward guidance. In particular, we analyze how the economy responds when there is a shock to the expected path of the policy rate, followed by a series of conventional policy shocks that make the initial change in short-rate expectations materialize as anticipated. Our results suggest that such a pre-announced reduction in the policy-rate path over the one-year horizon results in a significantly larger and more-rapid stimulus than the same reduction in the path does when it is not anticipated. Again, this difference is much smaller when applied to longer-horizon expectations.

These results on the effectiveness of anticipated monetary-policy changes qualitatively support the basic mechanism underlying forward guidance in New Keynesian models—expectations for unusually accommodative policy in the future boost the macroeconomy today. In the next section, using a simple New Keynesian model under a standard calibration we show that an anticipated 25-basis-point cut in the short rate over the coming year raises today's output gap and annual inflation rate by about 1.5 and 3.5 percentage points, respectively. These magnitudes are in the ballpark of what our empirical results suggest. Importantly, however, our results are substantially at odds with New Keynesian predictions in other respects. First, we find that the effect of forward-guidance on inflation is short lived, essentially taking the form of a one-time jump in the price level. In contrast, most theoretical models obtain an inflation response that is persistent and often even growing larger over time; consequently, they predict a much larger cumulative effect on prices than we find in the data. Second, New Keynesian models typically predict that forward-rate guidance should have a larger effect on current outcomes when it pertains to horizons that are farther in the future (see, e.g., Carlstrom et al., 2012). Our results suggest the opposite: the effect of shocks to policy expectations is smaller when the expectations involve more-distant periods. In this sense, we quantify the forward-guidance puzzle discussed in Del Negro et al. (2013).[3]

Our use of direct measures of beliefs relates to several different branches of the literature. First, a number of recent papers show that augmenting VARs with survey forecasts of the nominal short rate, real GDP growth, and inflation leads to a significant improvement in the fit of the term structure and in forecasting yields out of sample (e.g., Chun, 2011, and Orphanides and Wei, 2012), as well as to a better understanding of the expectation component of interest rates (Kim and Orphanides, 2012; Piazessi et al., 2015). Second, a growing body of work studies the impact of "news" shocks on macroeconomic fluctuations by incorporating various forward-looking measures either into reduced-form analysis (Beaudry and Portier, 2006; Romer and Romer, 2010; Ramey, 2011; Barsky and Sims, 2012; Leduc and Sill, 2013; Barsky, Basu, and Lee, 2014) or into DSGE models (Milani and Rajbhandari, 2012; Miyamoto and Nguyen, 2014). These studies are mostly concerned with the analysis of anticipated changes to future fiscal policy or nonpolicy fundamentals such as total factor productivity. We focus on changes in expectations about future monetary policy, but we discuss in detail how these changes—and forward guidance in particular—can in some cases be interpreted as a type of news shock. As noted above, Campbell et al (2012), Gurkaynak et al. (2005), and Gertler and Karadi (2014) have also considered the effects of monetary-policy expectations, but those papers have not distinguished expectations for exogenous policy shocks from expectations for endogenous policy responses to economic conditions, nor have they considered differential effects of expectations about different horizons.

In Section 2 of the paper, we first describe a process of expectations formation that is general enough to accommodate various forms of deviations between subjective and statistical beliefs encountered in the literature, and we then motivate our identification strategy by embedding these expectational deviations in a simple New Keynesian model. In Section 3, we discuss the details of our survey-augmented VAR. Section 4 summarizes the baseline results and discusses in depth the causality of monetary-policy expectations shocks. In Section 5, we use these results to construct monetary policy experiments similar to forward rate guidance and analyze its impact. Section 6 conducts a battery of robustness checks, and Section 7 concludes the paper.

[3]On the other hand, our results could be consistent with modifications of the standard model, such as Milani and Treadwell (2012) and McKay et al. (2015), that give forward guidance its most powerful effects at relatively short horizons.

2 Modeling Shocks to Expectations

2.1 Subjective expectations: A general framework

Since, in our empirical work, we intend to identify shocks to monetary-policy expectations and examine the response of the economy to those shocks, we need to clarify what we mean by "shocks to expectations." In order to talk meaningfully about such shocks, it must be the case that expectations can contain some exogenous component that is not related to observed fundamentals. In other words, we have to allow for the possibility that subjective beliefs (in our case, measured by survey forecasts) might deviate from statistical beliefs derived only from historical data (e.g., Piazzesi et al., 2015).

The literature contains a variety of structures in which agents form expectations in a way that differs from the full-information, rational-expectations ("objective") statistical belief. One set of models relaxes the rationality assumption. For example, in Bullard, Evans, and Honkapohja (2008), agents' forecasting models include a "judgement" term that is tacked on the objective forecast. In Milani (2011), a similar term is motivated by agents' differing degrees of pessimism and optimism. Indeed, most notions of "market sentiment" or "animal spirits" can be modeled in this way. A second set of models maintains rationality, but allows agents' information sets to differ from those of the econometrician. Agents may use less information than statistical beliefs would imply, either because information is "sticky" (as in Mankiw and Reis, 2002), or because they face noisy information (as in Lucas, 1972; Woodford, 2002; and Sims, 2003). Recent work by Coibion and Gorodnichenko (2015) indeed shows that forecast revisions have a strong predictive power for ex-post mean forecast errors across different variables in various surveys, supporting this class of models with information rigidities. Alternatively, agents' information sets may be *larger* than those of the econometrician. In models of "news" in the sense of Barsky and Sims (2012) or perfect foresight as in Leeper et al. (2013) the exogenous shift in expectations is due to information about changes in future fundamentals that is not directly reflected in the current state vector. Forward rate guidance may be thought of as an example of news: agents anticipate changes in future monetary policy as a result of explicit central bank communication aimed at signaling upcoming deviations from the historical policy rule.[4]

Since we want to remain agnostic about the specific process governing

[4] See for example the following sentence in 2014 and 2015 FOMC statements: "The Committee currently anticipates that, even after employment and inflation are near mandate-consistent levels, economic conditions may, for some time, warrant keeping the target federal funds rate below levels the Committee views as normal in the longer run."

information flows and beliefs formation, we require a framework that is general enough to encompass all of these possibilities. To that end, we consider models of the form

$$x_t = Ax_{t-1} + BE_t^S[x_{t+1}] + \Sigma\varepsilon_t \tag{1}$$

where A, B, and Σ are parameter matrices, ε_t is a vector of iid "fundamental" shocks with mean zero and identity covariance matrix, and $E_t^S x_{t+1}$ denotes agents' "subjective expectation" of the 1-period-ahead state vector. Expectations are subjective in the sense that may deviate from the statistical expectation that an agent or an econometrician with knowledge of both the time-t state and the model parameters would compute.

We assume that equation (1) satisfies the conditions for invertibility, that agents have knowledge of the structure of the economy in (1), including the values of A, B, and Σ, and that the operator E_t^S obeys the law of iterated expectations (i.e., $E_t^S\left[E_{t+h}^S[x_{t+j}]\right] = E_t^S[x_{t+j}]$ for$j > h > 0$). Under these assumptions, (1) can be rewritten as

$$x_t = \sum_{l=1}^{\infty}\Phi_l x_{t-l} + \sum_{h=1}^{\infty}\Psi^h E_t^S[\varepsilon_{t+h}] + \Sigma\varepsilon_t \tag{2}$$

where the matrices Φ_l and Ψ^h are reduced-form combinations of A, B, and Σ. If agents' information set consists of the history of the state $\{x_t, x_{t-1}, ...\}$ and subjective expectations are rational, then $E_t^S[\varepsilon_{t+h}] = 0$ for all $h > 0$.

To move beyond the full-information, rational-expectations benchmark, we allow subjective expectations of future fundamental shocks to follow the general linear process:

$$E_t^S[\varepsilon_{t+h}] = \sum_{l=1}^{\infty}C_l^h x_{t-l} + \sum_{l=1}^{\infty}D_l^h E_{t-l}^S[\varepsilon_{t+h}] + F^h\varepsilon_t + \eta_t^h \tag{3}$$

where C_l^h, D_l^h and F^h are coefficient matrices and η_t^h is an iid random vector representing shocks to expectations. (Given equation (2) and the assumption that agents know the structural parameters, characterizing $E_t^S[\varepsilon_{t+j}]$ for $j = 1, ..., h$ is sufficient to uniquely characterize $E_t^S[x_{t+h}]$.) We assume that η_t^h is independent of ε_t for all h. However, to allow for the possibility that agents may receive *informative* signals about the future, we do not restrict η_t^h to be independent of ε_{t+h} for $h > 0$. In particular, we can write

$$\eta_t^h = \kappa^h\varepsilon_{t+h} + u_t^h$$

where u_t^h is independent of all leads and lags of ε_t, that is, is an *erroneous* signal about the state of the economy.

This framework encompasses a number of interesting special cases. For example, since expectations of future fundamental shocks are formed as arbitrary linear functions of their own lags, previous state values, fundamental shocks, and noise, equation (3) can be consistent with a variety of belief-formation processes, including certain models of learning and sticky information. However, we are particularly interested in two important cases:

1. *News.* If $\kappa^h \neq 0$ for some h, then agents effectively receive informative signals (i.e., news) about period $t+h$ in period t. The most intuitive case is $\kappa^h = 1$, which implies that the signal is unbiased. This setup is consistent with how forward guidance about monetary policy has been modeled in Laseen and Svensson (2011), Campbell et al. (2012), and Del Negro et al. (2013).

2. *Noise.* If $\text{var}[u_t^h] > 0$ for some h, then agents' beliefs are subject to random fluctuations that do not correspond to any past, current, or future fundamental shocks. This type of information flow is consistent with models of sentiment or judgment. It is also consistent with models in which, for whatever reason, agents pay attention to a signal that has no economic content.

There are two relevant observations to make about the effects of expectations shocks that are news versus those that are noise. First, note that if *both* news and noise are potentially present at some horizon (i.e., $\kappa^h \neq 0$ and $\text{var}[u_t^h] > 0$), they are observationally equivalent to agents and to econometricians in periods t through $t+h-1$. In other words, since expectations only involve the term η_t^h (but not its exact decomposition), and since this term responds equally to both news and noise (up to the scaling factor κ^h), both types of shocks have the same effect on $E_t^S\left[\varepsilon_{t+h}\right]$ and therefore on x_t. Only in period $t+h$ does a difference emerge, because in that period the shock ε_{t+h} is realized in equation (2) and agents infer how correct the initial signal was. Second, although the path of the economy may differ for news and noise shocks after period $t+h-1$, the portion of this path that is *caused by* the change in expectations is the same for both shocks. The difference between the two paths results only from the direct effect that the actual materialization of the shock has on the economy, that is, Σ in (2), and not from the effect (Ψ^h) that η_t^h has on the economy through the expectation term within the same equation.

Thus, although the impulse-responses differ between the news and the noise cases, the extent to which beliefs *cause* fluctuations in the state is the same.

This implies that, while for noise shocks, the entire impulse-response function is caused by the expectation shock, for news shocks, we must subtract off the response to the fundamental shock that would have occurred even if such shock had not been anticipated—namely, the effect following from $\Sigma\varepsilon_t$. Fortunately, in the particular case of monetary-policy VARs, we have an estimate of this effect, since it is precisely the impulse-response of the economy to a (conventional) unanticipated monetary-policy shock.

We dwell on this issue because it will be important for us in two ways. First, we do not need to separately identify news and noise shocks in order to determine how the economy changes following a change in expectations. Indeed, as noted by Blanchard et al. (2013), it is generally impossible to do so because of the observational-equivalence problem. Instead, our empirical exercise will identify the random variable η_t^h, without attempting to decompose it into ε_{t+h} and u_t^h. Of course, as just discussed, the extent to which our estimates of the economic response to η_t^h can be interpreted as causal will depend on its news/noise composition. However, in practice, we find that our inference about the causal effects of expectations under the assumption that $\eta_t^h = u_t^h$ (expectations shocks are all noise) is not much different from our inference under the assumption $\eta_t^h = \varepsilon_{t+h}$ (expectations shocks are all news). We discuss this result further in Section 4.2.

Second, since the path of the economy following the revelation of news about ε_{t+h} is equal to the path that is caused by the change in time-t expectations plus the path that would have arisen if ε_{t+h} had been realized (in period $t+h$) without having been anticipated, one can construct the response of the economy to the revelation of news by adding together the appropriately weighted impulse-response functions for these two shocks. In our particular case, this means that we can construct forward-guidance scenarios by a combination of expectations shocks and conventional policy shocks. A situation in which agents receive surprising forward guidance at time t (assuming it is credible) is equivalent to a situation in which their time-t short-rate expectations change exogenously and then subsequent shocks to the actual short rate occur such that the initial change in expectations turn out to be correct. We will have estimates of how the economy responds when there are shocks to both the expected and actual short rates, so simulating the effects of forward guidance as the sum of these estimated responses is straightforward.

2.2 Expectations Shocks in a New Keynesian Model

We now consider what happens when we allow for exogenous fluctuations in subjective expectations of future monetary policy in an otherwise standard

New Keynesian (NK) model. The purpose of this exercise is threefold. First, it illustrates in a familiar setting the mechanism underlying the impact of the expectations shocks mentioned above. Second, it demonstrates the qualitative and quantitative responses to such shocks implied by NK models, providing hypotheses (such as the so-called forward-guidance puzzle) to be tested in our empirical work. Lastly, it illustrates how the sign restrictions that will be used to identify monetary-policy expectations shocks in our VAR are specified by the theory.

We borrow the basics of the model from Gali (2008). Specifically, under standard NK assumptions, the equilibrium conditions can be written as follows:

$$\pi_t = \beta E_t^S \pi_{t+1} + \kappa y_t \tag{4}$$

$$y_t = E_t^S y_{t+1} - \frac{1}{\sigma}\left(i_t - E_t^S \pi_{t+1} - r^*\right) \tag{5}$$

where y_t is the output gap, r^* is the natural rate of interest, $0 < \beta < 1$ is the rate of time preference, $\sigma > 0$ is the coefficient of relative risk aversion, and $\kappa > 0$ is a nonlinear combination of structural parameters. In addition, assume that the short-term interest rate is set by the central bank according to the rule

$$i_t = \phi_y y_t + \phi_\pi \pi_t + \upsilon_t \tag{6}$$

where

$$\upsilon_t = \rho \upsilon_{t-1} + \varepsilon_t \tag{7}$$

with ε_t being a mean-zero iid shock, and $\phi_\pi \geq 0$, $\phi_y \geq 0$, and $0 \leq \rho \leq 1$.

We depart from the standard treatment only by assuming that expectations are formed under the subjective measure defined in equation (3) of the previous section. However, to keep the exposition simple, we assume that C, D, and F are all equal to zero—that is, $E_t^S \varepsilon_{t+h} = \eta_t^h$. This specification is similar in some respects to models of beliefs shocks (news or noise), as, for example, in Schmitt-Grohe and Uribe (2012) and Lorenzoni (2009).[5] In the special case in which the variance of η_t^h is zero for all h, it reduces to the standard NK model.

To see how monetary-policy expectations shocks affect the current output gap and inflation in this model, note that the model can be solved forward to obtain a solution for time-t inflation and output as a function of the current policy stance υ_t and an infinite-order moving average of expected future shocks:

[5] Milani and Treadwell (2012) also present a related DSGE analysis in which monetary policy shocks may be anticipated by agents. Although the details of their model differ from those here (for example, they incorporate habit formation), they also find that the effects of the shocks to anticipated future policy are larger than those to current policy.

$$\pi_t = \psi_\pi^0 \upsilon_t + \sum_{h=1}^{\infty} \psi_\pi^h E_t^S \varepsilon_{t+h} = \psi_\pi^0 \upsilon_t + \sum_{h=1}^{\infty} \psi_\pi^h \eta_t^h$$

$$y_t = \psi_y^0 \upsilon_t + \sum_{h=1}^{\infty} \psi_y^h E_t^S \varepsilon_{t+h} = \psi_y^0 \upsilon_t + \sum_{h=1}^{\infty} \psi_y^h \eta_t^h$$

The multipliers ψ can be found as follows. First, note that the effect of an unanticipated monetary-policy shock ε_t, which is given by the multiplier on υ_t, is the same as in the usual case. In particular,

$$\psi_\pi^0 = -\kappa\Lambda \tag{8}$$

$$\psi_y^0 = -(1-\beta\rho)\Lambda \tag{9}$$

$$\psi_i^0 = [(1-\rho)(1-\beta\rho) - \kappa\rho]\Lambda \tag{10}$$

where $\Lambda = \left[\kappa(\phi_\pi - \rho) + (1-\beta\rho)\left(\phi_y + \sigma(1-\rho)\right)\right]^{-1}$. (See Gali, 2008, for a derivation.) Since ψ_π^0 and ψ_y^0 are necessarily negative for admissible values of the structural parameters, time-t inflation and output move in the *opposite* direction of the monetary-policy shock ε_t. Under standard parameterizations, ψ_i^0 is positive, implying that the nominal short rate moves in the *same* direction as the shock, and we will assume for the remainder of the discussion that this is the case.[6] One can show that the multipliers for shocks to expectations about horizon $h > 0$ are given by the recursion:

$$\begin{pmatrix} \psi_\pi^h \\ \psi_y^h \end{pmatrix} = R \begin{pmatrix} \psi_\pi^{h-1} \\ \psi_y^{h-1} \end{pmatrix} \tag{11}$$

where

$$R = \begin{pmatrix} \kappa + \beta\left(\phi_y + \sigma(1-\rho)\right) & \kappa\sigma \\ 1 - \beta\phi_\pi & \sigma(1-\beta\rho) \end{pmatrix} \Lambda$$

To take an example, consider how an economy that is initially in the steady state ($\upsilon_t = 0$) responds at time t to a shock to monetary-policy expectations one period ahead, η_t^1. First note how expectations of the state variables themselves react in the period of the shock:

$$\begin{aligned} E_t^S \pi_{t+1} &= \psi_\pi^0 \eta_t^1 \\ E_t^S y_{t+1} &= \psi_y^0 \eta_t^1 \\ E_t^S i_{t+1} &= \psi_i^0 \eta_t^1 \end{aligned}$$

[6] The expected real interest rate, $r_t = i_t - E_t\pi_{t+1}$, necessarily moves in the same direction as the shock, with $\psi_r^0 = [(1-\rho)(1-\beta\rho)\sigma]\Lambda$. This implies a slightly different set of sign restrictions than what we will use for our baseline empirical model, which we consider as robustness checks.

Intuitively, expectations of a future monetary-policy change have on expectations of future inflation, output, and interest rates the same impact that current policy shocks have on current inflation, output, and interest rates. That is, a shock to future policy expectations causes both $E_t^S \pi_{t+1}$ and $E_t^S y_{t+1}$ to move in the opposite direction of $E_t^S i_{t+1}$. This observation motivates our sign-based identification scheme. Notably, no other shock in standard models of this type can produce this response pattern. For example, a shock to expectations about future technology, which would enter through r^*, would generally move the short rate in the same direction as expected output and inflation. A "markup shock," which would appear as an additional stochastic term in equation (4), would generally move inflation and output in opposite directions.

From (11), the responses of time-t inflation and output to the expectations shock are:

$$\begin{aligned}
\pi_t &= \psi_\pi^1 \eta_t^1 = \left\{ \left[\kappa + \beta \left(\phi_y + \sigma(1-\rho) \right) \right] \psi_\pi^0 + \kappa \sigma \psi_y^0 \right\} \Lambda \eta_t^1 \\
y_t &= \psi_y^1 \eta_t^1 = \left[\left(1 - \beta \phi_\pi \right) \psi_\pi^0 + \sigma \left(1 - \beta \rho \right) \psi_y^0 \right] \Lambda \eta_t^1
\end{aligned}$$

So long as $\phi_\pi > \rho$, the time-t response of inflation to a monetary-policy expectations shock in $t+1$, ψ_π^1 , has the same sign as the change in expected $t+1$ inflation, ψ_π^0. (I.e., an expected tightening of policy results in lower inflation both today and tomorrow.) This effect represents the impounding of future expected inflation into today's prices. On the other hand, the sign of ψ_y^1 is ambiguous. If the central bank does not respond too aggressively to inflation, then it is negative—lower expected interest rates cause a rise in output today as consumers attempt to smooth out the anticipated boost in future income. But if ϕ_π is large, the central bank's response to the higher time-t inflation can more than offset this smoothing effect and result in a decrease in time-t output. Beyond the one-period horizon, the signs of both responses will depend on the specific parameterization, and they may increase or decrease in magnitude as the horizon increases. Thus, even within the context of this very stylized NK model, there is no clear prediction for which direction the effects of expectations shocks should go, let alone for their size. The response of the economy depends on the central bank's behavior.[7]

To get a sense of the magnitudes associated with these shocks and how the responses vary across the expectational horizon, Figure 1 illustrates how the state of the economy responds in a typical calibration to expectations shocks

[7] A particularly relevant case is that, at the ZLB, small changes in inflation do not result in any change in the interest rate, so that ϕ_π is effectively zero. Thus, at the ZLB the smoothing effect always dominates, and accommodative shocks to future expected policy always raise current output.

that are 1 to 4 periods ahead. Taking periods to be quarterly (and again following Gali, 2008), let $\sigma = 1$, $\beta = .99$, $\kappa = .15$, $\phi_y = .125$, $\phi_\pi = 1.5$, and $\rho = .5$. (In this case, $\psi_\pi^0 = -.32$, $\psi_y^0 = -1.08$, and $\psi_i^0 = .38$.) The impulses are shocks η_t^h that are sufficient to lower the expected h-period-ahead annualized interest rate by 25 basis points, where $h = 1, ..., 4$. Given the calibration, this translates into an expected ε_{t+h} equal to -0.17 basis points (under the subjective measure).

We first consider the case in which η_t^h consists purely of noise ($\eta_t^h = u_t^h$). That is, once period h arrives, there is no actual policy shock. As shown in panel A of the figure, inflation rises immediately in response to the expectations shocks, and it rises by more the farther in the future the shock to the short rate is expected to occur. For an anticipated monetary easing of 25 basis points one year ahead (the blue line) current quarterly inflation rises by about 3 percent (at an annual rate). As noted, this effect is somewhat damped because of the systematic response of policy. This reaction is reflected in higher nominal and real short-term rates. For this calibration, the policy response is large enough to drive the output gap negative in early periods, even though the expectations shock itself is a stimulative one. Further, since no fundamental shocks actually materialize in these examples, and since the subjective expectational errors are assumed not to be persistent, the state always returns to zero once period h has passed.

Panel B illustrates the case in which η_t^h consists of news. That is, $\eta_t^h = \varepsilon_{t+h}$. As noted in the previous section, the response of the economy to news shocks is the same as its response to noise shocks up until period $t+h$. After that time, the economy receives the additional stimulus that it would have received from an unanticipated monetary policy shock of 25 basis points at time $t+h$. This case is one that could, in principle, result from credible forward guidance—agents are made to believe that a policy shock will occur in the future, and then it actually does. However, if the path of the economy shown in this panel resulted from deliberate policy, the central bank's behavior would be somewhat bizarre. As in panel A, the systematic response of monetary policy causes nominal and real rates to rise in the near term when a future easing is anticipated; thus, the central bank mechanically finds itself raising rates in response to its own forward rate guidance. While there is nothing logically inconsistent about this outcome, it seems unrealistic that a central bank would announce an unusually accommodative future policy only to offset part of that accommodation now by adhering to its usual rule.

We therefore consider a more realistic forward-guidance scenario, in which the central bank maintains nominal rates at their time-$t-1$ levels until period $t+h$, at which point it adopts the pre-announced change. To achieve this outcome, it must introduce additional monetary policy shocks in each period

$t, ..., t + h - 1$ in order to offset its own systematic response to the economy and keep the short rate at its initial level. We assume that these additional policy shocks are also anticipated at time t by agents. (I.e., agents correctly believe that the path of the short rate will be unchanged until period $t + h$.) Panel C shows the impacts in the theoretical model. Without the short-term policy offset to the expected future easing that was present in panel B, the output gap now rises substantially. Given the stabilized nominal short rate, the higher inflation results in a significant downward movement in real rates.[8]

Finally, in panel D, we show what happens if the central bank promises to lower the short rate by 25 basis points, not just in period $t + h$, but for the entirety of the period $t + 1$ through $t + h$. This is closer to what central banks have done in practice, and it essentially mirrors the forward-guidance experiments we will conduct with our empirical results in Section 5. Perhaps surprisingly, the responses are only slightly greater than in panel C. The reason is that, in the forward-guidance scenario, most of the effect derives from the large short-rate shock that is needed in the first period to keep rates from rising. The size of that shock primarily depends on the timing and magnitude of the change in expectations that is farthest in the future, which is the same in both panels C and D.

The magnitudes of the responses in Figure 1 are large when compared to those of conventional monetary policy shocks within the same model. For example, an unanticipated shock to the actual short rate has an initial impact of only +0.2 percentage points on both the inflation rate and the output gap—an order of magnitude smaller than when the same shock is anticipated to occur a year in the future. These are manifestations of the "forward guidance puzzle" pointed out by del Negro et al. (2013). They are not specific to the structure of the simple model here, its calibration (within reason), or its assumed policy rule. Rather, as discussed by McKay et al. (2015), they result from the large influence of future interest rates on the path of the output gap and the way that path compounds into inflation via the NK Phillips Curve. While some authors, such as Kiley (2014b) and McKay et al. (2015), have proposed modifications to the basic NK structure that can reduce the effect of forward guidance, it is unclear what a reasonable result from such models

[8] The output gap is much higher in panel C than in panel B, but inflation is only slightly higher. The reason is subtle. Since the short-rate shocks that occur in t through $t + h - 1$ in panel C are persistent, less of an expectations shock is needed to achieve a given value of $E_t^S v_{t+h}$ than was needed in panel B. For inflation, the effect of the short-rate and expectations shocks is about the same, so trading off one for the other makes little difference. But for the output gap, negative shocks to the short rate have a positive effect, whereas negative shocks to the *expected* short rate mostly have a negative effect (as shown in panels A and B). Consequently, the shift in the source of the shocks provides a large positive boost.

should be, since there is no empirical work estimating this impact in a model-free way. Our results below provide some benchmarks along these lines.

3 The Survey-Augmented VAR

3.1 Specification and Data

Returning to the more general model of Section 2.1, note that we can write equations (2) and (3) in the reduced form

$$x_t = \sum_{l=1}^{\infty} \Theta_l^{11} x_{t-l} + \sum_{h=1}^{\infty} \sum_{l=1}^{\infty} \Theta_{h,l}^{12} E_{t-l}^S \left[x_{t+h} \right] + \epsilon_t^x \tag{12}$$

$$E_t^S \left[x_{t+h} \right] = \sum_{l=1}^{\infty} \Theta_{h,l}^{21} x_{t-l} + \sum_{l=1}^{\infty} \Theta_{h,l}^{22} E_{t-l}^S \left[x_{t+h} \right] + \epsilon_t^E \tag{13}$$

This sets up a VAR system, which will be the target of our estimation. It will be useful to divide the vector x_t into macroeconomic variables that we will assume cannot respond contemporaneously to conventional monetary-policy shocks ($\mathbf{x}_{1t}$), those that potentially can ($\mathbf{x}_{2t}$), and the short rate itself (i_t). We can stack the data in the vector $\mathbf{X}_t = \begin{pmatrix} \mathbf{x}_{1t} & i_t & \mathbf{x_{2t}} & E_t^S[\mathbf{x}_{t+h}] \end{pmatrix}'$, where $E_t^S[x_{t+h}]$ is the subjective measures of expectations about the macro data at horizon h. Also let $\boldsymbol{\epsilon}_t$ be a corresponding stacked vector of the reduced-form errors, ϵ_t^x and ϵ_t^E, with covariance matrix $\boldsymbol{\Sigma} = \boldsymbol{\Gamma}\boldsymbol{\Gamma}'$. We rewrite the system as

$$\mathbf{X}_t = \boldsymbol{\Theta}(L)\mathbf{X}_t + \boldsymbol{\epsilon}_t. \tag{14}$$

(We make the usual assumption that the infinite sums in the above system can be well approximated by a VAR process of low order, which we will determine using information criteria.)

To measure agents' subjective expectations, we use survey data from both the Survey of Professional Forecasters (SPF) and the Blue Chip Survey (BCS).[9] The principal advantages of the SPF data are that they begins in 1981 (the year when the three-month Treasury bill rate forecast becomes available) and are reported at a consistent quarterly frequency. However, the longest available forecasting horizon in these data is one year ahead. The BCS data, by contrast, include forecasts of up to 11 years in the future, but they do not begin until 1983 and for some forecasting horizons are reported only twice a

[9] We obtained the SPF data from the Federal Reserve Bank of Philadelphia's website.

year at a slightly irregular interval. Each survey reports the respondents' average forecasts of GDP growth, CPI inflation, and the three-month Treasury bill (3-month T-Bill) rate, which we use as a proxy for the monetary-policy instrument. For the one-year horizon, where both surveys are available, we obtain VAR results that are quite similar whether we use one survey or the other. Therefore, in our baseline specifications, we focus on the BCS, leaving the SPF results as a robustness check.

Due to idiosyncrasies in the conventions and timing of their reporting, the survey data from both sources require some manipulation to be useful in our VAR model. Our method for obtaining constant-horizon quarterly series from these data is described in detail in the appendix. The three panels of Figure 2 plot the resulting time series of the survey-based expectations of the average 3-month T-Bill rate, CPI inflation, and GDP growth over the next year. The projections of the 3-month T-Bill rate and CPI inflation are very similar between the two surveys. In the case of GDP growth, on the other hand, the SPF projections are more volatile and, at least through about the year 2000, more pessimistic than the BCS projections. Miyamoto and Nguyen (2014) compare the SPF data not only to the BCS forecasts but also to the Consensus Forecasts and the Fed's Greenbook forecasts and also conclude that they are similar. These findings are comforting because, if survey data on expectations agree across a large set of forecasters, it is more likely that they represent the actual expectations of agents in the economy. Figure 3 illustrates the properties of the term structure of BCS forecasts for the same set of variables (3-month T-Bill, CPI inflation, and GDP growth) by plotting their time series at the one-, six-, and 11-year horizon. Shorter-term expectations (blue lines) display much more variation than longer-term expectations, and there is very little difference between 6- and 11-year projections (red and green lines, respectively). These results are consistent with the stylized fact that it is difficult to forecast economic variables far in the future.

Apart from the inclusion of the survey data, the specification of our baseline VAR model is similar to others in the literature. Specifically, we build loosely on Christiano, Eichenbaum, and Evans (2005) in our choice of macro variables. In x_{1t} we include log GDP, log CPI, and log labor productivity.[10] In x_{2t} we include log real profits and the M2 growth rate. (To conserve degrees of freedom, we omit a few variables—consumption, investment, and wages—that were of specific interest to Christiano et al. (2005) but are nearly collinear with the other variables in the VAR.) We also include a long-term Treasury yield in x_{2t}, with a maturity corresponding to the horizon of the survey expectations used in each model specification, in order to capture any effects of expected

[10] We will also use the results to discuss employment, which of course can be calculated as the difference between output and productivity.

short rates that operate through longer-term spot rates.

Overall, we found that, although the basic sign and magnitude patterns of our results were consistent across specifications, the choice of lag length mattered in some cases for the confidence bounds around the results. In our baseline model, we use the BIC to select lag length. The robustness checks in Section 6 consider some alternatives to this specification, including different choices of regressors and lag length and estimation using Bayesian methods.

A necessary condition for our exercise to work is that the VAR to must do a better job of forecasting the economic variables than the surveys do. There are two reasons for this requirement. First, as with virtually any VAR, an implicit assumption is that the estimated model closely approximates the true probability model of the economy. If the surveys performed better than the VAR, that would call into question the specification. Second, we need the survey-based expectational deviations to be non-negligible, because otherwise they would add little information to the VAR and produce a poor identification of the anticipated changes to policy. These two conditions jointly imply that the survey expectations must not be more accurate on average—and preferably not nearly as accurate—as the expectations based on the survey-augmented VAR.

Table 1 shows that the VAR forecasts are indeed much more accurate than the survey forecasts by comparing root mean-squared errors. For example, the BCS has errors about 60% larger than those of the VAR when it comes to forecasting the 3-month T-Bill rate one year ahead. At long horizons, the RMSEs of the survey data are 1.8 to 6.5 times as large as those of the VAR. Of course, the VAR has several advantages over the survey data, in that it is using *ex post* data, forecasting in-sample, and including information from the surveys themselves. If we were running a horse race between the two forecasts, this comparison would not be fair. (On the other hand, it is not strictly guaranteed that the VAR must do better, since it minimizes one-step-ahead errors, and these are multi-step forecasts.) But the purpose of the survey-augmented VAR is not to attempt to mimic real-time forecasts, but rather to come as close as possible to the true probabilities. It seems clear that the VAR does a considerably better job than the surveys in this regard. Consequently, we are comfortable interpreting differences between the VAR forecasts and the survey forecasts as reflecting expectations shocks in the sense of Section 2.

3.2 Identification of structural shocks

We will distinguish three types of structural shocks, conventional (unanticipated) monetary-policy shocks (e_t), policy-expectations shocks (η_t^h), and a vector of other shocks that we leave unspecified (*other*). The contemporaneous coefficients $\mathbf{\Gamma}$ can be partitioned conformably with $\mathbf{X}_t$:

$$\mathbf{\Gamma} = \begin{pmatrix} \mathbf{\Gamma}_e^{x_1} & \mathbf{\Gamma}_{\eta^h}^{x_1} & \mathbf{\Gamma}_{other}^{x_1} \\ \Gamma_e^{i} & \Gamma_{\eta^h}^{i} & \mathbf{\Gamma}_{other}^{i} \\ \mathbf{\Gamma}_e^{x_2} & \mathbf{\Gamma}_{\eta^h}^{x_2} & \mathbf{\Gamma}_{other}^{x_2} \\ \mathbf{\Gamma}_e^{E^S[x]} & \mathbf{\Gamma}_{\eta^h}^{E^S[x]} & \mathbf{\Gamma}_{other}^{E^S[x]} \end{pmatrix} \tag{15}$$

where, for example, $\mathbf{\Gamma}_e^{x_1}$ is a vector containing the response of the block $\mathbf{x}_{1t}$ to the standard monetary-policy shock and $\Gamma_{\eta^h}^{i}$ is a scalar representing the contemporaneous response of the policy rate to the policy-expectations shock. (Elements of the $\mathbf{\Gamma}$ matrix highlighted in bold represent vectors, while the others are scalars.)

In order to identify the elements of $\mathbf{\Gamma}$, we impose a combination of exact and partial identification restrictions. As noted, we assume that $\mathbf{x}_{1t}$ does not respond contemporaneously to standard monetary-policy shocks, providing us with a set of short-run exclusion restrictions, as are common in the monetary-policy VAR literature. The exact restrictions then amount to:[11]

$$\mathbf{\Gamma}_e^{x_1} = \mathbf{0} \tag{16}$$

Expectations shocks are identified by drawing from the space of possible $\mathbf{\Gamma}$ matrices that satisfy the exclusion restrictions just described and discarding all draws that do not satisfy sign restrictions on the contemporaneous impacts on the surveys. Those sign restrictions—intended to capture changes in expectations about future monetary policy—enforce the following condition: the time-t impact on the survey forecast of the average T-Bill rate over periods t to $t+h$ must be in the opposite direction of the impact on the survey forecast of the time-$t+h$ GDP and price level. To ensure that the expectations shocks are strongly identified from our conventional shocks, we also impose that the contemporaneous T-Bill rate does not move in the same direction as the forecasted T-Bill rate in response to an expectations shock. These assumptions about the contemporaneous impacts of expectations shocks are consistent with the predictions of the NK model discussed earlier and, indeed, with a large class of forward-looking macroeconomic models. As a normalization, we consider expectations shocks that move expected short rates in

[11] Note that we do not require the other half of the usual short-run restriction: policy can respond contemporaneously to *all* of the macro variables and expectations.

the negative direction (i.e., expectations for future policy easing). Thus, the partial restrictions amount to:

$$\begin{aligned} \Gamma_{\eta^h}^{E^S[i]} &< 0 \\ \left\{ \Gamma_{\eta^h}^{E^S[\pi]}, \Gamma_{\eta^h}^{E^S[y]}, \Gamma_{\eta^h}^{i} \right\} &> 0 \end{aligned} \tag{17}$$

Note that the way we have identified our expectations shocks rules out two potential sources of contamination. First, one might be concerned that we are erroneously picking up conventional monetary-policy shocks in time t: perhaps the Fed is lowering rates today, leading to expectations of lower rates and higher output and inflation tomorrow, as well as boosting output and inflation today. If we have correctly and fully identified conventional policy shocks with the exclusion restriction (16), this should not occur. But even if some conventional policy shocks do not exactly satisfy that restriction, our imposition that $\Gamma_{\eta^h}^{i} > 0$ in (17) implies that they cannot be misinterpreted as expectations shocks. As we have set it up, expectations shocks associated with anticipated lower rates tomorrow cannot also be associated with lower realized rates today. Second, one might be concerned that we are actually picking up the effects of time-t aggregate-demand shocks: perhaps output and inflation rise today, and persistence causes expectations for their values tomorrow to rise as well, rather than the other way around. But, since the Fed raises rates in response to exogenous increases in output and inflation, short-rate expectations would rise in that scenario. The first condition in (17) ensures that we do not include such situations among the expectations shocks that we identify.

Table 2 summarizes the baseline identification restrictions on the contemporaneous impacts of the two types of shocks. To implement this identification scheme, we follow the procedure of Arias et al. (2014), who show how to draw uniformly (under the Haar measure) from the possible set of $\mathbf{\Gamma}$ matrices that satisfy a given set of zero restrictions. To compute impulse-response functions (IRFs), we draw jointly $10,000$ times from the posterior distribution of the VAR parameters and the set of admissible $\mathbf{\Gamma}$'s, and we simulate the effects of a one-standard-deviation shock under each draw over 44 subsequent quarters. (This matches the horizon of our longest-range surveys.) Following other studies using partial identification, we focus on the pointwise medians across all of the draws.

4 Results

4.1 Baseline

Table 3 displays the contemporaneous impacts of the policy-expectations shocks on the survey expectations themselves. By construction, these shocks have negative effects on expected T-Bill rates and positive effects on expected GDP and inflation. However, nothing guarantees *a priori* the magnitude or significance of these effects. The table shows that exogenous shocks to expectations of the policy rate are modest, resulting, on impact, in an average change of the one-year expected T-Bill rate of just 3 basis points. A decline of this magnitude in expected short rates is associated with a contemporaneous increase in the four-quarter-ahead level of GDP of 0.14 percent and an increase in one-year expected inflation of 0.09 percent.

For longer-horizon expectations, the size of the impact of expectations shocks on the expected T-Bill rate is about the same, that is, about -3 basis points. However, since this is the average effect over a much longer time period, it represents a larger change in beliefs than the shock to the same rate over a one-year period and, presumably, should impart a greater amount of stimulus. Yet, while the effects of the 6-year and 11-year policy-expectations shocks on the projected levels of GDP and the CPI are indeed monotonically increasing across maturities, the implied expected average growth rates are decreasing. A policy-expectations shock that lowers the expected average short rate over the next 11 years by 3 basis points only raises expected average annual GDP growth and inflation over the same period by 0.03 percent. A likely explanation for this finding is that agents do not believe that monetary policy innovations can have sustained effects on output and inflation over such long horizons. A policy that results in a 3-basis-point reduction in short-term rates for a period of eleven years in a row may be interpreted as a structural change in the policy rule or the steady state of the economy, rather than as monetary stimulus.

Table 4 offers some evidence that the policy-expectations shocks that we have identified do indeed correspond to periods in which agents' expectations for future monetary policy may have shifted. In particular, we list all of the quarters in which expectations shocks larger than one standard deviation occurred between 1999, when the FOMC began including meaningful forward-looking commentaries in its statements, and 2008, when the effective lower bound was reached.[12] In nearly all of these periods, we can match our iden-

[12]We exclude the ZLB period from this analysis, even though several clear forward-guidance events do show up in our model as large expectations shocks, because nearly every quarter during this period contains *some* FOMC communication that could be interpreted

tified shocks to obvious changes to the wording of the statement that point toward future policy moves in the same direction of the shocks. Some of these events, such as the introduction of the "patient" language in 2004, are also those that are identified by Gurkaynak et al. (2005) as being particularly potent episodes of forward guidance.[13]

Panel A of Figure 4 shows the responses of key variables to each of the two shocks, standard monetary-policy shocks (e_t) and policy-expectations shocks (η_t^h), in our baseline model using the one-year BCS expectations. The IRFs are represented as medians (black line), interquartile ranges (red region), and interdecile ranges (blue regions) across draws of the reduced-form coefficients, and the shocks considered are all one-standard-deviation in an accommodative direction (lower interest rates).

The estimated responses to conventional monetary-policy shocks are fairly standard—for example, they are similar to those found in Christiano et al. (2005). Output rises slowly but persistently in the quarters following the shock and peaks at about 0.2 percent after three years, while there is a marginally significant and sluggish response of inflation following an initial modest price puzzle. Interestingly, while these are the standard findings over samples that include the 1970s, exclusion restrictions do not typically deliver these results over the post-1982 period used in this study, likely due to the monetary policy reaction function becoming more forward-looking (see Barakchian and Crowe, 2013). Our use of the survey data in the VAR seems to help with some of the problems related to the existing identification schemes. However, note that the price puzzle remains even though we include the forward-looking survey data on inflation among our regressors.

The expectations shock has a large immediate impact on output, with the response reaching a peak of about 0.1 percent within the first year, but it decays relatively quickly, stabilizing after about three years. The response of the price level to this shock reaches its peak of 0.1 percent at impact, and it reverts only very slowly. The effects of these shocks on employment are also quite large, especially in the short run. (This can be seen by comparing the IRFs for GDP and labor productivity.) These findings indicate that, particularly at short horizons, shocks to expectations can be quite powerful. Note that the expectations shocks do not exhibit a price puzzle.

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as dovish and because of possible concerns about identification during this time.

[13] In constructing this table, we have taken care to account for the timing of the surveys relative to FOMC meetings. In particular, the BCS data for each quarter is typically gathered in the first week of the last month of each quarter, while the last FOMC meeting of the quarter takes place a couple of weeks later and therefore would not be reflected in survey responses until the following quarter. The dates in the table reflect the dates of the shock, not of the corresponding FOMC statement.

Also note that the amount by which expectations shocks actually affect short-rate forecasts is quite modest. A one-standard-deviation shock generates only a 3-basis-point change in the survey forecast on impact. Such a small magnitude is to be expected in a world in which agents typically do not have much reason to anticipate deviations from the policy rule. In contrast, conventional policy shocks move contemporaneous one-year short-rate expectations, and the contemporaneous short rate itself, by 11 basis points on average. Thus, although the IRFs for the two shocks depicted in Figure 4 are of similar magnitude, the basis-point size of the expectations shock needed to generate this response is much smaller. To see this comparison more precisely, Table 5 displays the size of conventional policy shocks required to equal the macroeconomic effect of a -25-basis-point one-year expectations shock. Over the short run, the expectations shock is five times more effective, as the magnitude of the conventional policy shock should be of almost -125 basis points to achieve the same cumulative effect on GDP and over 200 basis points to have the same effect on hours worked. Over the long-run, the expectations shock is about twice as effective as the conventional policy shock for the cumulative effect on GDP and CPI. The point estimate of its effect on hours is smaller, although (not shown in the table) the differences at these horizons are not statistically significant.

Panels B and C of Figure 4 show the effects using longer-horizon surveys. The responses to policy-expectations shocks are similar in magnitude although they are shorter-lived, becoming statistically insignificant after two to three years. The responses to the standard monetary-policy shocks are similar to those in Panel A. When the model is estimated with these longer maturities, the expectations shocks are less important relative to monetary-policy shocks, although they still have some substantial effects, particularly for near-term inflation and employment.

4.2 Causality of expectations shocks: news versus noise

As discussed in Section 2.1, the IRFs shown above describe what happens to the economy in the aftermath of a policy-expectations shock, but they do not necessarily imply that the expectations shock *causes* the entire responses. In the period of the shock itself, this is not an issue—any movement must be due to the effects of changes in expectations, because nothing else has had time to happen yet. However, some of the changes subsequent to the period of the shock could have taken place even if they had not been anticipated. Therefore, in order to isolate the causal effect of the expectations shocks beyond the first period, we need to purge the IRFs of the response that would have materialized anyway.

To do this, we exploit the distinction made earlier between news (anticipated policy changes that actually occur) and noise (anticipated policy changes that do not occur). We consider two extreme cases in which our identified shocks consist either entirely of news or entirely of noise. If the the expectations shocks that we have identified entirely reflect noise ($\kappa_h = 0$ in the notation of Section 2.1), then the IRFs depicted in Figure 4 only reflect causality—since the shocks do not embed any fundamental changes, any response of the economy must arise only from the effects of the shift in beliefs. On the other hand, if the identified shocks entirely reflect news ($\text{var}[u_t^h] = 0$), then the IRFs depicted in Figure 4 are equal to the effect of the change in beliefs plus the effect of the subsequent policy change itself. Thus, to isolate the causality of expectations in that case, we must subtract the effect of a conventional policy shock of the anticipated size. Fortunately, we also have an estimate of exactly this object.

One complication is that, because of the way the survey data are reported, our measures of subjective expectations are averages over several periods. Thus, there are generally multiple possible expected short-rate paths that would be consistent with any initial expectations shock, and consequently the appropriate series of conventional policy shocks to use in the above-mentioned subtraction is not uniquely determined. (For example, a decline of 25 basis points in the expected one-year average rate could be consistent with a path of short rates that is 25 basis points lower for the entire year or with a path that is unchanged over the first six months and 50 basis points lower over the last six months.) For the purposes of this exercise, we assume shocks that would be sufficient to generate a constant short rate at the anticipated average level over the forecast period. Reasonable variations on this choice make little quantitative difference.

The "all noise" and "all news" cases are obviously extreme. In reality, the expectations shocks that we have identified likely reflect a combination of both noise and news. Intuitively, assuming convexity, as in the linear model of Section 2.1, the true effects of expectations shocks must lie somewhere between these two polar cases that we can actually compute. Consequently, if these two cases are empirically close to each other, we will have a fairly precise idea of the causality of expectations shocks, and the distinction between news and noise will not be particularly relevant.

Figure 5.A shows the upper (blue) bounds for the case of fully noise and the lower bounds (red) for the case of fully news for our one-year model, given an expectations shock of -25 basis points. The difference between news and noise affects our interpretation of the GDP IRF by at most 0.4 percentage points, at medium horizons. At short horizons, and at all horizons

for inflation, there is virtually no difference. This is not surprising since we already knew from the estimated responses plotted in panel A of Figure 4 that unanticipated monetary-policy shocks (e_t) have modest effects relative to the policy-expectations shocks (η_t^h) and therefore, in the case of news, the cumulative impact that needs to be removed is fairly small. Figure 5.B shows the same comparison using the six-year expectations. (The 11-year results are very similar to the 6-year and are omitted from here on.) Again, the bounds are generally quite close to each other quantitatively and are never statistically different. Thus, we conclude that our procedure identifies the effects of policy-expectations shocks—in the causal sense—within a fairly tight range.

5 Modeling forward rate guidance

In this section, we use the results of our model to consider the effects of credible, Odyssean forward guidance—a shock to expectations of future short-term rates that is followed by deviations from the policy rule that are sufficient to make the expectations materialize. This method of constructing policy scenarios as combinations of different fundamental structural shocks over several quarters is also employed, for example, by Mountford and Uhlig (2012) in the context of fiscal policy.

Apart from some timing differences, the forward-guidance scenarios we consider here are conceptually the same as those we analyzed in the theoretical model of Section 2.2 (depicted in panels C and D of Figure 1). In particular, we simulate a shock to h-period expectations in period 0, followed by conventional monetary-policy shocks in periods 1 through h that cause the initial change in short-rate expectations to be exactly correct. As above, we assume that the Fed maintains the short rate constant at the level it has announced over the entire period covered by the forecast.

The blue lines in Figure 6, panel A show the effect of a -25-basis-point forward-guidance shock over a one-year horizon, together with $10-90$ percent confidence regions. Again, in the period of impact, the responses are the same as those estimated for the expectations shock and pictured in Figure 4. However, in Figure 4, the actual short rate tightens following the expectations shock. It is precisely this outcome that we neutralize here. To do so, we must impose that the Fed hits the economy with multiple stimulative shocks to the actual short rate following the shift in the expected rate, just as we did in the theoretical model of Section 2.2. As a consequence, the responses of GDP and inflation are generally higher than what would be generated by a -25-basis-point expectations shock alone. Indeed, the forward rate guidance raises GDP in the short run by over 1 percent and the price level by nearly 1 percent.

The initial responses of output and inflation to forward guidance are quantitatively similar to those produced by the NK model. (See Figure 1, panel D.) There, the output gap rose by about 1.5 percentage points in response to a one-year forward-guidance shock of -25 basis points, and inflation rose by about 3.5 percent. Indeed, the empirical increase in the price level is essentially a one-quarter jump, which translates into an annualized inflation rate of about 3.7 percent. More importantly, however, while the empirical price level is little changed after the first quarter (and even declines a bit), in the theoretical model inflation continues to be positive for several quarters. Thus, while the response on impact is similar, the theoretical model predicts a much higher *cumulative* change in inflation. In contrast, the output gap in the theoretical model is much less persistent than our empirical response, but this is not surprising because the theoretical model that we considered did not have much of a built-in persistence mechanism, which, for example, could be introduced through habit formation.

To assess whether forward guidance is itself effective, we need to compare it to what would have happened if the Fed had pursued the same short-rate policy without announcing it in advance. The red lines in Figure 6 plot a simlulation of what would have occurred if the Fed had followed the same short-rate path that it maintained under the forward-guidance scenario but with no preceding change in expectations. (Note that this implies a different series of conventional policy shocks than were used to construct the blue line.) Looking at the difference between the red and the blue, the marginal effects of 25-basis-point forward guidance on both GDP and prices are as much as 1 percentage point in the short- to medium-run and about 0.5 percent after ten years, with the differences being statistically significant for this entire period. The marginal effect on hours is also about 1 percent in the short run, although it decays somewhat faster. To the best of our knowledge, the importance of this expectations channel in the data has not previously been documented.

Panel B shows the same type of forward-guidance scenario and comparison for the model based on the six-year survey data. In this case, the experiment considered is the rather heroic one of the Fed announcing a credible 25-basis-point reduction in the short rate for the entirety of the next six years and then following through on that promise. Despite the much longer horizon of this forward rate guidance, the effect relative to adopting the same short-rate path without pre-announcing it is still about 1 percent on GDP and about 0.5 percent on the price level, with neither statistically significant after two to three years. The marginal effect on hours is similar to that in the one-year-forward-guidance case. These results contrast with the New Keynesian simulations depicted in Figure 1, where the impact of forward guidance was stronger at longer horizons. The discrepancy we document between the model and the data in this respect can be viewed as quantifying the "forward-guidance puzzle."

6 Robustness Checks

In this section, we conduct a battery of robustness checks, whose results are summarized in Table 6. Since our most significant results were for one-year expectations, we focus on that horizon. The results using the 6- and 11-year surveys are not shown but are also generally robust. As a summary measure, for each specification the table reports the estimated effect of the forward guidance scenario, relative to the same path of short rates when it is not announced in advance—i.e., the difference between the blue and red lines in Figure 6A. We report the median magnitude of this difference across parameter draws after both one and five years. Asterisks indicate statistical "significance" at the 5% level——-that is, whether at least 95% of the parameter draws result in a positive marginal effect of forward guidance.

First, as stressed for example in Leahy (2013), when it comes to the analysis of the recent financial crisis, two issues that are generally important in macro modeling, expectations and nonlinearities, become even more crucial. In this study, we have focused our attention on expectations, but we still use a linear model. Since the effective zero bound on nominal interest rates could be the most important source of non-linearity in our sample period, our first robustness check aims at verifying the stability of our results to the exclusion of the ZLB period. The pre-ZLB sample is also important to consider in order to show that our results are not just driven by the relatively short period in which forward rate guidance has been most actively used as a policy tool. As shown in the second row of Table 6, when we re-estimate the VAR using only the pre-ZLB period, the estimated impact of forward rate guidance on inflation and output is almost unchanged, and the effect on hours is only modestly smaller. These results are in contrast to a number of other VAR studies that exhibit apparent structural breaks at the ZLB (e.g., Baumeister and Benati, 2013). A likely explanation for the robustness of our results in this dimension is that direct measures of expectations help with the stability of the reduced-form parameters in the presence of nonlinearities because those expectations are not required to be linear functions of the data, even though the model itself is linear.

Second, we estimated alternative specifications of the VAR. In particular, we increased the number of lags, we used forecasts from the SPF forecasts instead of the BCS, and we included both the one- and six-year horizon BCS forecasts within the same VAR. As shown in rows 3, 4, and 5 of Table 6, none of these changes altered the results significantly; although, in some cases the statistical significance is weaker at the five-year horizon. When we use the SPF data, overall, the impact of forward guidance seems to be a bit larger across all three key variables. This result could be due in part to the extension of the sample back to 1981. As shown in Figure 2, 1981 and 1982 are particularly important for the inflation expectations process and the early 1980s is when the SPF and BCS GDP forecasts diverge the most.

Third, we also considered different identification schemes for both the expectations shock and the conventional policy shock. In the first case, we imposed the sign restriction on the expected real yield rather than the nominal yield, as discussed in footnote 6 of Section 2.2. (The expected real yield is calculated as the one-year survey forecast of the average 3-month TBill minus the one-year forecast of CPI inflation.) In the second case, instead of using standard timing restrictions, we followed Uhlig (2005) by imposing that policy shocks lower the short rate and raise the CPI for at least five quarters. As shown in rows 6 and 7, these alternative identifications left the results very little changed.

Finally, instead of using a flat prior on the VAR parameters we used the Minnesota prior (row 8), and again we found very similar results, except that for CPI the cumulative impact of forward guidance becomes a bit larger in magnitude at both horizons.

Overall, from this set of empirical exercises we conclude that the findings of this study are quite robust.

7 Conclusion

In this paper, we used a survey-augmented VAR with sign restrictions to identify the effects of anticipated monetary policy on the macroeconomy. We found that, at a one-year horizon, accommodative monetary policy expectations shocks lead to large and rapid increases in both GDP and inflation. We argued that most of this response is likely causal. At longer horizons, the effects of these shocks are smaller and not always significant. These results indicate that forward-guidance policies can potentially be quite effective and that they are likely to have the greatest impact when targeted at shorter horizons.

Our results both support and challenge the conclusions of standard New Keynesian models that have been used to argue for forward-guidance policy. On the one hand, we do show that the anticipation channel exist in the data and that, consequently, forward-guidance can have large and immediate effects. On the other hand, those effects are smaller than most theoretical models would predict, particularly with respect to inflation. They also decrease with the horizon of the guidance, in contrast to New Keynesian predictions. Modifications like those proposed in McKay et al. (2015) may help to bring the New Keynesian models into closer alignment with what our results suggest.

Finally, while we think our results are informative for the debate about monetary-policy tools at the zero-lower bound, some caution is warranted in interpreting them in that context. Although expectations for short-term rates are clearly shaped in part by FOMC communications, forward rate guidance has also not historically been a prominent policy instrument. Moreover, FOMC communications about future short-term rates may not be viewed as credible, particularly if they are expressed as Committee forecasts rather than as commitments, and, in this case, they may even have perverse effects on expectations as suggested by Campbell et al. (2012). Thus, while our findings show that forward guidance can be a powerful policy tool under the right conditions, a variety of institutional impediments may dampen its efficacy in practice.

Appendix: Treatment of the Survey Data

The SPF in quarter t asks respondents for their forecasts in quarters $t-1$ through $t+4$. We thus have one-year forecasts reported quarterly from 1981:4 through 2014:3, as well as "nowcasts" of the contemporaneous data and "backcasts" of the lagged data. The main issue we face with these data is transforming the reported forecast growth rates into levels, which we require for our VAR. Although the SPF does ask for GDP and CPI forecasts in terms of levels, this is not always useful to the researcher *ex post* because rebenchmarking introduces discrete breaks in the series. To obtain consistent series we assume that the average survey backcast of quarter $t-1$ is correct in the sense that any difference between this value and the revised value we observe in the most-recent data is due entirely to rebenchmarking and does not reflect any fundamental change in agents' beliefs about the economy. By then applying the reported SPF growth rates for the subsequent five quarters, we obtain a forecast for the $t+4$ levels of GDP and CPI that are based on the same indexation as the 2014 data. Finally, for each quarter, we average the $t+1$ through $t+4$ forecasts of the T-Bill rate to obtain forecasts of the average T-Bill rate over the following year.

The same difficulty with benchmarking applies to the BCS, but there we face the added complication that we do not have a backcast for $t-1$. Therefore, to index the level in the BCS data, we assume that BCS respondents have the same estimate of the quarter-t data level as the SPF respondents. (This is likely a reasonable assumption, given that, as shown below, the SPF and BCS data are generally quite similar in other respects.)

Apart from this, the BCS data on one-year expectations are reasonably straightforward, and we construct one-year expectations by averaging the forecasts for quarters $t+1$ through $t+4$ in the last month of each quarter. However, the BCS data also include forecasts at longer horizons, and these involve complications related to the timing and scope of their reporting. To obtain as much consistency as possible from this information, we build a new dataset of long-term expectations from the BCS at a quarterly frequency from 1983 to 2014.

Specifically, since 1983, the BCS has been providing semiannual long-range (2- to 6-year and 7- to 11-year) consensus forecasts for various interest rates, including the 3-month T-Bill rate, as well as real GDP, GDP deflator, and CPI. These long-range consensus forecasts were originally provided every March and October in both the Blue Chip Economic Indicators (BCEI) and the Blue Chip Financial Forecasts (BCFF). Starting in 1996, the BCFF switched to providing these long-range projections in June and December, while the BCEI continued reporting them in March in October. We thus have observations of long-term expectations of our main variables of interest twice per year prior to

1996 and four times per year after that time. These inconsistent frequencies and the fact that the observations are not equally spaced across the year mean that we cannot use these data directly in the VAR.[14]

We address both of these issues through interpolation. Specifically, from 1983 to 1996, when the long-range forecasts are available only in March and October, we use the results from the BCEI and linearly interpolate to obtain June, September, and December values. Once the June and December values become directly observable, we interpolate to obtain only the September value. Interpolation was not necessary for the one-year horizon, because those are available on a monthly basis from the BCEI. Once we have adjusted the timing in this way and computed survey expectations for the average values of variables in the first year following the survey, it is possible to compute medium-term expectations—that is, the expected average value over the next 6 years—by taking the weighted average of the one-year and 2-6-year expectations, and long-term expectations—that is, the expected average value over the next 11 years—by taking the weighted average of the one-year, 2-6-year, and 7-11-year expectations, respectively.

[14] In the pre-1996 part of the sample, the availability of long-range forecasts in BCFF for the same months of BCEI allowed us to compare projections for the variables in common across the two Blue Chip surveys. We found that differences in forecasted values were very small, indicating that it was not inappropriate to splice together the results from both surveys from 1996 to 2014.

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Table 1. Forecast RMSEs

1 Year (Forecasts for 1983 – 2014)

	Ave. 3m T Bill	Ave. GDP growth	Ave. CPI Inflation
VAR	0.58%	1.33%	1.01%
BCS	0.92%	1.93%	1.29%

1 Year (Forecasts for 1982 – 2014)

	Ave. 3m T Bill	Ave. GDP growth	Ave. CPI Inflation
VAR	0.61%	1.37%	0.99%
SPF	1.04%	2.19%	1.35%

6 Year (Forecasts for 1988 – 2014)

	Ave. 3m T Bill	Ave. GDP growth	Ave. CPI Inflation
VAR	0.51%	0.69%	0.21%
BCS	1.84%	1.21%	0.65%

11 Year (Forecasts for 1993 – 2014)

	Ave. 3m T Bill	Ave. GDP growth	Ave. CPI Inflation
VAR	0.32%	0.39%	0.13%
BCS	1.88%	0.83%	0.84%

Table 2. Baseline identification restrictions on contemporaneous impact of shocks

Block / Variable		Shock: Policy expectations (η)	Shock: Conventaional policy (e)
$x1$	GDP	?	0
	CPI	?	0
	Labor productivity	?	0
$x2$	M2 growth	?	?
	Corporate profits	?	?
	Longer-term yield	?	?
i	3m T-Bill rate	+	–
$E^s[x_{t+h}]$	Survey GDP	+	?
	Survey CPI	+	?
	Survey 3m T-Bill	–	?

Notes: The table shows the restrictions imposed to identify structural shocks in the baseline VAR.

Table 3. Response of survey forecasts to expectations shocks

Change in expectations of…	Shock to 1-year expectations	Shock to 6-year expectations	Shock to 11-year expectations
3m T Bill	-0.03%	-0.03%	-0.02%
Log GDP	0.0014	0.0018	0.0028
Implied expected annual growth	*0.14%*	*0.03%*	*0.03%*
Log CPI	0.0009	0.0016	0.0022
Implied expected annual inflation	*0.09%*	*0.03%*	*0.02%*
Implied change in growth following 25 bp exp. sho	*1.22%*	*0.26%*	*0.26%*
Implied change in inflation following 25 bp exp. shock	*0.79%*	*0.23%*	*0.20%*

Note: Based on VARs using Blue Chip Survey under the baseline identification. Table shows responses to a one-standard-deviation shock to policy expectations at different horizons. Responses are reported for survey-based expectations at the same horizon as the shock in the period when the shock occurs.

Table 4. Largest expectations shocks identified in the VAR, 1999 - 2008

Std. Dev.	Date	FOMC Events
		Expected-Easing Shocks
-2.5	2000Q3	"Expansion of aggregate demand may be moderating"
-2.1	2001Q3	[Sept. 11]
-1.1	2001Q1	Balance of risks shifted to downside; easing cycle begins
-1.1	2006Q1	"Some further policy firming may be needed" (rather than likely)
-1.1	2002Q3	Balance of risks shifted to downside
-1.0	2004Q1	"Committee believes it can be patient…"
-1.0	2006Q3	Removal of phrase "some further policy firming may yet be needed"; "Economic growth has moderated"
-1.0	2008Q1	"Economic growth is slowing… Recent developments... have increased the uncertainty surrounding the outlook"; 75 bp intermeeting cut and downside risks
		Expected-Tightening Shocks
1.9	2005Q4	"Committee judges that some further policy firming is likely" (removed "measured pace" language)
1.5	2001Q4	???
1.5	2004Q3	Started tightening cycle
1.5	2005Q2	"Pressures on inflation have picked up in recent months", changed balance of risks from "roughly equal" to "should be kept roughly equal" with "appropriate monetary policy"
1.4	2006Q4	???
1.3	2002Q2	"Economy is expanding at a significant pace," downside balance of risks removed
1.2	2000Q2	50bp tightening. "The Committee is concerned that this disparity in the growth of demand and potential supply will continue, which could foster inflationary imbalances."
1.2	2007Q1	"Committee's predominant concern remains the risk that inflation will fail to moderate."

Notes: The table shows the quarters in which the largest expectations shocks occurred during the period 1999 – 2008, as identified by the VAR model. The right-hand column reports changes in the FOMC statement whose timing corresponded to the timing of those shocks.

Table 5. Size of conventional policy shocks required to equal the effect of a -25 bp one-year expectations shock

Horizon	Equal cumulative effect on GDP	Equal cumulative effect on CPI	Equal cumulative effect on hours
1Y	-123	--	-210
2Y	-46	--	-61
4Y	-18	-81	-4
8 Y	-40	-54	-6

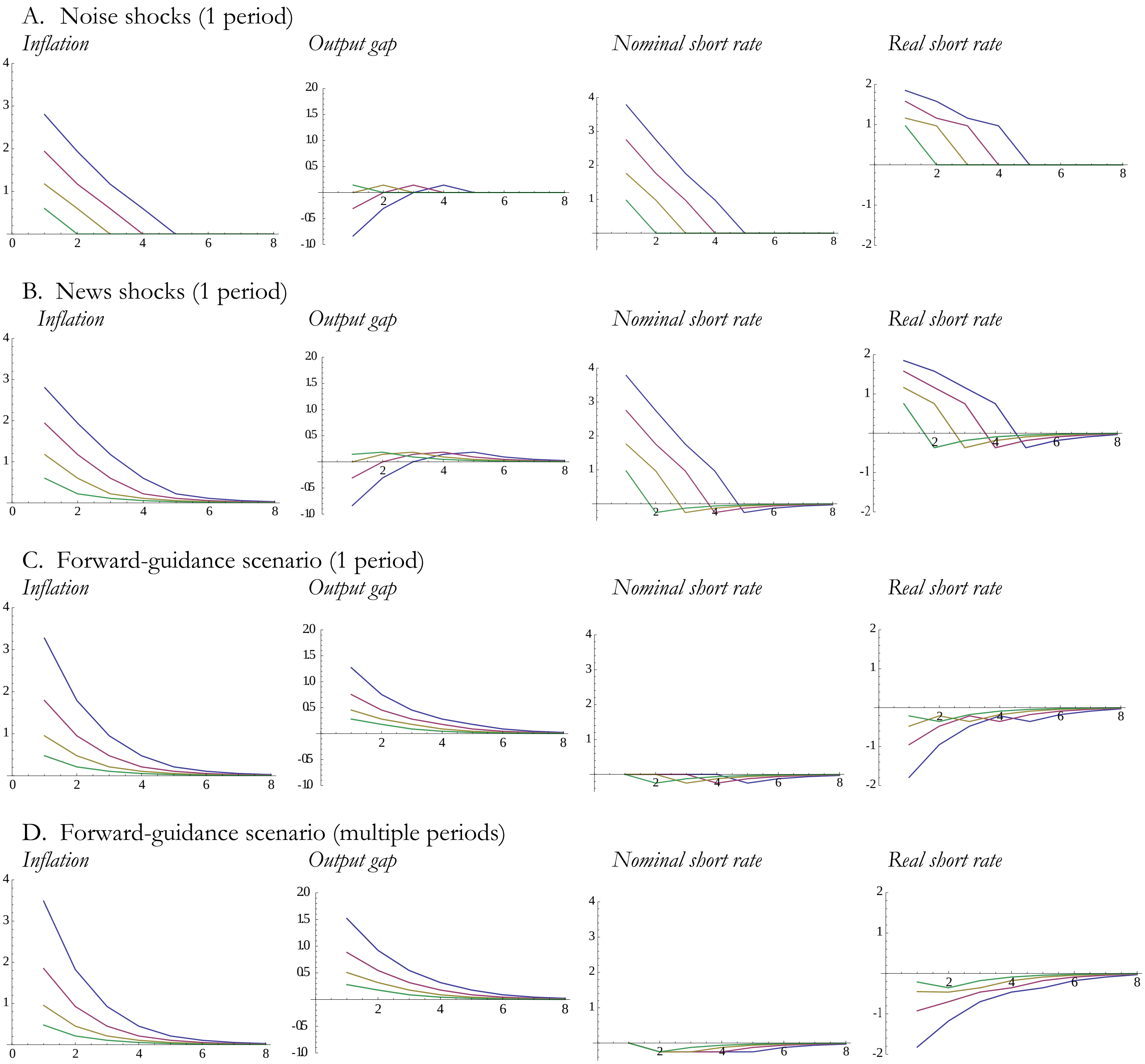
Notes: The table shows the size of an exogenous shock to the short rate (a "conventional" policy shock) that would be necessary to equal the effect of a -25bp shock to one-year expectations for the short rate on each of the indicated macro variables. One- and two-year effects on the CPI are omitted due to the negative estimated sign of the conventional policy shock at those horizons.

Table 6. Marginal effects of one-year forward guidance under alternative specifications

	GDP		CPI		Hours	
	1Y	5Y	1Y	5Y	1Y	5Y
Baseline	1.2%*	0.9%*	0.9%*	0.7%*	1.3%*	0.6%*
Pre-ZLB period	1.2%*	1.0%*	0.9%*	0.9%*	0.8%*	0.3%
More lags	1.3%*	1.2%	0.9%*	0.7%	1.4%*	0.6%
SPF instead of BCS (begins 1981)	1.6%*	1.1%*	1.4%*	1.1%*	1.5%*	0.9%*
1Y and 6Y surveys both included	1.0%*	0.7%	0.9%*	0.7%*	0.7%*	0.1%
Expectations shocks use sign restriction on real yield	1.3%*	1.0%*	0.9%*	0.8%*	1.3%*	0.6%
Policy shocks identified by sign restrictions	1.0%*	0.7%	1.0%*	0.7%	1.0%*	0.4%
Minnesota prior	1.0%*	1.2%	1.4%*	1.1%*	1.4%*	0.8%

Notes: Under various modeling alternatives, the table reports simulations of a "forward guidance" policy that commits to maintain the short-term interest rate 25 basis points below the value prescribed by the policy rule for the next four quarters, relative to a situation in which the central bank adopts this same path for the short rate without announcing it in advance. The columns show the difference between the effects of these two policies on macroeconomic variables one and five years after the forward-guidance announcement. See Section 5 of the text for details on the construction of the scenario in the baseline case. GDP and CPI are reported in terms of cumulative log levels. Hours are reported as forward (non-cumulative) log levels. Numbers in the table are medians across 10,000 parameter-vector draws. Asterisks indicate that the marginal effects of forward guidance are positive for at least 95% of the draws.

Figure 1. Expectations and Forward-Guidance Shocks in the New Keynesian Model



Notes: The figures show the effects of a shock to subjective expectations for monetary policy that is sufficient to lower expectations of the short-term interest rate h periods ahead by 25 basis points, where h= 1 (green), 2 (yellow), 3 (red), and 4 (blue). In panel A, we the anticipated shock to policy does not materialize. In panel B, the anticipated shock does materialize and the central bank takes no other actions. In panel C, the anticipated shock materializes and in addition central bank introduces anticipated policy shocks in order to maintain the nominal short rate at zero in periods t through $t+h-1$. In panel D, the central bank holds the short rate at -.25 in periods $t+1$ through $t+h$. Responses are shown for the period of the expectations shock and seven subsequent periods. Calibration of the model is as described in the text. All variables are in percentage points. Inflation and interest rates are expressed as annual rates.

Figure 2. Comparison of SPF and BCS one-year forecasts

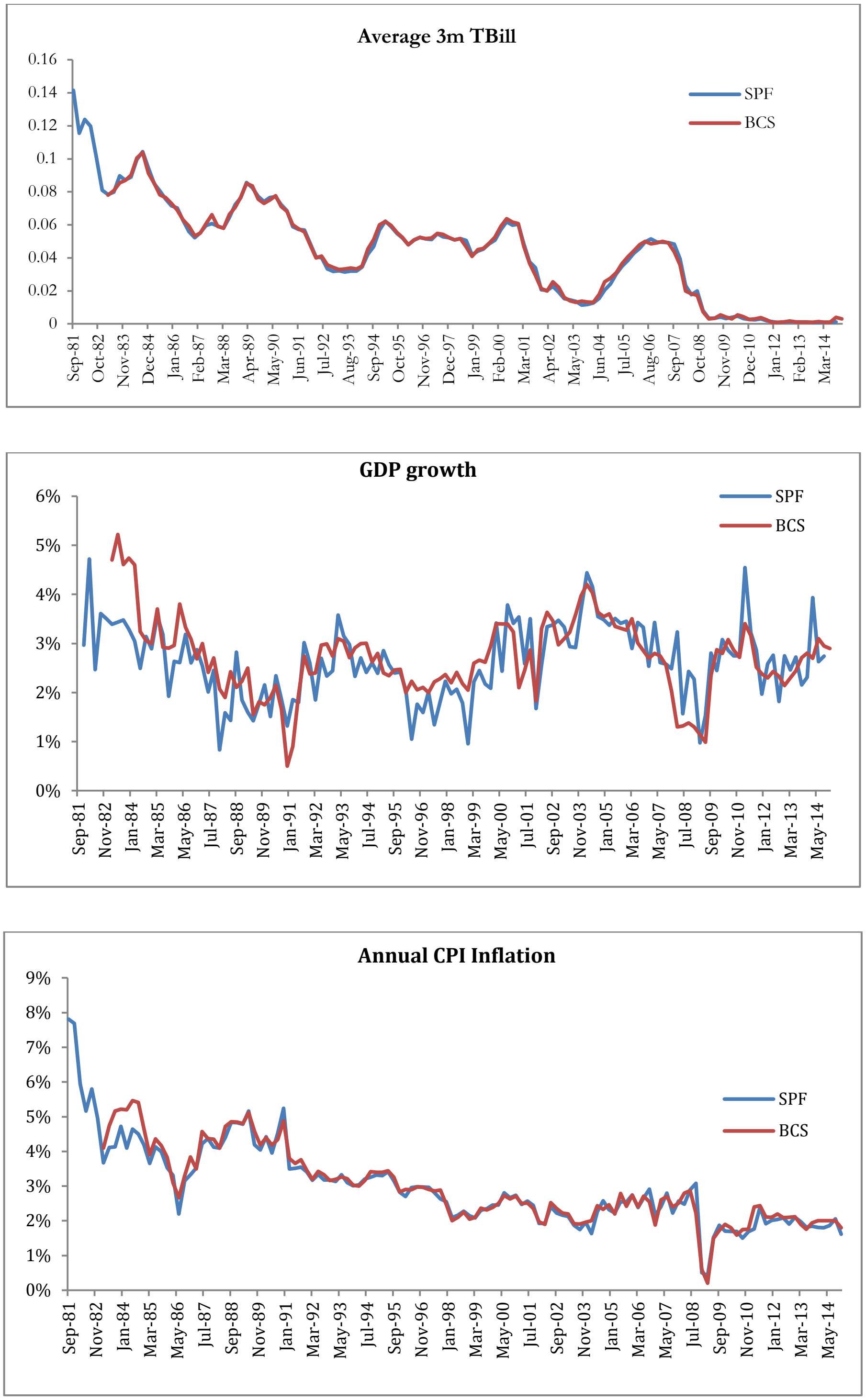
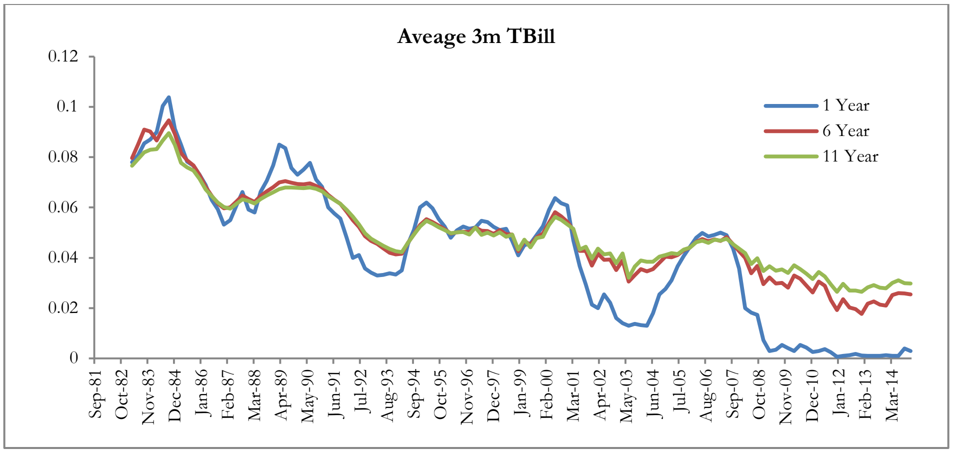
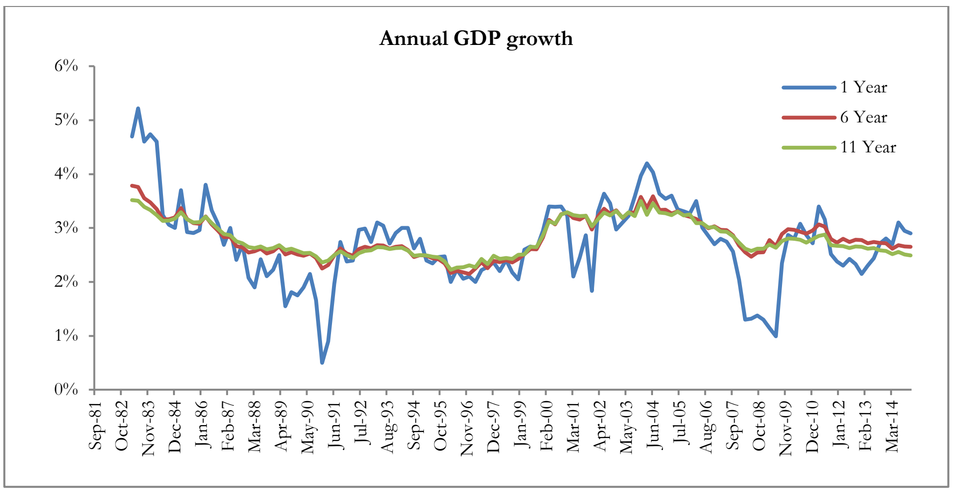


Figure 3. Term structure of BCS forecasts





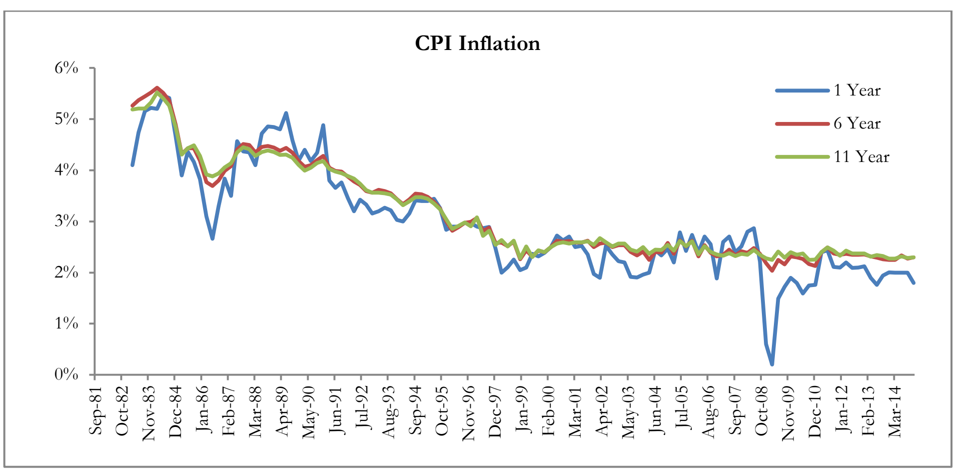
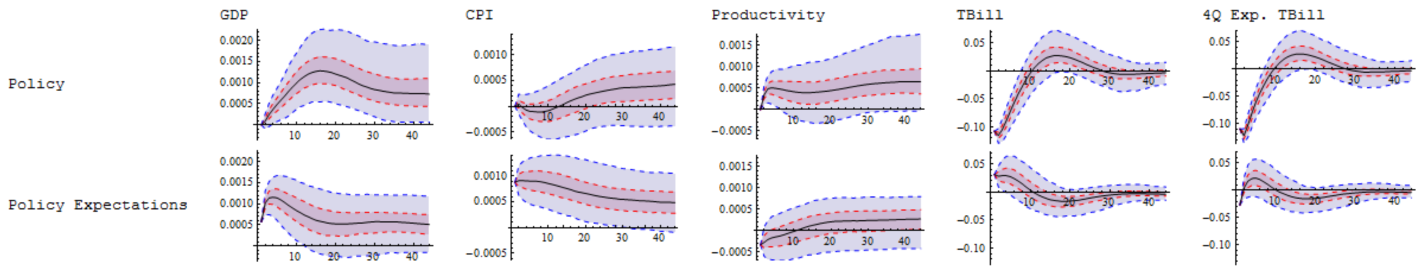
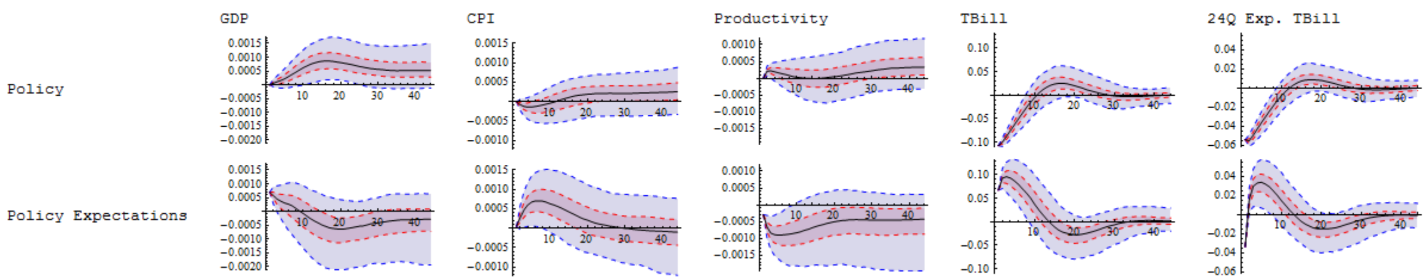


Figure 4. Impulse-response functions

A. Using 1-year expectations



B. Using 6-year expectations



C. Using 11-year expectations

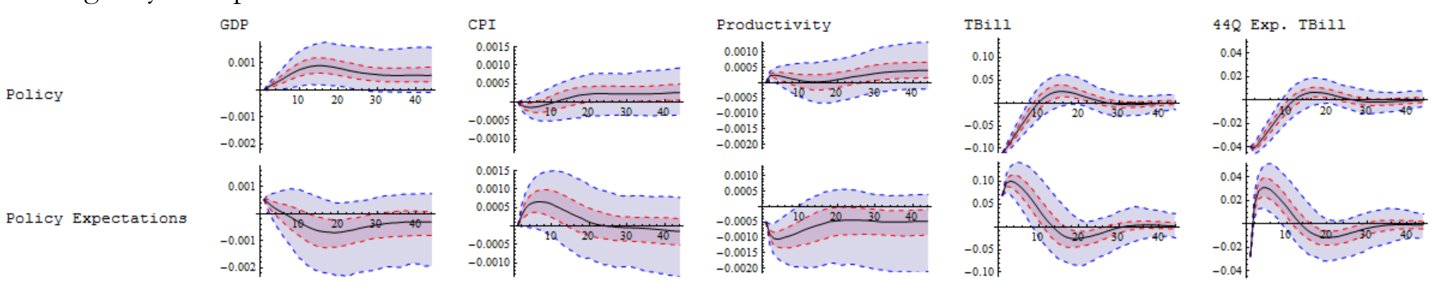
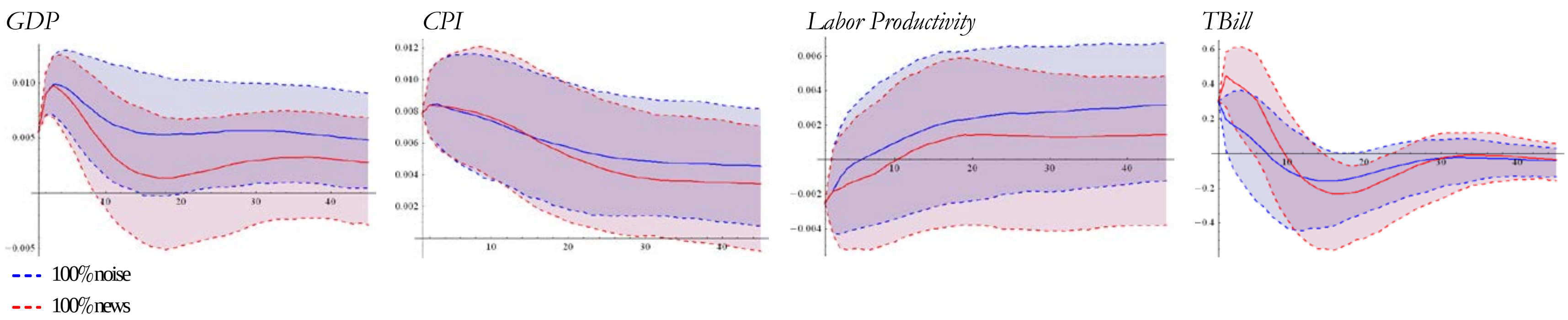


Figure 5. Causality bounds on 25-basis-point expectations shocks

A. Using 1-year expectations



B. Using 6-year expectations

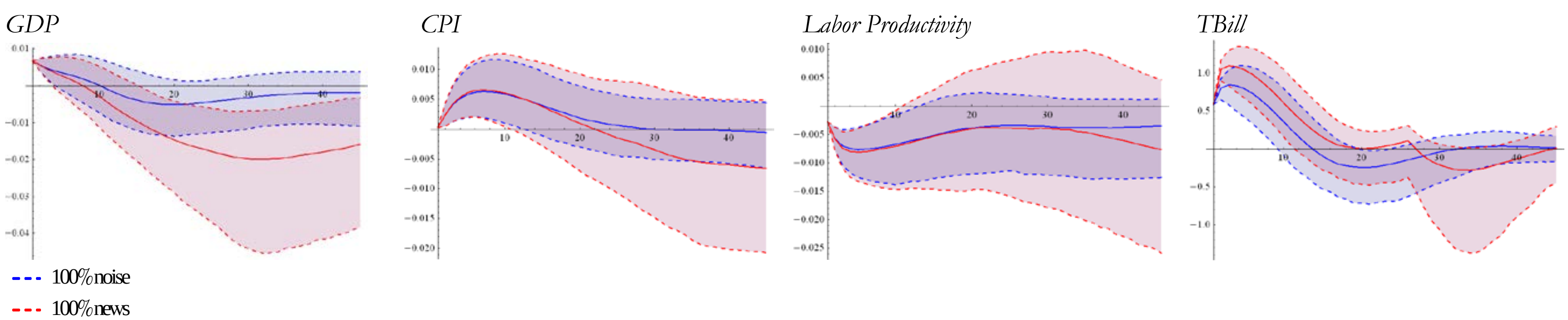
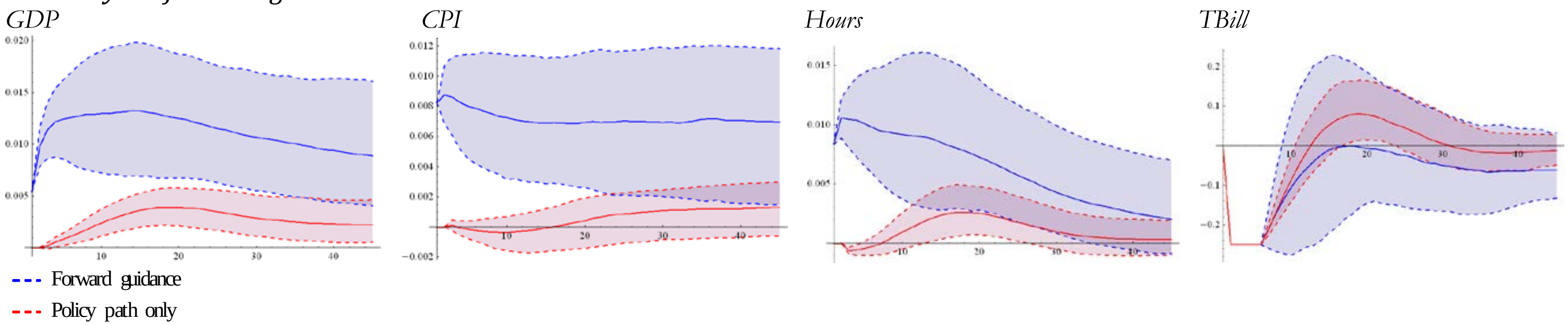


Figure 6. The effects of "forward guidance" scenario

A. One-year forward guidance



B. Six-year forward guidance