The Effectiveness of "Forward Guidance" during the Great Recession*

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Abstract

This paper examines the performance of the Federal Reserve's "forward guidance" policy during the "Great Recession." We first develop an algorithm to solve linear rational expectations models with forward guidance policy in the presence of non-linear zero lower bound (ZLB) of interest rate, and then examine the policy implications in an estimated New Keynesian model of the U.S. economy. Empirical analysis suggests that the ZLB imposes a severe constraint to conventional interest rate policy during 2009-2010, generating a binding horizon of 4 to 6 years. The Federal Reserve's "forward guidance" by then, however, is not strong enough to overcome such a constraint. In contrast, alternative "history dependent" approaches would have prescribed a much more aggressive forward guidance, and would have led to a significantly quicker economic recovery, with simulated short-term interest rate beginning to rise above zero in late-2012 to mid-2013.

KEYWORDS: Forward guidance, Monetary policy, Zero lower bound, ZLB

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1. Introduction

A central bank's "forward guidance" on future interest rates is a "natural" part of its policy exercise (Svensson 2015), because general public's consumption and investment decisions are based on not only the current economic conditions, but more importantly, their expectations of future state of the economy including interest rates. When the nominal short-term interest rates become constrained by the zero lower bound (ZLB) as a number of central banks have experienced during the recent "Great Recession," influencing public's expectations of future short-term interest rates through forward guidance becomes an even more important policy tool, as there is little room left to implement conventional monetary policy and cut the nominal interest rates substantially below zero.[1]

However, how to conduct effective "forward guidance" at the ZLB remains a big challenge to central banks around the world, and different approaches have been experimented as central banks move into uncharted waters of this unconventional monetary policy. For instance, after the federal funds rate essentially hit the ZLB by the end of 2008 in the U.S., the Federal Reserve has been actively communicating with general public over its future interest rate policy on a regular basis, and has changed its approaches several times: First, it announced that the federal funds rate would remain at "exceptionally low levels" for "some time" (FOMC statement, December 16, 2008) and later "an extended period" (March 18, 2009), and then switched to an approach with more specific calendar date of "at least through mid-2013" (August 9, 2011), and further extended the date to "at least through late 2014" (January 25, 2012) and then again "at least through mid-2015" (September 13, 2012); Later, the FOMC changed the guidance format again, from the date-based approach to a threshold-based approach, linking the "lift-off" or the first increase of federal funds rate target to specific economic indicators including unemployment rate and inflation expectation (December 12, 2012). More recently, the format was changed again, back to the initial qualitative approach and promised to maintain the federal funds rate target at the near-zero level for "a considerable time after the asset purchase program ends"

[1] Nominal interest rates have been reduced to be slightly negative in several recent scenarios. For instance, in June 2014, the European Central Bank lowered its deposit rate to -0.10 percent, and further reduced it to -0.20 percent in September 2014. More recently, in early 2015, both Swiss National Bank and Danmarks Nationalbank lowered their policy rates to -0.75 percent. However, the potential capacity of conducting this kind of policy is rather limited, as there still exists a lower bound of nominal interest rate below which economic agents would explore the possibility of alternative payment, clearing, and settlement systems.

(March 19, 2014). Such frequent changes over time may reflect not only the constantly changing macroeconomic and financial fundamentals, but also a continuing experiment with different communication approaches, largely due to a general unfamiliarity of policy environment, for both general public and the central bank. This calls for a better understanding and assessment of the effectiveness of different strategies of forward guidance, which is the focus of this paper.

Alternative monetary policy approaches in the presence of the ZLB have attracted many researchers' attention since the pioneering works of Krugman (1998) and Eggertsson and Woodford (2003). More recently, a number of studies have analyzed the effectiveness of "forward guidance" at the ZLB, for instance Levin, López-Salido, Nelson, and Yun (2010), Campbell, Evans, Fisher, and Justiniano (2012), and Chung, Laforte, Reifschneider, and Williams (2012). However, most of this line of research focuses on analyzing the announcement effect of this kind of policy, in particular on financial asset prices such as federal funds futures, bond prices, equity, or exchange rates (e.g. Bauer 2012, Femia, Friedman, and Sack 2013, Filardo and Hofmann 2014), but much less on real economic activities. Even the very few studies which have analyzed the real macroeconomic dynamics are often limited to either quantifying the announcement effect of market projections of future economy, or analyzing the theoretical implications of "forward guidance" policy in well-calibrated general equilibrium models in a non-stochastic settingwith a perfect foresight, and do not examine the on-going policy measures in the current ZLB environment, or explore the performance of alternative formats or rules of "forward guidance."[2] On the other hand, since the onset of the recent crisis, many studies have been conducted to analyze the unconventional monetary policy experiences in the U.S. and other countries during the "Great Recession" — a short list includes Gagnon, Raskin, Remache, and Sack (2011), Krishnamurthy and Vissing-Jorgensen (2011), Christensen and Rudebusch (2012), Swanson and Williams (2013), Wu (2013), among others — yet most of them focus on the implications of another kind of unconventional monetary policy, i.e. central bank asset purchase programs, on asset prices such as long-term bond yields, largely by taking an event-study approach, but few have taken a model-based approach to examine the macroeconomic implications of forward guidance policy on future interest rates.

[2] Moreover, these DSGE models often generate the so-called "forward guidance puzzle," that is, they tend to "grossly over-estimate the impact of forward guidance on the macroeconomy" (Del Negro, Giannoni, and Patterson 2013), stemming from their specifications of purely forward-looking inflation expectations, as well as a high interest-rate elasticity as calibrated in the IS equation (Weale 2013).

This paper analyzes the effectiveness of the U.S. Federal Reserve's forward guidance policy since early 2009 in an empirical New Keynesian macroeconomic model. To overcome the difficulties of imposing a non-linear ZLB constraint in a linear rational expectations model, we model the presence of the ZLB and the central bank's forward guidance announcements as a series of anticipated shocks similar to Laséen and Svensson (2011), and develop an algorithm to numerically solve the model-consistent expectations of future state of the economy including the future interest rate paths under the forward guidance as announced in each period, based on which model solution is presented. We then examine the macroeconomic implications of the Fed's forward guidance policy since early 2009 in an estimated New Keynesian model, and conduct a series of simulation experiments to analyze the performance of several alternative forward guidance policy rules that have been proposed by the literature, in particular a "compensation rule" by Reifschneider and Williams (2000), and a "price-level target rule" similar to Krugman (1998) and Eggertsson and Woodford (2003).

Empirical analysis generates several interesting conclusions. First, the magnitude of the adverse shocks at the onset of the "Great Recession," as implied by model estimation, is comparable to but not significantly more severe than what prevailed during the two recessions in 1980-1982 in the U.S. However, due to the low-inflation and low-interest rate environment prior to the current crisis, the ZLB becomes a severely binding constraint, for a horizon of 4 to 6 years as of 2009 and 2010, and thus has greatly limited the usefulness of conventional short-term interest rate policy. The Fed's forward guidance policy in the first two years of "Great Recession" (2009-2010), however, is not aggressive enough to substantially change the public's expectations of future short-term interest rates and thus lower the long-term interest rates, as the policy announcements by then only imply a near zero-rate horizon for the following three to four quarters, significantly shorter than what the ZLB constraint would actually have implied. Thus such forward guidance announcements have little effect in lowering public's expectations of future short-term interest rate path or stimulating real economic activities, beyond what has already been implied by the ZLB even without forward guidance. The Fed's "forward guidance" exercises since 2011, on the other hand, have substantially overcome the constraint that the ZLB imposes on future short-term interest rate path and long-term interest rates, and thus have been able to effectively provide additional monetary stimulus as needed. Counter-factual analysis also suggests that two alternative "history dependent" rules would have prescribed a much more aggressive guidance in keeping future interest rates low from the beginning of the "Great Recession," and thus would have led to a significantly quicker economic recovery, with simulated short-term interest rate beginning to rise above zero in late-2012 to mid-2013.

The rest of the paper is structured as follows. Section 2 lays out the theoretical framework and develops an algorithm to conveniently solve linear rational expectations models with "forward guidance" policy in the presence of the non-linear ZLB constraint. Section 3 specifies and estimates an empirical New Keynesian model for the U.S. economy, and Section 4 examines the implications of the ZLB and the Fed's forward guidance exercises on the U.S. economy during the "Great Recession." Section 5 conducts several counter-factual simulation experiments to analyze the performance of alternative "forward guidance" policy rules and compares with the actual economic performance since early 2009. It also examines the robustness of the main conclusions in particular in the face of a flatter Phillips curve. Section 6 compares different features and limitations of various approaches to conduct "forward guidance," and Section 7 concludes.

2. The ZLB and Forward Guidance in Rational Expectations Models

Let us start from a standard New Keynesian dynamic stochastic general equilibrium (DSGE) model as the ones in Clarida, Galí, and Gertler (1999) and Woodford (2003). The reduced form of such models generally consists of two key equations: a New Keynesian Phillips curve (NKPC)

$$\pi_t = \beta E_t \pi_{t+1} + \lambda y_t + \varepsilon_{\pi,t} \tag{2.1}$$

where π_t and $E_t \pi_{t+1}$ denote the one-period inflation rate and the expected inflation over next period, respectively. y_t is the output gap, β the representative household's time preference, λ the slope coefficient of the NKPC and $\varepsilon_{\pi,t}$ a disturbance on the supply side which is often referred to as mark-up shocks in the literature, and an IS curve directly from households' Euler equation

$$y_t = E_t y_{t+1} + \gamma(i_t - E_t \pi_{t+1}) + \varepsilon_{y,t} \tag{2.2}$$

where $i_t - E_t \pi_{t+1}$ is the ex-ante one-period real interest rate, and $\varepsilon_{y,t}$ a disturbance from the aggregate demand side such as government purchases or financial frictions. The model is usually completed with a monetary policy rule in terms of one-period interest rate, for instance, a simple Taylor rule or its variant

$$i_t = f(\{\pi_{t-k}\}_{k=0}^{\infty}, \{y_{t-k}\}_{k=0}^{\infty}) \tag{2.3}$$

and is often assumed to be subject to a nominal interest rate shock $\varepsilon_{i,t}$ which mimics monetary policy shock.

Iterating equation (2.2), we obtain

$$y_t = \gamma \sum_{k=0}^{\infty}(E_t i_{t+k} - E_t \pi_{t+k+1}) + \sum_{k=0}^{\infty} E_t \varepsilon_{y,t+k} \tag{2.4}$$

Thus, the output gap primarily depends on not only the real interest rate in the current period, but also on the expected real interest rates in the future. Through the Phillips curve equation (2.1) the expected future real interest rates will also affect inflation, as current inflation is determined by the current output gap as well as the expected output gap going forward:

$$\pi_t = \lambda \sum_{k=0}^{\infty} \beta^k E_t y_{t+k} + \sum_{k=0}^{\infty} E_t \varepsilon_{\pi,t+k} \tag{2.5}$$

Therefore, both real output and inflation depend not only on the interest rate in the current period, but more importantly, on the public's expectations of future interest rates. This implies that, after short-term interest rates become constrained by the ZLB, a central bank may still be able to influence output and inflation in the *current* period, through influencing the public's expectation of *future* short-term interest rates, i.e., "forward guidance."

Empirical examination of the effects of "forward guidance" in rational expectations models, however, can be computationally challenging. In addition to the complications arising from imposing a non-negativity constraint (the ZLB) in linear models, the current format of forward guidance policies also brings additional difficulties in finding model solutions. For instance, in the rational expectations literature, model solutions are usually expressed in terms of an infinite moving average representation of current and future exogenous shocks including policy shocks. However, when making "forward guidance" announcements, most central banks in practice would commit to an explicit interest rate path for the future, for example, keeping the policy rate at zero for x quarters. The magnitude of monetary policy shocks such a promise represents is not explicitly given, but partly determined by the public's current expectations of future state of the economy including interest rate, which in turn, are also affected by the current "forward guidance" announcement. More importantly, in the presence of forward guidance, even the severity of the ZLB becomes endogenous — suppose that with a given set of exogenous shocks, the ZLB may become a binding constraint for q periods, i.e., the central bank would have to keep the interest rate at zero for q periods. However, the central bank's forward guidance will change economic agents' expectations of future state of the economy, and consequently the output and inflation dynamics as well as the interest rate path as intended by the central bank will also change, and that the ZLB may become less binding, i.e., for q' period instead of q period. This implies that the magnitude of policy accommodation embodied in this x-quarter forward guidance announcement becomes an endogenous variable and needs to be determined along with a model-consistent expectational path of future state variables. In contrast, most existing DSGE studies of "forward guidance" avoid this complication by simply assuming that the length of ZLB-binding period is invariant and exogenously given, which is not only unrealistic but also limits the scope to examine the policy effectiveness in changing public's expectations.

Therefore, the usual approaches to solve rational expectations models cannot be directly applied, and we need to first find a way to quantify the anticipated policy shocks as implied by each "forward guidance" announcement, as well as the model-consistent expectational path of future state variables. Another layer of technical difficulty is that each "forward guidance" announcement implies a *path* of the level of future policy rates instead of a *point* as in conventional interest rate policy announcements, therefore the dimensionality of the state variables constitutes another challenge when analyzing "forward guidance" policy in rational expectations models.

To solve such linear rational expectations models in a tractable way, we develop the following algorithm, based on an earlier algorithm proposed by Laséen and Svensson (2011) in analyzing anticipated policy shocks. Note that with the presence of the ZLB and "forward guidance," the original interest-rate rule (2.3) does not hold any more, but rather, is subject to a shock ψ_t

$$\begin{aligned} i_t &= f(\{\pi_{t-k}\}_{k=0}^{\infty}, \{y_{t-k}\}_{k=0}^{\infty}) + \psi_t \\ &= i_t^* + \psi_t \end{aligned} \tag{2.6}$$

where i_t^* denotes the level of interest rate that central bank would intend to keep if there were no ZLB or forward guidance, and the shock ψ_t is equal to either $-i_t^*$ or zero. Therefore, whenever i_t^* is negative and the ZLB becomes a binding constraint in period t, $\psi_t = -i_t^* > 0$, and the interest rate stays at zero; when the ZLB is not binding any more and i_t^* becomes positive, as long as the central bank still intends to keep the interest rate i_t at zero, it can achieve the goal by introducing a negative shock $\psi_t = -i_t^* < 0$; and finally, when the central bank eventually decides to go back to the original interest rate rule (2.3), ψ_t is reduced to zero.

Therefore, a central bank's "forward guidance" practice can be conveniently summarized in the following fashion. We first denote the expectation of future shock ψ_t in period $t-j$ as $\psi_{t,t-j}$, so that the short-term interest rate in period t as anticipated in period $t-j$ becomes

$$\begin{aligned} E_{t-j}i_t &= E_{t-j}\{f(\{\pi_{t-k}\}_{k=0}^{\infty}, \{y_{t-k}\}_{k=0}^{\infty})\} + \psi_{t,t-j} \\ &= E_{t-j}i_t^* + \psi_{t,t-j}, \qquad j = 0, 1, .. \end{aligned} \tag{2.7}$$

In particular, $\psi_{t,t-j}$ is equal to either $-E_{t-j}i_t^*$ or zero, so that when the ZLB is expected to be a binding constraint in period t, $\psi_{t,t-j} = -E_{t-j}i_t^* > 0$, and the expected interest rate $E_{t-j}i_t$ equals zero; when the ZLB is expected to become non-binding in period t and $E_{t-j}i_t^* > 0$, yet the central bank still commits to a zero interest rate for that period, $\psi_{t,t-j} = -E_{t-j}i_t^* < 0$ and the expected interest rate $E_{t-j}i_t$ remains zero under the central bank's "forward guidance"; and finally, when the ZLB is non-binding and the central bank is also expected to let the interest rate go above zero in period t as of period $t-j$, $\psi_{t,t-j}$ reduces to zero. Thereby, a central bank's forward guidance in period t is essentially announcing a series of anticipated shocks $\{\psi_{t+j,t}\}_{j=0}^{\infty}$.

Since the public and the central bank constantly update their expectations of the future state of the economy and therefore the magnitude of $E_{t-j}i_t^*$, even when the interest rate in period t is expected to remain zero, the magnitude of $\psi_{t,t-j} = -E_{t-j}i_t^*$ will change over time. Therefore, $\psi_t = E_t\psi_t = \psi_{t,t}$ is best modeled as a martingale process

$$\psi_t = \psi_{t,t} = \sum_{j=0}^{\infty}(E_{t-j}\psi_t - E_{t-j-1}\psi_t) = \sum_{j=0}^{\infty}(\psi_{t,t-j} - \psi_{t,t-j-1}) = \sum_{j=0}^{\infty}\eta_{t,t-j} \tag{2.8}$$

where $\eta_{t,t-j} = E_{t-j}\psi_t - E_{t-j-1}\psi_t$ is a zero-mean *i.i.d.* process representing the updates of the expectation of future policy-rate deviation ψ_t from i_t^*, based on updated information in period $t-j$.

The implementation of this algorithm is surprisingly straightforward. For tractability, assume that ψ_t is an $MA(N)$ process, so that $\psi_t = \sum_{j=0}^{N}\eta_{t,t-j}$, N being a number sufficiently large, for instance, 40 quarters. Moreover, let an $(N+1)$-vector $\psi^t = (\psi_{t,t}, \psi_{t+1,t}, \psi_{t+2,t}, ..., \psi_{t+N,t})'$ denote the expectation of the stochastic variables ψ_{t+j} as in period t, $j = 0, 1, 2, ..., N$, and $\eta^t \equiv (\eta_{t,t}, \eta_{t+1,t}, \eta_{t+2,t}, ..., \eta_{t+N,t})'$ a zero-mean *i.i.d.* random $(N+1)$-vector to be realized at the beginning of period t. Thus we have

$$\psi^t = A_\psi\psi^{t-1} + \eta^t \tag{2.9}$$

where

$$A_\psi = \begin{bmatrix} 0_{N\times 1} & I_N \\ 0 & 0_{1\times N} \end{bmatrix}$$

and the $(N+1)$-vector $\psi^t \equiv \{\psi_{t+j,t}\}_{j=0}^N$ is specified to follow an $MA(N)$ process. Therefore, we can append the process (2.9) to the state-space representation of the original rational expectations model (2.1) to (2.3) and examine the impacts of specific forward guidance under the ZLB constraint.

Before turning to the model specifications in the next section, we would like to distinguish two possible scenarios of "forward guidance" that have very different macroeconomic implications. When the ZLB becomes a binding constraint, the interest rate will have to stay at zero for some time even without any "forward guidance." Therefore, whenever a central bank commits to keep nominal interest rate at zero, for instance, for x quarters, we need to distinguish whether such a promise simply reflects the fact that the interest rate will be bounded by the ZLB for x quarters, or truly reflects an active policy commitment to provide extra monetary stimulus beyond the ZLB-implied zero-rate horizon. These two kinds of "forward guidance" policy announcements represent very different policy actions and would generate different reactions in real economy, yet such a distinction has been generally ignored in recent studies of "forward guidance." The notation above provides a simple way to distinguish these two kinds of "forward guidance" in the model, in particular, we define the former case a "passive" forward guidance whenever $\psi_{t+j,t}$ is positive or zero for all $j \geq 0$, and the latter case an "active" forward guidance whenever the policy announcement generates a negative $\psi_{t+j,t}$ for at least one periods $t+j$. The empirical policy analysis later will show examples of these two scenarios.[3]

[3]It may be tempting to describe these two kinds of forward guidance as "Delphic" and "Odyssean" as in Campbell et. al. (2012)'s terminology. However, there is a conceptual difference: according to Campbell et.al. (2012), Delphic forwad guidance publishes a forecast of future macroeconomic conditions and the intended monetary policy actions based on the policymaker's potentially superior information, but central bankers do not commit themselves to a particular course of action, whereas Odyssean forward guidance does publicly commit the central bankers. In the current study, the central bank does not have superior information, and both "passive" and "active" forward guidance will be solid promises to keep. Their difference lies in the magnitude of policy effect, i.e., whether they are strong enough to overcome the binding constraint of the ZLB and provide additional monetary accommodation so as to materially change the public's expectations of future state of the economy.

3. Model Specifications and Estimation

To investigate the performance of the current forward guidance exercise and other alternative policy rules in the current ZLB environment in the U.S., I use a very simple, reduced-form version of the New Keynesian model as in Section 2. In particular, the first equation is a hybrid New Keynesian Phillips curve as in Galí and Gertler (1999), among others:

$$\pi_t = \alpha_0 + \rho_\pi \sum_{i=1}^{4} \frac{\pi_{t-i}}{4} + (1-\rho_\pi) \sum_{i=1}^{4} \frac{E_t \pi_{t+i}}{4} + \lambda \sum_{i=1}^{2} \frac{y_{t-i}}{2} + \varepsilon_{\pi,t} \tag{3.1}$$

where $\sum_{i=1}^{4} \frac{\pi_{t-i}}{4}$ is the average inflation rate in the past four quarters, $\sum_{i=1}^{4} \frac{E_t \pi_{t+i}}{4}$ the expected inflation rate over the next four quarters, and $\sum_{i=1}^{2} \frac{y_{t-i}}{2}$ the average unemployment rate gap in the previous two quarters. The lagged inflation rates are included to reflect partial price indexation (Christiano, Eichenbaum, and Evans 2005, Sbordone 2005, Eichenbaum and Fisher 2007) or adaptive expectations (Roberts 1997), and help to capture the observed inflation persistence which is otherwise difficult to explain.

The second equation of the model is a modified equation (2.2) with a backward-looking term, which is crucial to account for real-world costs of adjustment and habit formation (Fuhrer and Rudebusch 2004)[4]:

$$y_t = \beta_0 + \rho_y \sum_{i=1}^{2} \frac{y_{t-i}}{2} + (1-\rho_y) \sum_{i=1}^{2} \frac{E_t y_{t+i}}{2} + \gamma\Big(\sum_{i=0}^{3} \frac{i_{t-i}}{4} - E_t \pi_{t+1}\Big) + u_{y,t} \tag{3.2}$$

In particular, unemployment rate gap depends on not only the current real interest rate and expected unemployment rate gaps over the next two quarters, but also the lagged unemployment rate gaps in the last two quarters. Similarly, lagged interest rates in the last three quarters are also included as in Rudebusch and Svensson (1999), among others. For parsimony, restrictions are imposed so that the sum of the lagged and forward inflation and unemployment rate gap terms equal one in both equations, respectively. A preliminary estimation suggests that the autocorrelations of the fitted residuals in Phillips curve equation (3.1) are very small, but quite large in the IS equation (3.2). Therefore, I modify the specification in equation (3.2) to incorporate an AR(2) specification in its residual term:

$$u_{y,t} = \rho_{u,1} u_{y,t-1} + \rho_{u,2} u_{y,t-2} + \varepsilon_{y,t}. \tag{3.3}$$

[4] Rudebusch and Wu (2008) provide evidence from term structure supporting this hybrid version of IS curve.

Finally, the model is closed with a simple Taylor rule with the following specifications featuring interest rate smoothing:

$$i_t = \eta_0 + \rho_i i_{t-1} + (1-\rho_i)[\mu_\pi \sum_{i=0}^{3} \frac{\pi_{t-i}}{4} + \mu_y \sum_{i=0}^{1} \frac{y_{t-i}}{2}] + \varepsilon_{i,t} \tag{3.4}$$

The model is estimated based on a post-war U.S. sample from 1979:Q1 to 2008:Q4.[5] Inflation rate π_t is measured using the GDP chain-weighted price index, and unemployment rate gap y_t is measured by the difference between the unemployment rate and the Congressional Budget Office's estimates of natural rate of unemployment. Interest rate i_t is the quarterly average of effective federal funds rate. Inflation expectation is based on the median response of the Survey of Professional Forecasters, and the expected unemployment rate gap is proxied by the forecast of a univariate AR(3) model over a recursive sample starting 1949:Q1. As displayed in Table 1, coefficients estimates are very close to the standard results from the literature for post-war U.S. economy.

The empirical policy analysis and simulations of alternative policy rules in the next two sections will be based on the model specifications described above as well as coefficient estimates reported in Table 1, although the expectational terms of inflation and unemployment rate gap will be endogenously derived in a model-consistent way, rather than relying on survey results. We choose to end the estimation sample in 2008:Q4, since the monetary policy environment has obviously changed after the ZLB becomes binding in 2009:Q1, and we prefer not to have the period of unconventional monetary policy to compromise the estimation results. Another reason for doing so is that the policy analysis and simulations may be more realistic, because of the real-time feature of estimation sample.

Here we choose a very simple model specification and estimation method to illustrate the implementation of the methodology developed in Section 2. More complicated model specifications or estimation strategies may generate somewhat different and potentially more accurate

[5] Here I use a direct measure of inflation expectations from the Survey of Professional Forecasters, similar to Clark et. al. (1996), Roberts (1998), and Rudebusch (2002). In the past two decades, literature has developed alternative methods to estimate the hybrid New Keynesian model, for instance, the GMM estimator advocated by Galí and Gertler (1999). However, Linde (2005) and Rudd and Whelan (2005) suggest that the GMM estimator may generate a substantial small-sample bias, and the direction of the bias could be either upward or downward. Another alternative is the Full-inflation Maximum Likelihood (FIML) estimator used by Fuhrer (1997), in which he closes the model with unrestricted autoregressive equations and model-consistent expectations, and obtains an almost zero estimate of the forward-looking term in Phillips curve.

estimation results. However, the literature has very diverse opinions on the specifications and estimation methodology of empirical New Keynesian Phillips curve and IS equations.[6] Because the main goal of this section is to obtain a realistic workhorse model with reasonable parameter values as the basis of policy analysis and simulations in later sections, we choose this very standard model specification and simple estimation strategy, and the standard parameter values that the literature largely agree on. On the other hand, in later sections we do examine the implications of alternative model specifications, for instance, a flatter Phillips curve.

Figure 1 displays the impulse responses of the estimated model. In particular, a one-standard-deviation inflation shock raises the inflation rate by 98 basis points in the current quarter, and 42 basis points for the first four quarters after shock on average. In response to higher inflation, central bank will gradually raise nominal interest rate, reaching a maximum of 40 basis points in six quarters. Real interest rate rises as well, leading to a gradual increase of unemployment rate, with the maximal response coming in eight quarters after the initial shock at 16 basis points. On the other hand, an exogenous shock to unemployment rate leads to a gradual reduction in nominal interest rate and inflation (column 2), and an exogenous monetary policy shock to current quarter's interest rate would lead to a gradual increase in unemployment rate and a decline in inflation (column 3), all consistent with usual findings in empirical literature.

Column 4 of Figure 1 plots the impulse responses to a different kind of monetary policy shock, which raises the interest rate in the current and following three quarters by 25 basis points each, i.e., a 25-basis point increase of $\eta_{t,t}, \eta_{t+t,t}, \eta_{t+2,t}$, and $\eta_{t+3,t}$ under the above notation. Because of the forward-looking feature of the model, the impulse responses of inflation and unemployment rate to such an anticipated policy shock are quantitatively very similar to those displayed in column 3, when only the interest rate in the current quarter is subject to a 100-basis point shock. Responses of long-term bond yields to these two kinds of policy shocks are also very similar, although responses of one-year bond yield in column 4 are somewhat different from column 3 as one would expect. These response patterns suggest that "forward guidance" of this format can potentially be effective, if delivered in a fully credible way.

[6] For the former, see the discussions between Lindė (2005) and Galí, Gertler, and Lopez-Salido (2005) over the GMM and FIML estimation strategies of Phillips curve; For the latter, see Fuhrer (2000) and Rudebusch (2002).

4. Evaluation of the FOMC's "Forward Guidance": A First Look

Next we examine the performance of "forward guidance" exercise in the U.S. since 2009:Q1. Our plan is to first impute the model-implied shock series including real shocks ($\varepsilon_{\pi,t}$ and $\varepsilon_{y,t}$) and the anticipated policy shocks as implied by the FOMC's "forward guidance" exercise ($\psi_{t,t-j}$ and $\eta_{t,t-j}$'s), for each quarter during 2009-2013. This allows us to examine the evolution of market expectations of future interest rate path as well as the performance of "forward guidance" policy since early 2009. In the next section, we then conduct counter-factual experiments and simulate model economy under alternative "forward guidance" policy rules, and compare their implications with the actual policy performance. Finally, we will examine the robustness of alternative policy rules under various kinds of macroeconomic uncertainties, and discuss the implementation of alternative forward guidance rules.

We first derive the model-implied shock series since 2009:Q1, based on the actual "forward guidance" policy exercise. Recall from Section 2 that the vector of anticipated shocks $(\psi_{t,t}, \psi_{t+1,t}, .., \psi_{t+N,t})'$ measures the differences between the interest-rate path in the next N periods as anticipated by the public and the path as implied by the original policy rule (3.4), and that the vector is an $MA(N)$ process with mean-zero innovations $(\eta_{t,t}, \eta_{t+1,t}, .., \eta_{t+N,t})'$ in period t (equation 2.9). Thus for each quarter since 2009:Q1, we can solve for a $(N+3)$-by-1 shock vector $(\varepsilon_{\pi,t}, \varepsilon_{y,t}, \eta_{t,t}, \eta_{t+1,t}, .., \eta_{t+N,t})'$, so that the model-implied $(\pi_t, y_t, \psi_{t,t}, \psi_{t+1,t}, .., \psi_{t+N,t})'$ are identical to the observed inflation, unemployment rate, as well as the public's perception of the FOMC's "forward guidance" policy in that quarter.

The format of the FOMC's "forward guidance" on the future interest-rate path has gone through substantial changes during this period. As noted in Section 1, at first the FOMC did not give an explicit time frame as to how long it expects to keep the federal funds rate at near-zero level, but instead had chosen to use a qualitative language of "some time" or "an extended period"; in August 2011, it began to announce an explicit calendar date for maintaining the federal funds rate to be close to zero, first "at least through mid-2013" (on August 9, 2011), and then extended the date to "at least through late 2014" (on January 25, 2012) and then again "at least through mid-2015" (on September 13, 2012); on December 12 2012, the FOMC changed its guidance format again, by associating the near-zero rate horizon with specific economic indicators in particular unemployment rate and inflation expectation.

The public's expectations of future federal funds rate path have been largely consistent with the FOMC's such policy announcements during 2009-2013. For instance, the upper panel of Figure 2 plots the number of quarters that the federal funds rate is expected to be kept around zero, according to the median responses to the Blue Chip Survey of Professional Forecasters and those to the Primary Dealers' Survey of New York Fed.[7] Before early 2011, survey respondents have generally anticipated that the federal funds rate would be kept around zero for three to four quarters. The expected zero-rate horizon expanded to more than eight quarters after the FOMC began to associate zero rate with explicit calendar dates in 2011:Q3, to a maximum of 12 quarters in 2012:Q3 which is consistent with the FOMC's guidance of "at least through mid-2015" by then, before beginning to decline steadily. As of 2013:Q4, survey respondents still anticipated that the near-zero interest rate would be maintained for seven quarters before the first federal funds rate increase.

Data from federal funds futures market also confirm with such an evolution of market expectations. As shown in Figure 3, even though the three-month and six-month federal funds futures rate declined to around 25 basis points or below satrting in early 2009, which is consistent with the survey results of three to four quarters of near-zero-rate horizon, the 12-month futures rate was persistently higher than 50 basis points until mid-2011, revealing that market participants did not believe that the near-zero federal funds rate would continue beyond four quarters. Only after the FOMC's "at least through mid-2013" announcement in early August 2011 did the 12-month futures rate decline substantially to below 25 basis points, as market participants finally changed their expectations of near-future short-rate path and began to expect a near-zero rate horizon beyond four quarters.

Such an evolution of market expectations implies substantial time variations in the near-zero rate horizon during 2009-2013. As an illustration, the lower panel of Figure 2 translates these real-time survey results into explicit calendar dates over time. It can be seen that in 2009:Q1, the public had generally anticipated that the first federal funds rate increase or rate "lift-off" would occur four quarters later, around 2010:Q1. Since then, the public has been constantly

[7] The forecast horizon in Blue Chip Survey is only up to seven quarters ahead, which is obviously not long enough for some of the years in Figure 2. The Primary Dealers' Survey provides a much longer forecast horizon. However, since the results of the latter survey is only available after 2011, for 2009 and 2010 we have to reply on the Blue Chip Survey. Fortunately, most Blue Chip Survey respondents by then predicted that the federal funds rate would rise above 25 basis points within seven quarters, thus the published survey results are sufficient to derive market expectations as displayed.

putting off their anticipated "lift-off" date, from early 2010 as of early 2009, to late 2012 as of mid-2011, and mid-2015 as of late 2012. This observation is somewhat confusing, since ideally, a fully credible and unconditional forward guidance would suggest a fixed "lift-off" date, i.e., a horizontal line across time in Figure 2b, rather than with a substantial upward slope, in particular almost along a 45 degree line as in Figure 2b. It is thus important to explore to what extent such continuing revisions in the same direction reflect a series of unpredictable adverse shocks in the U.S. economy since early 2009, or simply a lack of policy stimulus based on real-time information, and examine the implications of alternative policy measures.[8]

The best way to make such an assessment is through examining the exogenous shock series during 2009-2013. Therefore, in Figure 4, we plot model-implied, real-time estimates of exogenous shocks to Phillips curve (3.1) and IS equation (3.2), namely $\varepsilon_{\pi,t}$ and $\varepsilon_{y,t}$. In particular, the dashed lines in both panels display the shock series from 1979 to 2008 from model estimation, and the solid lines plot the implied shocks since 2009:Q1, based on the methodology described above. Apparently, shock dynamics of $\varepsilon_{\pi,t}$ since 2009:Q1 are largely consistent with the pre-2009 dynamics, with sizes and volatilities not uncommon during the "Great Moderation" period prior to 2009. On the other hand, shock to the IS equation $\varepsilon_{y,t}$ has a severe spike in 2009:Q1, with a size even larger than that of several spikes during 1979-1981. However, there is only one very severe spike in early 2009, compared to three in 1979-1981. The volatility of $\varepsilon_{y,t}$ during 2009-2013, when exclude the single spike of 2009:Q1, is similar to that during the "Great Moderation" period. This suggests that the severity of adverse shocks in 2009-2010 is comparable, but not significantly larger, than that in the two recessions in the early 1980s.[9]

[8]Another although very unlikely reason could be that the public's expectations of near-future interest rates may not reflect the FOMC's intended policy rate path. But this is very unlikely, since the essense of forward guidance policy is to guide public expectations of future interest rates. If the central bank has observed substantial deviations in the public expectations from its inteneded policy rate path, it should act so as to eliminate such deviations. And in practice, as shown in Figure 2a, we do observe a close resemblence between the FOMC's announcements and the market participants' expectations, suggesting there should be little discrepancy between the FOMC's policy intention and market perception. This also seems to reveal a high degree of policy credibility during this period, which we will discuss further in Section 6.

[9]The estimation of the real shock series here only take into account of the "forward guidance" but not the other unconventional monetary policy in the U.S., namely, the Large Scale Asset Purchases (LSAP), which should also have provided extraordinaty monetary stimulus to the economy. Therefore, the estimated shock series during 2009-2013 in Figure 3 should be interpreted as those after taking into account of the LSAP policy. For a more detailed analysis on the impacts of the LSAP, see Wu (2013).

However, the zero lower bound (ZLB) of nominal interest rate has become a severe binding constraint on the implementation of conventional monetary policy since early 2009. Figure 5 provides a straightforward illustration by displaying two interest-rate paths as implied by the original interest-rate rule (3.4) in 2009:Q2, one under the assumption that the FOMC is not constrained by the ZLB and the interest rate can go negative, and the other under the assumption that the ZLB is binding but assumes that the FOMC chooses not to conduct any "forward guidance." If not constrained by the ZLB, the FOMC would have lowered the federal funds rate to a negative maximum of -2.4 percent before gradually raising it back to above zero, and the federal funds rate would stay below zero for 19 quarters, as implied by the interest-rate rule (3.4). On the other hand, if the ZLB is binding but the FOMC does not conduct any "forward guidance," the federal funds rate would have to stay at the near-zero level for even longer, 25 quarters before it gradually rises. The length of the ZLB-binding horizon if without forward guidance provides a natural metric to measure how severe a constraint the ZLB is to conventional monetary policy.

By promising to keep the interest rate at zero for the future and thus influencing the expectational terms, a central bank is able to change the underlying macroeconomic dynamics including the number of periods that the ZLB remains binding. However, it needs to promise a zero interest rate for a time horizon that goes beyond what is implied by the ZLB, otherwise such a promise is simply a recognition of the fact that the ZLB becomes binding at the moment but contains no further information that can possibly change the public's forward-looking expectations of future policy rate.[10] It would thus be interesting to compare the number of ZLB-binding quarters if without "forward guidance" (as implied by the solid line in Figure 4) with the market's perception of the actual "forward guidance" by the FOMC during 2009-2013. As shown in Figure 6, the former exceeds the latter substantially during 2009 and 2010, suggesting that much of the "forward guidance" during the first two years of the unconventional monetary policy exercise in the U.S. had provided little information to the public, other than

[10] In addition to specifying the time horizon for keeping interest rate at zero, another optional "forward guidance" component is to also promise a much slower speed to raise the interst rate after the it goes above zero, i.e., change the parameters in the original interest-rate rule (3.4). However, the Fed has not explicitly specified whether and how it would do so, after the first federal funds rate "lift-off," except for several remarks for instance Yellen (April 11 2012). And it is also not possible to infer whether the market had formulated such an expectation, since the time horizon of interest rate futures data usually do not go that far.

simply confirming that the ZLB became binding and that the near-zero federal funds rate would persist for several quarters. Later, as the severe shocks gradually moderate, the ZLB becomes less binding, and the number of ZLB-binding quarters if without "forward guidance" reduces to 8 quarters by end-2010, and is then exceeded by the FOMC's active "forward guidance," which was also switched to an explicit date-based approach in August 2011, with an extended horizon of two to three years.

The above finding that the FOMC's forward guidance during 2009 and 2010 was not aggressive enough to overcome the ZLB constraint may seem surprising but not entirely unreasonable. Levin, López-Salido, Nelson, and Yun (2010) have also noticed that despite the explicit forward guidance on federal funds rate that had been conducted by the FOMC around that time, the anticipated short-term rate path in the U.S., as revealed by Surveys of Professional Forecasters (SPF), was still fairly similar to those in Japan, the U.K. and Euro Area, where central bank communications had not emphasized forward guidance at all. Various speeches given by FOMC members back then also suggest that their focus had been largely on how forward guidance could help stabilize short-term funding market conditions, rather than actively influencing the public's expectations of future interest rates on a longer horizon. As Figure 6 reveals, not until the qualitative language was replaced by explicit calendar date-based guidance in August 2011 had the public extended their expectations of the near-zero rate horizon to substantially beyond one year. The following two sections will examine the associated macroeconomic performance of such forward guidance exercise and compare with that of alternative rule-based approaches.

5. Alternative Policy Rules to Conduct "Forward Guidance"

Since early 2009, the format that the FOMC has adopted to implement its "forward guidance" has changed substantially, generally in the directions of becoming more and more explicit over time. Thus a natural question to ask is: are these different formats largely consistent with each other, i.e., if the FOMC had adopted its latest rule as soon as the ZLB became binding in early 2009, would the U.S. economy have performed any differently? More importantly, the literature has proposed several alternative policy rules in the presence of the ZLB (see below). How would these alternative rules have prescribed forward guidance during 2009-2013? Would the macroeconomic performance since early 2009 have been substantially different if any of these alternative rules had been adopted? Is there any better way for the FOMC to communicate with the public regarding its "forward guidance," other than its current exercise? What are their implications on long-term interest rates and the Fed's "exit strategy"?

To answer these questions, in this section we examine the implied federal funds rate path and macroeconomic dynamics under alternative "forward guidance" rules, and compare their main features to those of the existing approaches in the next section. First we examine an indicator-based rule, which promises to keep the interest rate at the near-zero level till the unemployment rate reaches 6.5 percent, provided that inflation expectation remains below 2.5 percent. Such a rule is very similar to the FOMC's threshold-based rule, except that the 6.5 percent unemployment rate is a "trigger" in this rule, rather than a "threshold" as in the FOMC's statements. We will simulate the model with the estimated shock series as in Figure 4 and compare the simulated macroeconomic dynamics with the one as observed since 2009.

We will then examine the performance of two additional, "history dependent" rules in the ZLB environment. The first is a "compensation rule" proposed by Reifschneider and Williams (2000), which suggests that at the ZLB, a central bank can promise to modify the original interest rate rule and guarantee to keep the interest rate low even after the ZLB becomes non-binding any more, so that the accumulated extra policy stimulus going forward will be able to compensate for the loss of policy stimulus when the ZLB is binding.

In particular, using the notation in Sections 2 and 3, we denote $\psi_t = i_t - i_t^*$ as the deviation of actual policy rate i_t from the level as intended by the central bank i_t^*, and Z_t the cumulative sum of all past deviations $\psi_{t,t}$'s since the ZLB becomes binding. Thus the central bank's policy rule at the ZLB can be summarized as[11]

$$i_t = \max\{i_t^* - Z_t, 0\} \tag{5.1}$$

From the analysis in Section 2, we know that ψ_t will be positive as long as the ZLB remains a binding constraint, so that Z_t will be positive and accumulate over time. As the economy gradually recovers and that the ZLB becomes non-binding any more, the rule dictates that the central bank will still keep the actual interest rate i_t low, so that ψ_t becomes negative and gradually offsets the accumulated positive stock of Z_t, until eventually the actual interest rate i_t converges to the intended level i_t^* and monetary policy returns to normal. Thus in any period

[11] A central bank can also choose to only partially compensate the loss of monetary stimulus due to the ZLB, i.e., $i_t = \max\{i_t^* - \alpha Z_t, 0\}$ where $\alpha \in (0, 1]$ is the magnitude of the compensation that the central bank promises to make.

t, the general public will form their expectations of the future interest rate path based on their expectations of Z_t, which depends on the past deviations $\{\psi_{t-s,t-s}\}_{s=0}^{\infty}$ as well as expected deviations going forward $\{\psi_{t+s,t}\}_{x=1}^{\infty}$ from equations (2.7) and (2.8).

The second "history dependent" rule that we examine is a modified version of the explicit price-level target rule as proposed by Krugman (1998), which is a special case of the rule suggested by Eggertsson and Woodford (2003).[12] More recently, Gaspar, Smets and Vestin (2007) have also proposed a similar rule for the European Central Bank. In particular, the rule delivers an explicit and credible promise by the central bank to keep interest rate low until the general price level catches up a pre-announced target path, in the form of

$$p_t^T = p_0 + \pi^* t \tag{5.2}$$

where p_0 and p_t^T refer to the logarithm of initial price level and target level in period t, respectively. This makes p_t^T a trend stationary variable, so that following a deflationary shock, public will anticipate a temporary rise in inflation rate π_t for the actual price level p_t to catch up, thus they will expect a policy stance more expansionary than otherwise. As an irreversible shift to price-level targeting regime may prove to be a too radical change of the U.S. Federal Reserve and many other central banks' mandates (in most countries this would require substantial legislative changes), in the following simulations we also assume that the central bank only adopts this rule as a temporary measure, and makes it clear to the public that it will shift back to its normal policy rule (3.4) as soon as the price level is able to catch up to the targeted level and policy rate rises above zero, so as to minimize the needed change to central bank's mandates.[13] It should also be noted that both the "compensation rule" and the "price-level target rule" have been analyzed in calibrated dynamic stochastic general equilibrium models, but to our knowledge

[12] The optimal target prescribed by Eggertsson and Woodford (2003) is an "output-gap adjusted" price level, the log of which is defined as the log of a general price index plus a positive multiple of the output gap, with the multiplier depending on the weight on output-gap stabilization relative to inflation stabilization in the central bank's objective. Thus when the output-gap weight equals zero, the optimal rule shrinks to an explicit price-level target rule as proposed by Krugman (1998).

[13] Macroeconomic dynamics as implied by this temporary adoption of "price-level targe" rule during the ZLB-binding periods, as illustrated later, is very similar to the dynamics as implied by a permanent shift to "price-level targe" rule. For the periods after the ZLB becomes non-binding, in the former case the central bank will switch back to Taylor rule as promised, whereas in the latter case, the permanent shift to "price-level targe" rule would generate a steady inflation rate path fixed at the leve of π^*, as well as more volatile unemployment rate and interest rate paths.

never in such an empirical setting.

Next we conduct the following counter-factual experiment: for each quarter t since 2009:Q1, we assume the same shock series $\{\varepsilon_t, u_t\}$ as the one estimated in Section 3 and displayed in Figure 4; we then simulate the federal funds rate path under each of the three alternative policy rules, along with the implied unemployment rate and inflation for that quarter $\{y_t, \pi_t\}$.

We first examine the performance of the indicator-based forward guidance rule. Under such a rule, the FOMC would have announced at the beginning of 2009 that the federal funds rate would be kept at near-zero level at least for 4 to 6 years, instead of 4 quarters as perceived by the general public by then (Figure 7a). However, even this much longer horizon is still not stimulative enough, as it is still close to the zero-rate horizon that would be implied by the ZLB even without any active forward guidance stimulus (Figure 6). As a result, the macroeconomic performance of this rule would have been very similar to the actual observations during 2009-2011. Over time, as the economy gradually recovers, the ZLB becomes less binding, and this rule begins to imply a zero-rate horizon beyond what is implied by the ZLB and thus provides additional monetary stimulus, although not as much as the actual forward guidance announced by the FOMC (as in reality the 6.5 percent unemployment rate is regarded as a "threshold" rather than a "trigger"). For instance, as of 2013:Q3, this rule would imply an anticipated "lift-off" date of 2014:Q1, 6 quarters earlier than as indicated by the survey in reality. In general, the performance of the indicator-based rule would be very similar to the actual forward guidance by the FOMC, as both provide little extra policy stimulus beyond the ZLB and thus cannot substantially lower the public's expectations of future interest rate path in 2009-2010.

In contrast, the two "history dependent" rules would have prescribed a much more aggressive forward guidance, in response to the severe real shocks at the beginning of 2009. For instance, the "compensation rule" would imply a near-zero rate horizon of 7 to 8 years in the first half of 2009, i.e., an anticipated near-zero rate path till late 2016 or early 2017. As the economy gradually recovers, the forward guidance would be revised over time, with the near-zero rate horizon gradually shortened to 3 years by the end of 2010, and 6 quarters by the end of 2011. Eventually, the federal funds rate would have begun to rise in 2013:Q2, as the accumulated monetary stimulus till then has been enough to support the economy (Figure 7a). The simulated unemployment rate would be substantially lower than the actual reading, with the height coming in 2009:Q4 at 9.3 percent, instead of 9.9 percent as observed in data (Figure 7b). The simulated inflation rate is also higher than the actual reading, with a difference of about 0.5 percentage point in 2010-2012 (Figure 7c).

The "price-level target rule" implies an even more aggressive forward guidance in the first two years of the ZLB-biding period (2009-2010), as shown in Figure 7a, with an anticipated near-zero rate horizon till 2017:Q4 as of mid-2009.[14] Moreover, a fully credible "price-level target rule" would have also implied a substantially higher inflation expectation and therefore a much lower real interest rate path going forward, thereby generating a much faster recovery and helping to keep the unemployment rate below 8 percent since 2009 (Figure 7b). As the economy recovers much sooner, the FOMC would have been able to afford to raise interest rate in 2012:Q2, much earlier than the actual "lift-off" as well as what is implied by the other alternative rules.

In summary, the above model-based analysis suggests that the "forward guidance" conducted by the FOMC during 2009-2010 may not be aggressive enough, as the promised near-zero rate horizon is not long enough to overcome the constraint implied by the ZLB. An indicator-based rule similar to the FOMC's threshold-based rule can hardly do any better, although choosing an even lower unemployment rate (than 6.5%) as the "threshold" has the potential for better performance. In contrast, both "history dependent" rules would have been able to prescribe a much more aggressive forward guidance, in particular immediately after the initial adverse shocks in early 2009, and thus generate better macroeconomic performance. Moreover, rule-based approaches are also able to generate more consistent forward guidance, which makes the policy measures more credible, and also minimizes the policy shocks to market, if these "forward guidance" rules are credible and fully understood by the public.

A flatter Phillips Curve

A number of empirical studies have recorded a possible decline in the slope of Phillips curve in recent years, for instance Hall (2011). In particular, he argues that during the Great Recession, with unemployment rate hiking to almost 10 percent, most theories based on the concept of NAIRU would have predicted a substantial decline in inflation. However, the observed inflation rate in the U.S., although declined somewhat in early 2009, has largely remained contained since then. IMF (2013) has also recorded a gradual decline in the responsiveness of inflation to

[14] Here we assume an annual inflation target rate of 2.38 percent, which is the average annual change of GDP deflator during 1988-2008.

unemployment since mid-1970s, in a much larger sample of 21 countries, suggesting that this might be a global phenomenon.

To explore the implications under this possibility, we reduce the slope of Phillips curve λ in (3.1) by half, and conduct the same simulations as above and compare the performance of different forward guidance approaches. For comparison, the simulations are conducted using the same shock series as in Figures 4a and 4b (shock series backed out based on the flatter Phillips curve are quantitatively similar).

A flatter Phillips curve would imply that, for a given set of adverse aggregate-demand shocks $\varepsilon_{y,t}$, inflation would decline less than otherwise, therefore the ZLB becomes a less severe constraint to monetary policymakers than otherwise. As revealed in Figure 8, with the slope of the Phillips curve reduced by half, the number of ZLB-binding quarters during 2009 and 2010 declines substantially, by one to two years, compared to what is implied by the original parameter estimates. However, the near-zero interest rate horizon as reflected in the surveys is still substantially shorter than the ZLB-binding horizon, confirming the earlier conclusion that the FOMC's forward guidance during 2009-2010 was not aggressive enough to materially change the public's expectations of future interest rate path and provide extra monetary stimulus.

In response to a less constraining ZLB, both the compensation rule and the indicator-based rule would imply a less aggressive forward guidance in 2009-2010, with a zero-rate horizon one to two years shorter than what is implied by the original parameter estimates (Figure 9a). In contrast, the price-level target rule would now prescribe a longer zero-rate horizon than before, because the expected increase in inflation rate during recovery is now smaller due to the decline in the slope of Phillips curve, and thus a more aggressive forward guidance is needed to meet the pre-set price level target path. On the other hand, consistent with the pior findings, the forward guidance horizon as implied by either the compensation rule or price-level target rule would still be substantially more aggressive than the actual or indicator-based forward guidance, and thus generates a more favorable macroeconomic performance than the latter (Figures 9b and 9c).

6. Implementation of "Forward Guidance"

Because of its nature, the effectiveness of forward guidance policy depends crucially on its credibility and predictability, in other words, whether the policy is perceived as credible, to what extent general public understands the rationales of the announced measures, and how policy stance may likely to evolve in response to future changes in the underlying economic and financial conditions. During normal times, both credibility and predictability of a central bank's monetary policy can leverage a well-established policy history with a generally successful track record in achieving the central bank's mandates. However, in an unfamiliar policy environment where the central bank has to deviate from its past pattern of behavior, forward guidance becomes particularly challenging (Woodford 2012), and clear communications with the public are needed for the central bank to clarify its goal and policy strategy, so as to enhance the transmission mechanism.[15]

The frequent changes of the format of the FOMC's forward guidance since early 2009 reflect a continuing effort by the FOMC to seek a most appropriate communicaiton approach for such purposes. The credibility of forward guidance does not seem to be its major concern—as revealed in Figure 2a and many "announcement effect" studies, the FOMC's forward guidance during the "Great Recession" has not encountered serious problems regarding its credibility, as market participants have generally formulated and kept updating expectations that are very close to the FOMC's policy announcements, at least before it switched back to a qualitative forward guidance approach in March 2014. Svensson (2015) compares the market-based federal funds rate path and the median of the FOMC participants' federal funds rate projections, and his results also seem to suggest that, despite some minor discrepancy, these two policy rate paths had been largely well aligned throughout end-2013, i.e., the end of our sample period. Thereby, the focus seems to be on how to improve the public's understanding of the rationales of forward guidance and how to help them predict its likely changes in response to changes in the underlying macroeconomic conditions.

The initial qualitative approach adopted by the FOMC during 2009 to mid-2011 has helped stabilizing the short-term funding market conditions on the initial stages of the "Great Recession," as well as preserved flexibility and discretion to policymakers. However, as revealed in

[15] Throughout this analysis, we abstract from issues that could arise under imperfect credibility, and focus on the case—as in most existing ZLB literature—where the central bank has a perfect commitment technology. As revealed in Figure 2a and many "announcement effect" studies, the FOMC's forward guidance during the "Great Recession" has not encountered serious problems regarding its credibility. Svensson (2015)'s comparison of market-based federal funds rate path and the median of the FOMC participants' federal funds rate projections also seems to suggest that, despite some minor discrepancy, these two policy rate paths had been largely well alighed throughout end-2013, i.e., the end of our sample period.

previous sections, this policy has not been able to successfully deliver a market expectation of near-zero rate horizon that is beyond three or four quarters, far from long enough to overcome the constraint that the ZLB implies (Figures 6 and 8).

The shift from the qualitative approach to a calendar date-based approach in August 2011 very effectively guided a change in market expectations towards a much longer near-zero rate horizon, as reflected in both survey results (Figure 2) and interest rate futures market data (Figure 3). Even though such a shift may partially reflect a downward revision to economic outlook by the FOMC and hence a longer horizon for monetary policy to remain accommodative,[16] many have argued that the shift primarily reflects a change in policy reaction function, i.e., the FOMC decides to maintain a more accommodative policy stance for a longer period, even if the underlying economic fundamentals had not changed much (Femia, Friedman and Sack, 2013). Remarks from various FOMC members also explicitly indicate that the shift did not constitute a more pessimistic view on the economic outlook (e.g., Dudley 2012, Bullard 2013). Therefore, the observed downward shifts in future interest rate paths and the associated declines in long-term Treasury bond yields (Figure 3) indicate the success of the adoption of calendar date-based approach.

However, this new approach also has its limitations. Under this approach, the FOMC only communicates with general public on its projections on future policy rate, but not the rationales under which such decisions and policy projections are made. Of course, the public can try to infer the FOMC's policy reaction function through linking the policy announcements with the published economic projections by the FOMC participants. However, in practice, these projections are not always consistent with the FOMC's forward guidance announcements, thus complicating such efforts by the public. For instance, on the same day of the FOMC announcement of maintaining the near-zero federal funds rate "at least through mid-2015" (September 13, 2012), the simultaneously published *Summary of Economic Projections* (SEP) reveals that at least 6 of the 19 FOMC participants would like to raise the federal funds rate to above 1.5 percent by the end of 2014. Therefore, the FOMC's such decision making remains a "nontransparent process", and the public is largely ignorant as to why the FOMC makes a particular policy change, because

[16] For instance, as revealed by the published *Summary of Economic Projections* (SEP) by the FOMC participants, between June 2011 and early November 2011, the midpoint of the central tendency of their projections for real GDP growth in 2012 and 2013 were revised down by 0.8 and 0.6 percentage point, respectively, and that for unemployment rate were revised up by 0.6 and 0.8 percentage point, respectively.

the FOMC "does not provide any kind of fundamental information about how the policy is linked to the underlying outlook" (Bernanke, December 12, 2012). This will certainly generate substantial policy uncertainties, in particular when the market begins to speculate on a possible major revision of the policy rate path announcement. Moreover, this approach does not reveal any information regarding the policy rate path after the interest rate "lift-off," i.e., the exit strategy, leaving much of the associated policy uncertainties intact.

The FOMC's next switch of forward guidance format in December 2012, from the calendar date-based approach to a threshold-based approach, seems to reflect its further efforts to try to communicate with the public in a more rule-based approach. Under this approach, any substantial developments of macroeconomic conditions, in particular future unemployment rate and inflation outlook, will lead the public to automatically revise their projections on future federal funds rate path based on the announced threshold, without having to rely on the FOMC to update the near-zero interest rate horizons. This "acts like an automatic stabilizer" (Bernanke, December 12, 2012) and effectively helps the public to better formulate future policy expectations and reduces the associated policy uncertainties and thus risk premiums.

However, even though this practice of focusing on a single labor-market indicator can better facilitate the public's understanding of the threshold *per se* and thus improve the transparency of the FOMC's decision making, it also weakens the robustness of the monetary policy. This is because the single indicator chosen by the FOMC, the unemployment rate, is unable to fully capture the complexities of the economy and labor market, and therefore may generate biases to the policy stance. As Levin (2014) and a few other studies suggest, a substantial part of the steep decline in unemployment rate between 2011 and 2013 actually reflects a concomitant drop in labor force participation which is induced by the sluggish pace of economic recovery, rather than an overall improvement of labor market conditions. Therefore, as of mid-2015, even it is already more than one year after the observed unemployment rate fell below the threshold level of 6.5 percent in April 2014, the FOMC is still maintaining a near-zero interest rate, because of "the underutilization of labor resources." (FOMC statement, April 29, 2015).

Another problem with the threshold-based approach is on the choice of the numerical value of the threshold. After the threshold of unemployment rate at 6.5% was announced in December 2012, the FOMC has provided little explanation as to why such an index or numerical value is chosen. Indeed, alternative values had been publicly proposed by various FOMC members before the FOMC finally set the threshold at 6.5% unemployment rate,[17] revealing the diversity of FOMC members' views of the underlying macroeconomic dynamics as well as their policy preferences. Therefore, these aspects of the threshold-based approach remain untransparent to the public. Moreover, similar to date-based approach, the threshold-based approach can only convey information regarding the first interest rate increase but little on the policy rate path thereafter. Such uncertainties over the FOMC's exit strategy might have triggered the "taper tantrum" in mid-2013, and caused disruptions to the transmission mechanism of the forward guidance (Wu 2013). Finally, even though the threshold-based approach is closer to Woodford (2012)'s prescription of an optimal "forward guidance" policy commitment when compared to other approaches that the FOMC has experimented, it still falls short, as it is purely forward looking and not history-dependent, thus it fails to commit to "compensate subsequently for target misses due to the binding zero lower bound on interest rate policy" (Woodford 2012).

In contrast, as illustrated in the previous sections, both the "compensation rule" and the "price-level target rule" are history-dependent and would have led to a more aggressive forward guidance and a quicker recovery. Moreover, because of their nature, they would also imply more policy transparency as the public would have a better understanding of the central bank's decision-making process in keeping the policy rate low. In addition, the definitions of these rules have naturally prescribed a post "lift-off" interest rate path, i.e. the exit strategy, and thus the associated uncertainties can also be substantially reduced.[18]

The implementation of these history-dependent approaches can also be surprisingly straightforward. For instance, the central bank can periodically publish the cumulative shortfall of monetary stimulus, in the spirit of Z_t as in equation (5.1) which equals $\Sigma_{s=0}^{\infty}\psi_{t-s}$, or alternatively, an "intended" policy rate path had the ZLB not been binding, similar to the dashed red line in Figure 5. Publishing these indicators should enable the public to better gauge the severity of the ZLB constraint in policymakers' mind, and formulate expectations of future monetary policy that are consistent to the underlying macroeconomic fundamentals and central bank's

[17] For instance, Chicago Fed President Charles Evans had suggested a threshold of unemployment rate at 7 percent, as long as inflation does not exceed 3 percent. Minnesota Fed President Kocherlakota had also proposed a different threhold, 5.5 percent for unemployment rate, so long as inflation outlook does not breach 2.25 percent.

[18] In various speeches, Federal Reserve Chair Janet Yellen has also hinted the need to "commit to making up for at least some portion of the cumulative shortfall created by the zero lower bound" (e.g., Yellen, April 11, 2012). However, such a "compensation" strategy has never been officially and explicitly announced by the FOMC.

policy preferences, including the exit of unconventional monetary policy. On the other hand, such approaches are more robust than the those based on single economic indicator, and central bank will still possess enough flexibility, as much as under the conventional monetary policy regime.

7. Concluding Remarks

Monetary policy authorities in advanced economies have faced severe challenges when their short-term policy rates hit the zero lower bounds (ZLB) during the "Great Recession." In response, they have implemented different approaches to deliver "forward guidance" on future monetary policy, aiming at lowering the public's expectations of future short-term interest rates. With the help of an empirical New Keynesian model, we assess the performance of such "forward guidance" exercises in the U.S., and compare with the implications of several alternative "forward guidance" rules.

Our analysis suggests that during the early stages of the "Great Recession," the ZLB has implied a severe constraint to conventional interest rate policy, with a binding horizon of 4 to 6 years in early 2009 and 2 to 4 years as of 2010. The FOMC's "forward guidance" policy during this period, however, is not aggressive enough to overcome such a constraint. Only after early 2011 has the "forward guidance" begun to effectively provide substantial monetary stimulus through lowering the public's expectations of future short-rate path. In contrast, alternative "history dependent" approaches would have prescribed a much more aggressive forward guidance in 2009-2010, and would have led to a significantly quicker economic recovery, with simulated short-term interest rate beginning to rise above zero in late-2012 to mid-2013.

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Table 1: Coefficient Estimates of the New Keynesian Model

NKPC: $\pi_t = \alpha_0 + \rho_\pi \sum_{i=1}^{4} \frac{\pi_{t-i}}{4} + (1-\rho_\pi) \sum_{i=1}^{4} \frac{E_t \pi_{t+i}}{4} + \lambda \sum_{i=1}^{2} \frac{y_{t-i}}{2} + \varepsilon_{\pi,t}$

ρ_π	0.9373 (13.1018)	λ	−0.1866 (−2.4752)

IS Equation: $y_t = \beta_0 + \rho_y \sum_{i=1}^{2} \frac{y_{t-i}}{2} + (1-\rho_y) \sum_{i=1}^{2} \frac{E_t y_{t+i}}{2} - \gamma(\sum_{i=0}^{3} \frac{i_{t-i}}{4} - E_t \pi_{t+1}) + u_{y,t}$

ρ_y	0.4244 (18.0012)	γ	0.0109 (0.9602)

AR Specification of $u_{y,t}$: $u_{y,t} = \rho_{u,1} u_{t-1} + \rho_{u,2} u_{t-2} + \varepsilon_{y,t}$

$\rho_{u,1}$	0.3983 (4.5334)	$\rho_{u,1}$	0.2942 (2.4849)

Interest Rate Rule: $i_t = \eta_0 + \rho_i i_{t-1} + (1-\rho_i)[\mu_\pi \sum_{i=0}^{3} \frac{\pi_{t-i}}{4} + \mu_y \sum_{i=0}^{1} \frac{y_{t-i}}{2}] + \varepsilon_{i,t}$

ρ_i	0.8464 (14.8628)		
μ_π	0.3028 (2.3587)	μ_y	−0.1608 (−1.8055)

Figure 1: Impulse Responses

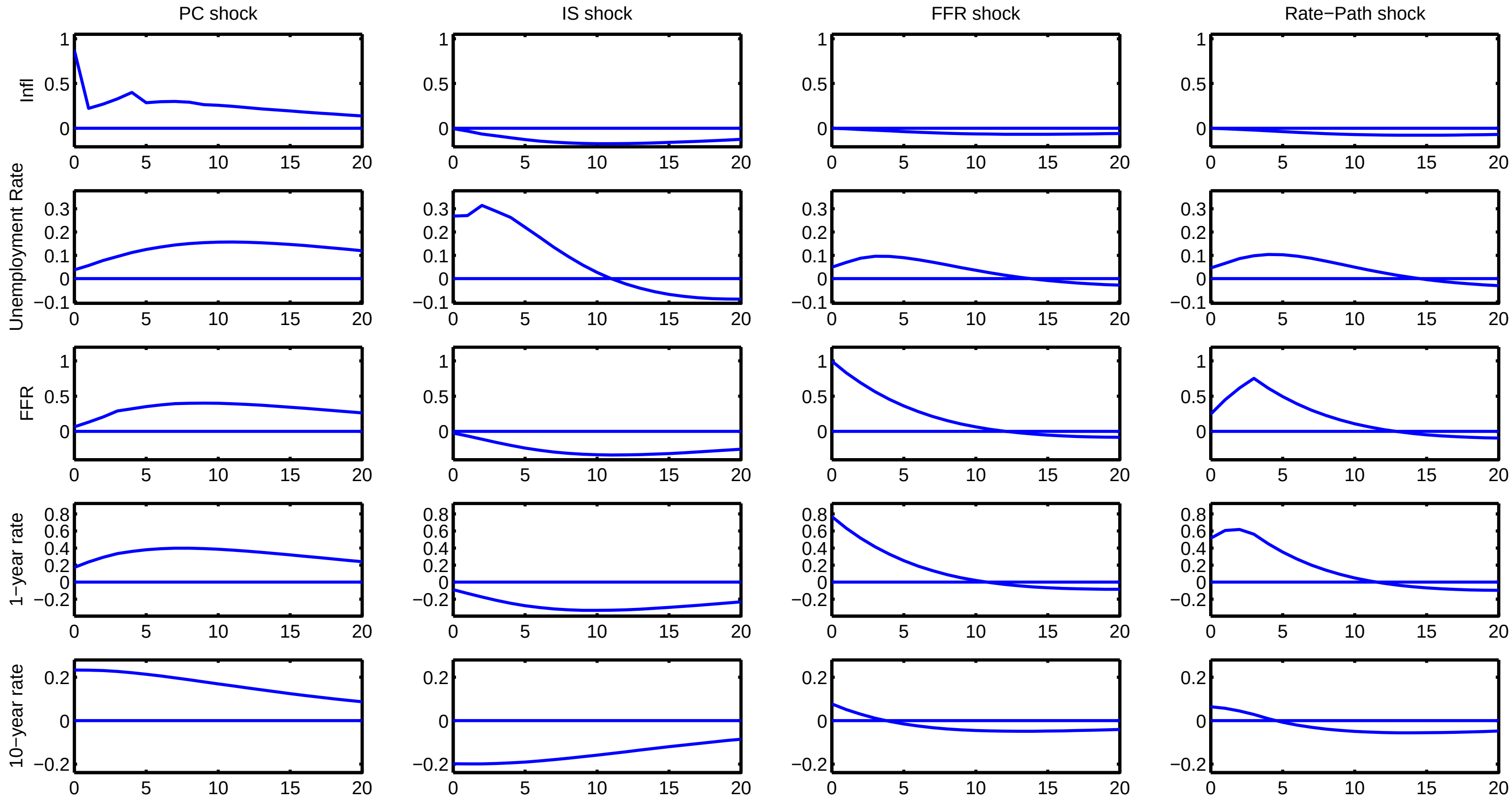


Figure 2a: Number of Quarters Ahead to Keep Near-Zero Interest Rate

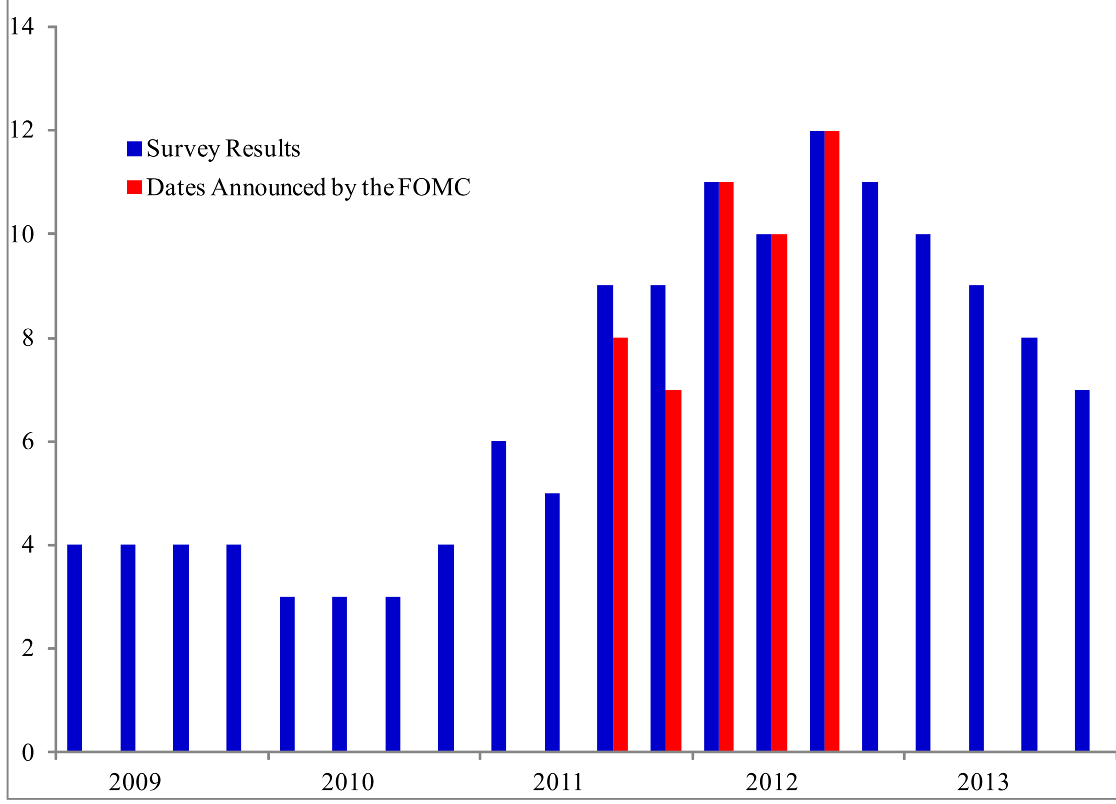


Figure 2b: Anticipated Time Frame to Keep Near-Zero Interest Rate

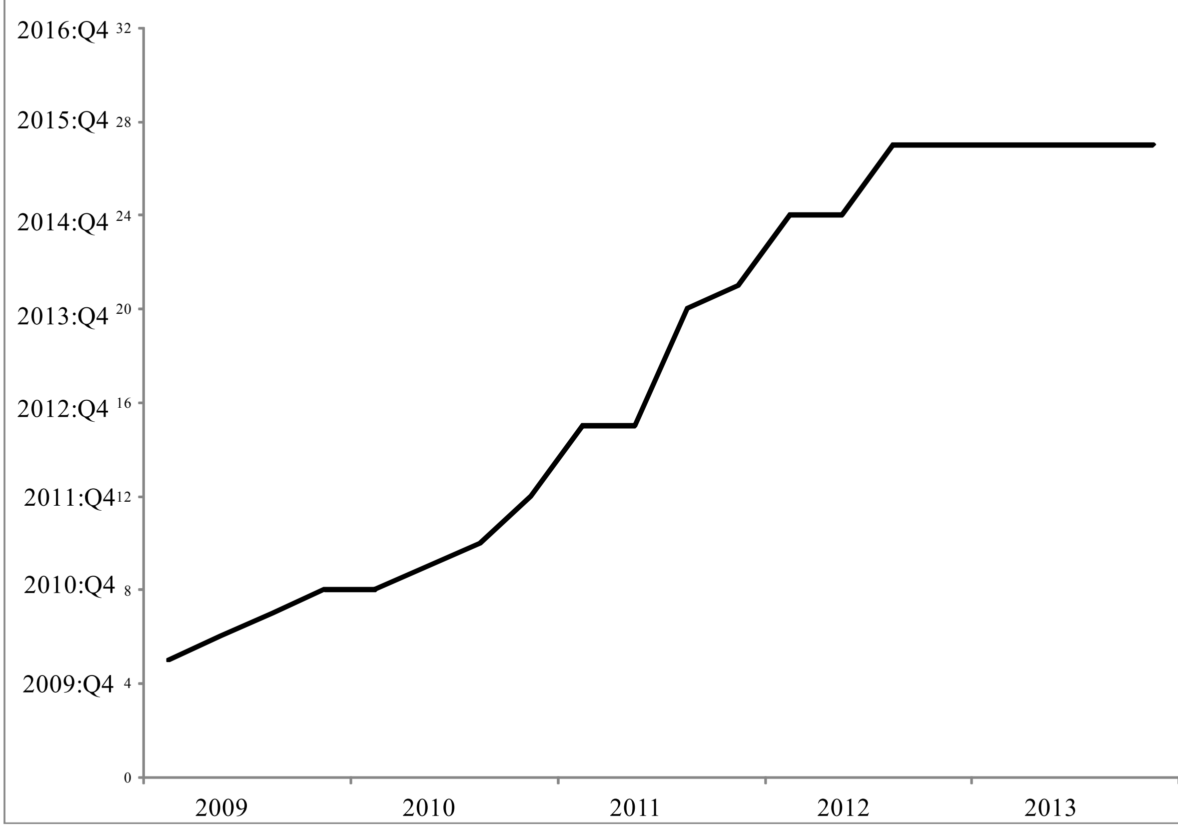


Figure 3: Federal Funds Futures Rates and Treasury Bond Yield

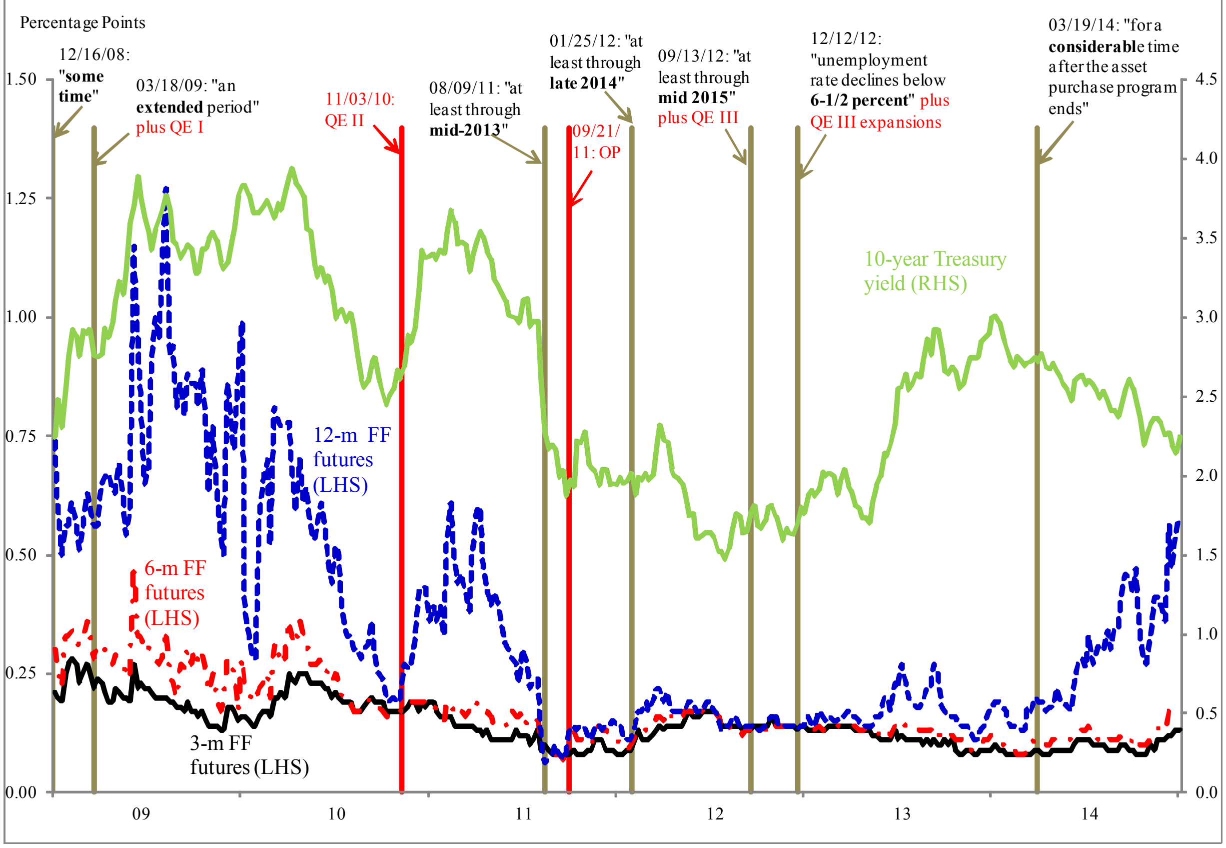


Figure 4a: Fitted Series of Phillips-Curve Shock

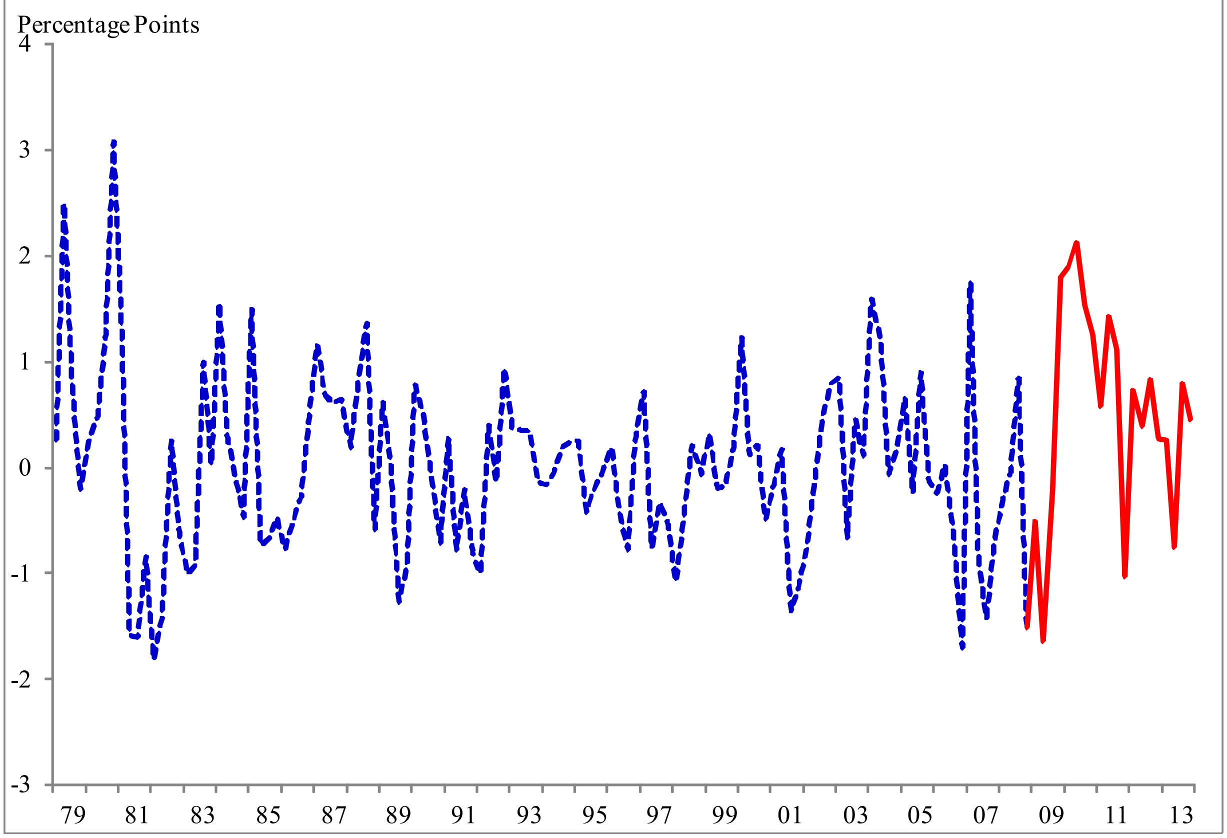
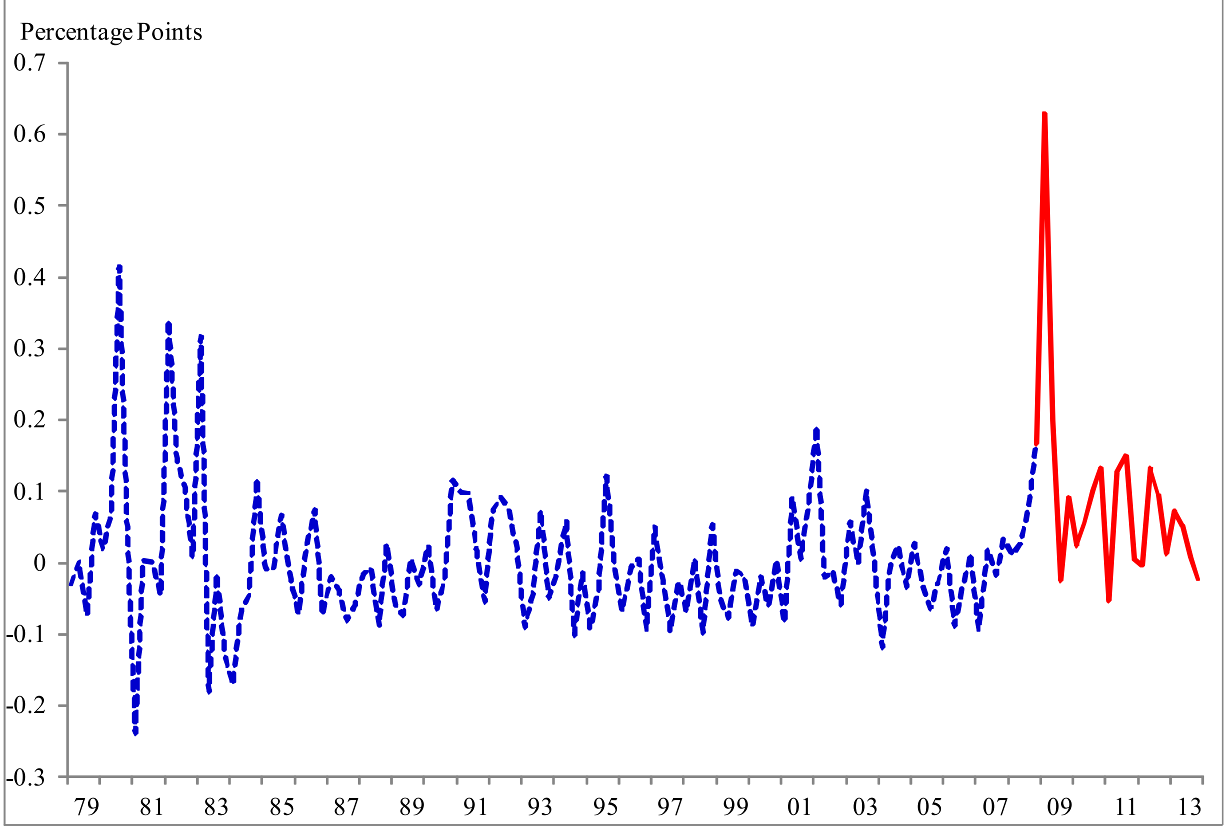


Figure 4b: Fitted Series of IS-Curve Shock



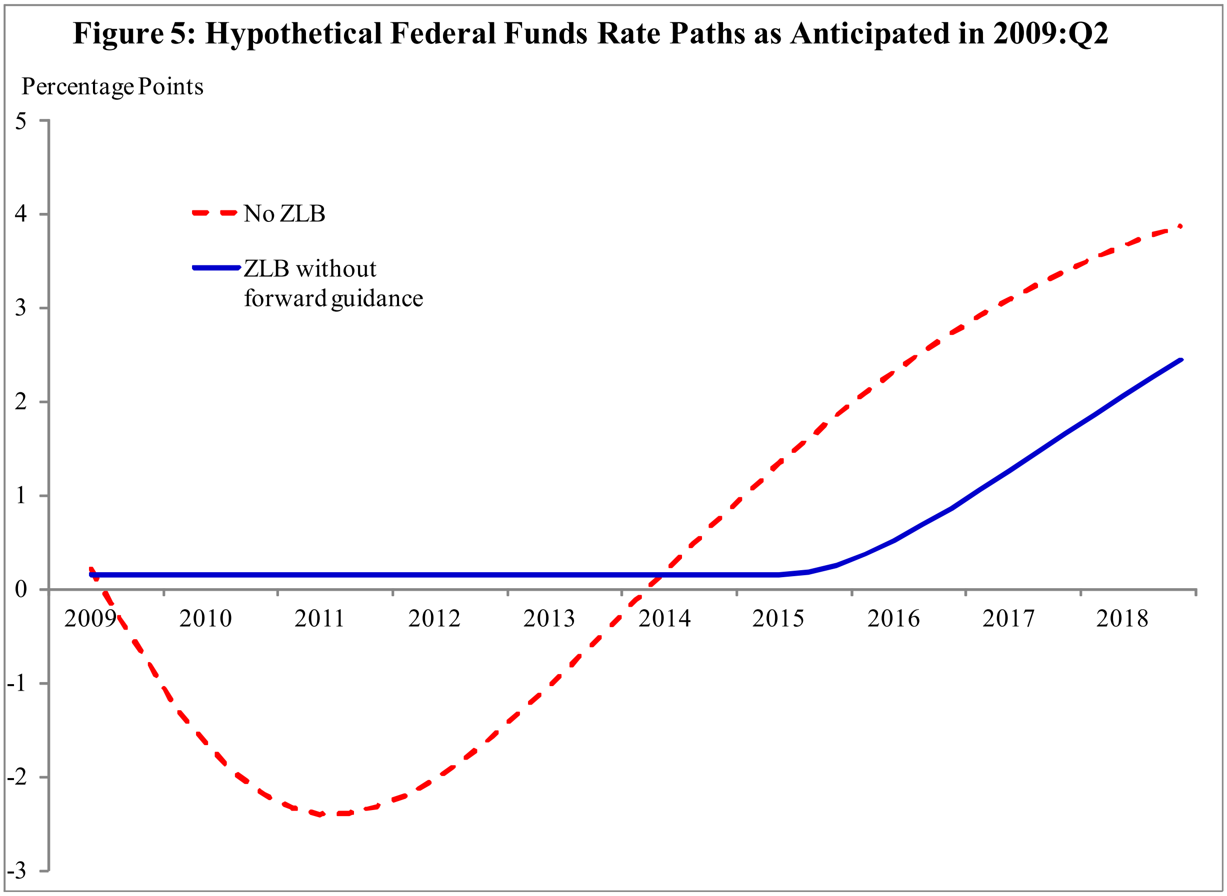


Figure 5: Hypothetical Federal Funds Rate Paths as Anticipated in 2009:Q2
Percentage Points
5
4
3
2
1
0
-1
-2
-3
No ZLB
ZLB without forward guidance
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

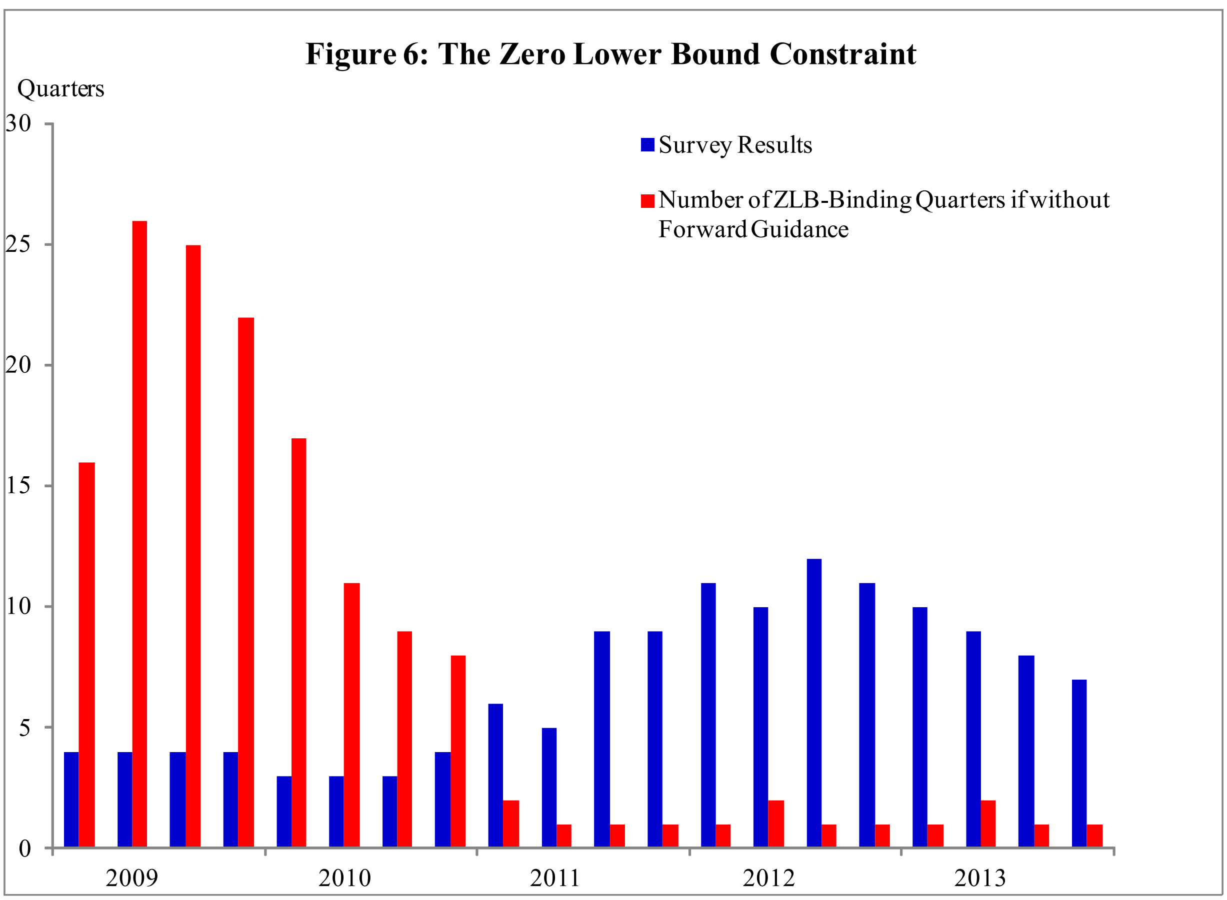


Figure 6: The Zero Lower Bound Constraint
Quarters
30
25
20
15
10
5
0
Survey Results
Number of ZLB-Binding Quarters if without Forward Guidance
2009
2010
2011
2012
2013

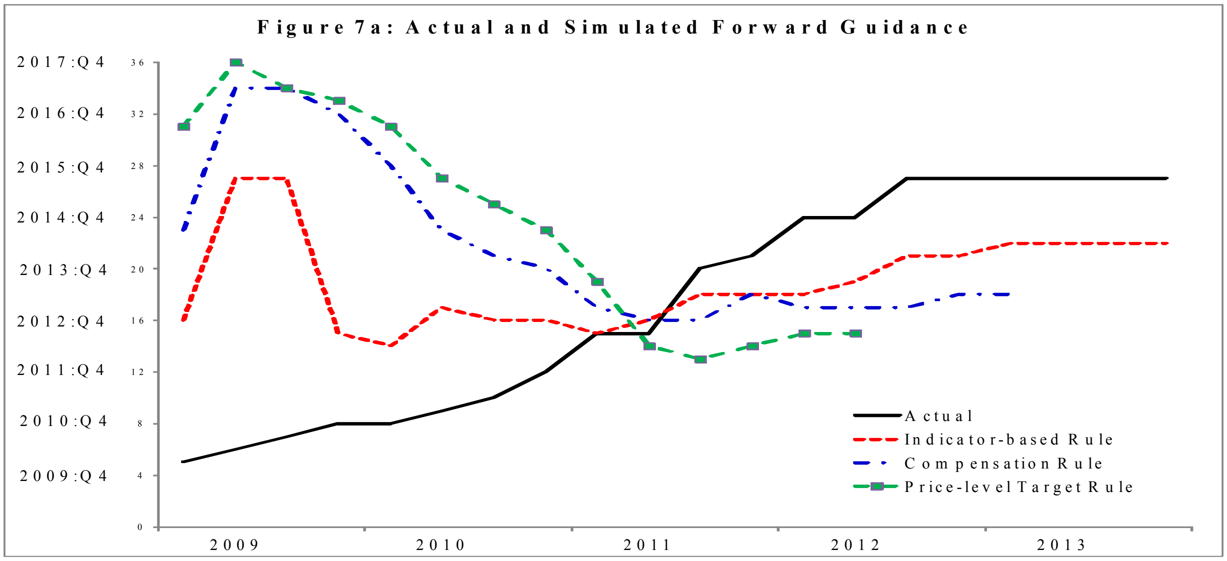


Figure 7a: Actual and Simulated Forward Guidance
2017:Q4
2016:Q4
2015:Q4
2014:Q4
2013:Q4
2012:Q4
2011:Q4
2010:Q4
2009:Q4
Actual
Indicator-based Rule
Compensation Rule
Price-level Target Rule
2009
2010
2011
2012
2013

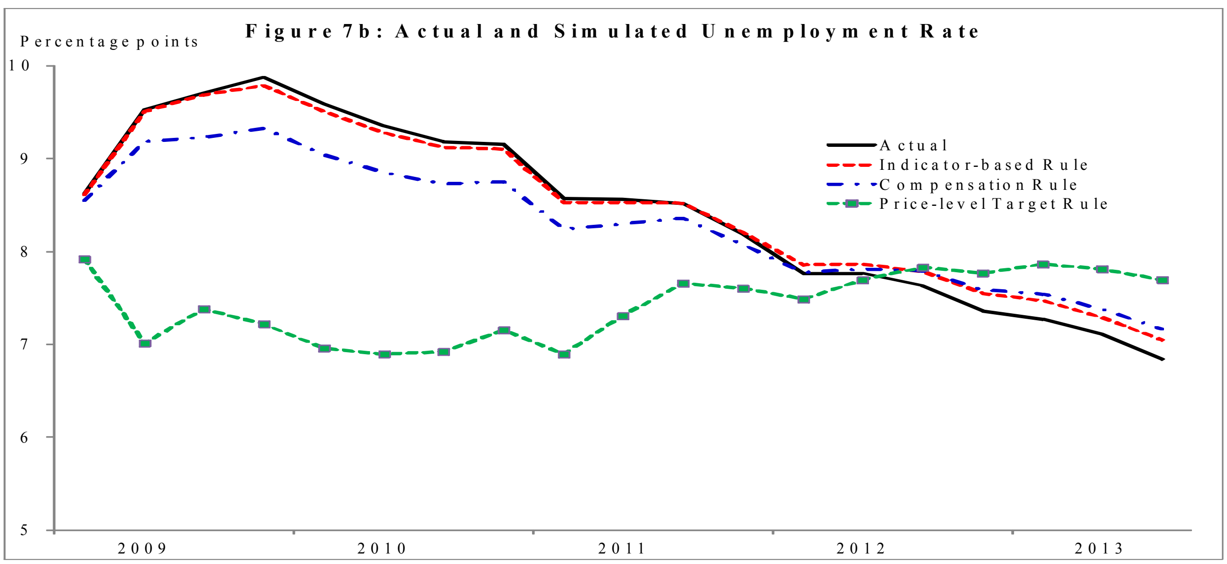


Figure 7b: Actual and Simulated Unemployment Rate
Percentage points
10
9
8
7
6
5
Actual
Indicator-based Rule
Compensation Rule
Price-level Target Rule
2009
2010
2011
2012
2013

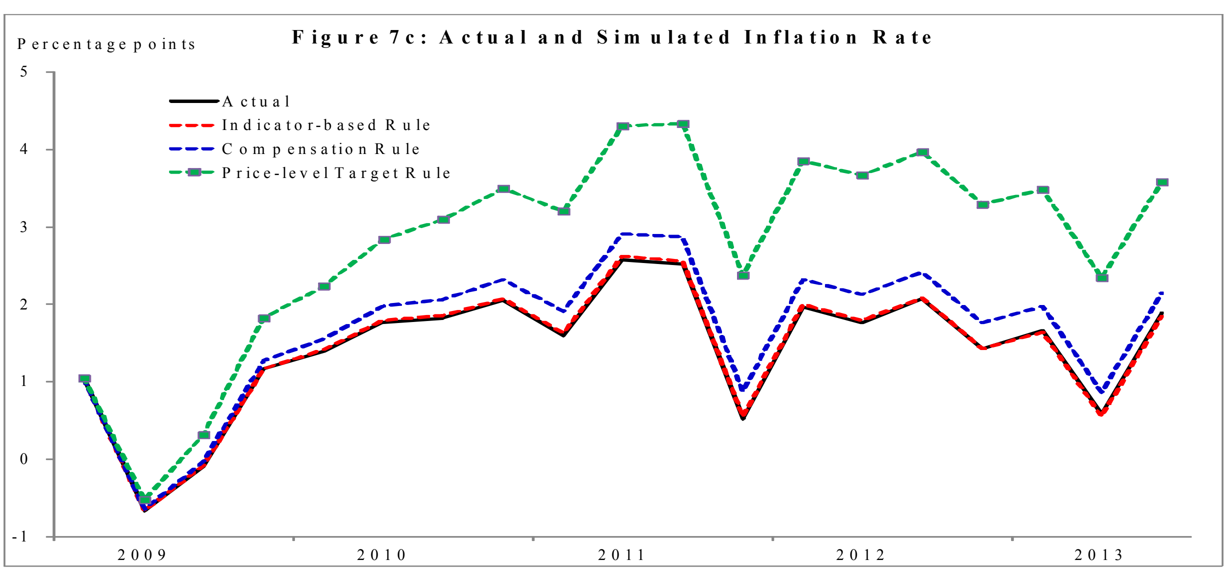


Figure 7c: Actual and Simulated Inflation Rate
Percentage points
5
4
3
2
1
0
-1
Actual
Indicator-based Rule
Compensation Rule
Price-level Target Rule
2009
2010
2011
2012
2013

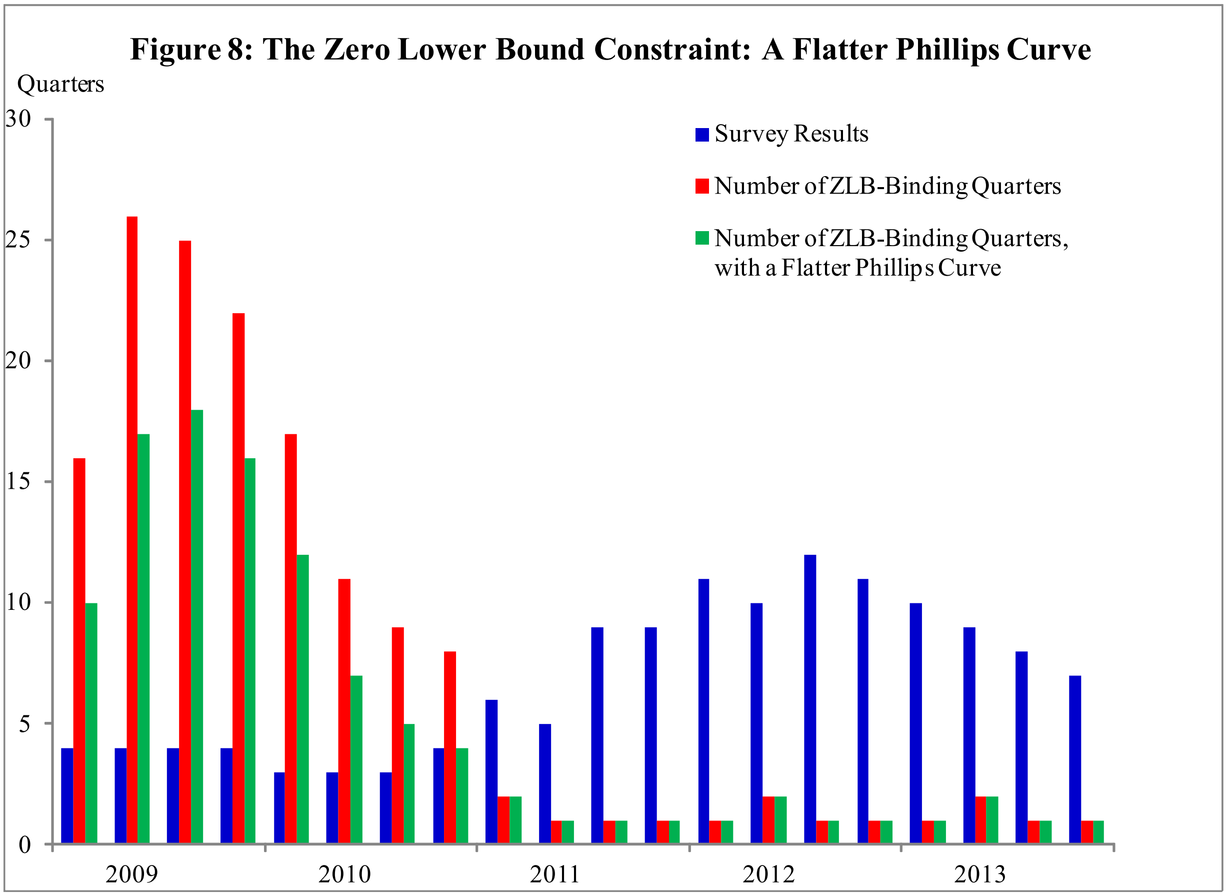


Figure 8: The Zero Lower Bound Constraint: A Flatter Phillips Curve
Quarters
30
25
20
15
10
5
0
Survey Results
Number of ZLB-Binding Quarters
Number of ZLB-Binding Quarters, with a Flatter Phillips Curve
2009
2010
2011
2012
2013

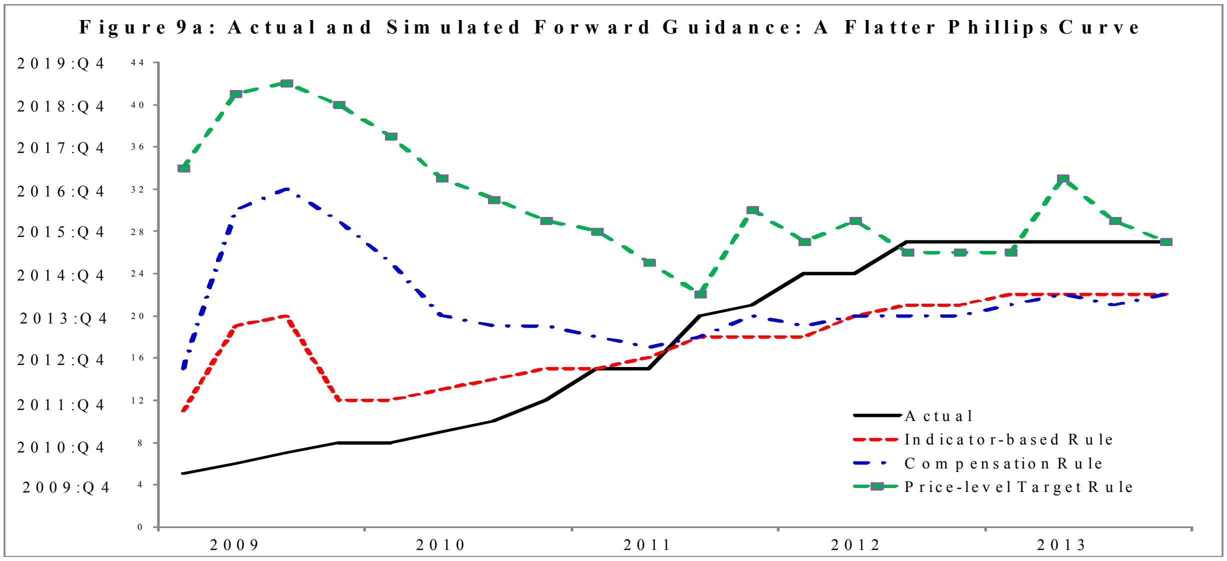


Figure 9a: Actual and Simulated Forward Guidance: A Flatter Phillips Curve

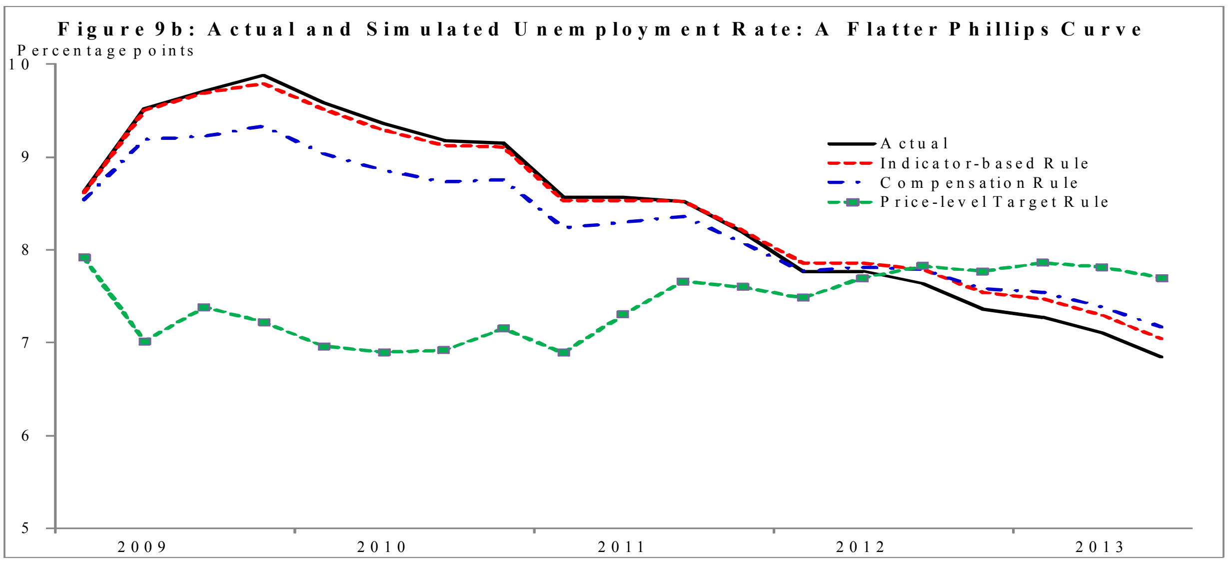


Figure 9b: Actual and Simulated Unemployment Rate: A Flatter Phillips Curve

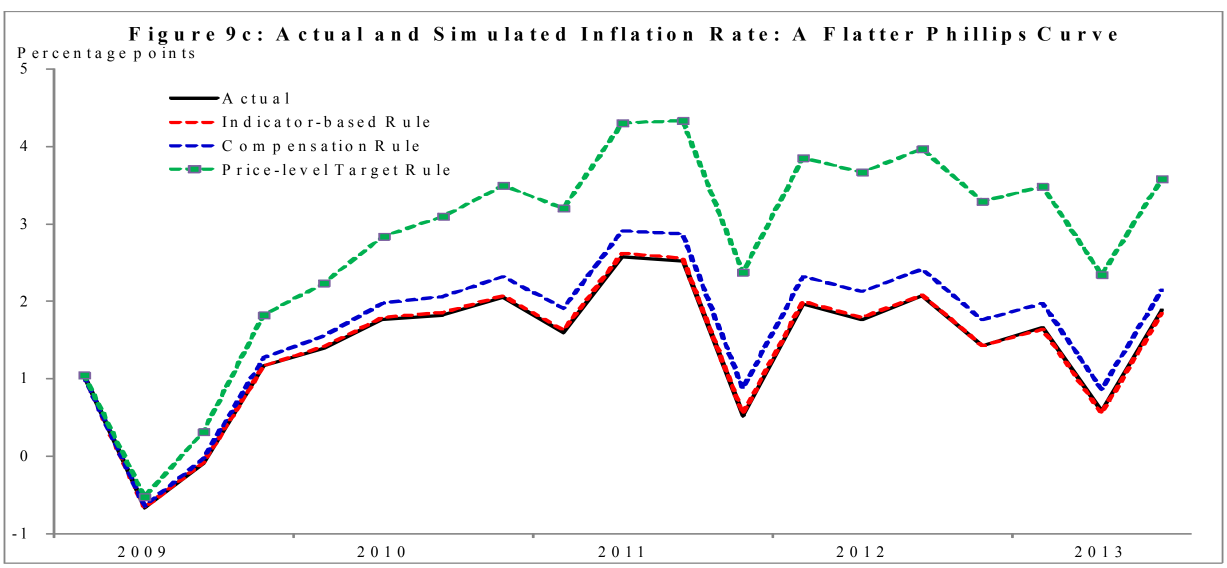


Figure 9c: Actual and Simulated Inflation Rate: A Flatter Phillips Curve