# Evaluating the Effects of Forward Guidance and Large-scale Asset Purchases

Xu Zhang*

*Department of Economics*
*University of California, San Diego*

February 15, 2018

## Abstract

This paper evaluates the effects of forward guidance and large-scale asset purchases (LSAP) when the nominal interest rate reaches the zero lower bound. I investigate the effects of the two policies in a dynamic new Keynesian model with financial frictions adapted from Gertler & Karadi (2011, 2013), with changes implemented so that the framework delivers realistic predictions for the effects of each policy on the entire yield curve. I then match the change that the model predicts would arise from a linear combination of the two shocks with the observed change in the yield curve in a high-frequency window around Federal Reserve announcements, allowing me to identify the separate contributions of each shock to the effects of the announcement. My estimates correspond closely to narrative elements of the FOMC announcements. My estimates imply that forward guidance was more important in influencing inflation, while LSAP was more important in influencing output.

*Xu Zhang: Department of Economics, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093 (email: xuz039@ucsd.edu). I thank James Hamilton, Johannes Wieland and Alisdair McKay, seminar and conference participants at University of California, San Diego and 2018 ASSA annual meeting for helpful discussions. I am grateful to Peter Karadi for sharing his codes. All errors are mine.

Between December 2008 and December 2015, the federal funds rate - the Federal Reserve (Fed)'s traditional monetary policy instrument - was near the zero lower bound. In response to this, the Federal Open Market Committee (FOMC) turned to unconventional measures to provide needed stimulus to the economy. Understanding the effects of these unconventional monetary policies is an important topic for both policymakers and researchers. In this paper, I investigate and compare the effects of two types of unconventional monetary policies, forward guidance and large-scale asset purchases (LSAP), reconciling the various interest rates' responses predicted from a dynamic stochastic general equilibrium (DSGE) model with observed high frequency yield curve data.

Communication about the likely future course of monetary policy is known as forward guidance. One example is the FOMC statement on December 16, 2008: "the Committee anticipates that weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate *for some time*". When the Fed provides forward guidance about the future path of monetary policy, individuals and businesses will use this information in making decisions about spending and investments. Eggertsson & Woodford (2003) show that lowering the expected path of policy rates can be highly effective in increasing economic activity and inflation for an economy at the zero lower bound. Moreover, using a variety of approaches, several studies generally agree that the explicit forward guidance has been effective at lowering various interest rates below levels that otherwise would have prevailed.[1]

LSAP is Fed purchases of longer-term securities issued by the U.S. government and longer-term securities issued or guaranteed by government-sponsored agencies such as Fannie Mae or Freddie Mac.[2] To study the effects of LSAP, Chen et al. (2012) augment a standard DSGE model with segmented bond markets, and Gertler & Karadi (2011, 2013) provide a framework where limits to arbitrage exist. In both papers, LSAP can reduce long-term interest rates because it decreases the risk premium and provide stimulus to the economy. Most empirical research has focused on analyzing the effects of LSAP on interest rates, output, inflation, term and risk in financial markets, and spillover effects in other countries.[3] Studies using a variety of methodologies generally agree that LSAP has been effective at lowering long-term interest rates and stimulating economic growth.

However, it's nontrivial to determine the type and size of unconventional monetary policy from the central bank's announcement. It becomes more difficult to evaluate the effects of different types of policies on the economic activity as well as the financial market. In this paper, I estimate the size of each type of monetary policy by combining the impulse response of yield curve to monetary

[1] There is a rapidly growing literature on assessing the effect of forward guidance that has been used during the Great Recession. Important contributions include Campbell et al. (2012), Swanson & Williams (2014), Gertler & Karadi (2015), Del Negro et al. (2015), Keen et al. (2016) and Swanson (2017).

[2] https://www.federalreserve.gov/faqs/what-were-the-federal-reserves-large-scale-asset-purchases.htm

[3] For example, Gagnon et al. (2011), Krishnamurthy et al. (2011), Gilchrist & Zakrajšek (2013), Bauer & Rudebusch (2014).

policy shocks from a structural model with the movement of yield curve in the data. I use the structural model to calculate the implied effects on macroeconomic variables of different types of monetary policy shocks. In this way, I'm able to overcome some key limitations of the event studies of the Fed's unconventional monetary policy. My method provides an analysis beyond the very short-run response of financial variables and provides direct evidence on aggregate effects within a unified framework.

I begin by building a New Keynesian DSGE model based on Gertler & Karadi (2011, 2013) and investigate the impact of forward guidance and LSAP policies on real activity and interest rates. In their model, Gertler and Karadi (GK) introduce LSAP as the central bank's tool to provide intermediation, and it can affect the economy to the extent there exist limits to arbitrage in private intermediation. I add the following new features. First, forward guidance shock is introduced into the model. It is modeled with news shocks to the interest rate rule, which one can think of as a modeling device for generating innovations in expected future interest rates as in Keen et al. (2016). Second, I introduce the one-period shadow nominal short-term interest rate and assume it follows a Taylor rule. The one-period nominal short-term interest rate has a zero lower bound (ZLB). Third, GK's assumption that one-period nominal short-term interest rate is pegged for certain periods is dropped. In this way, I can study the effects of "pure" forward guidance and LSAP. I calibrate the model to match the key features of the data. I also show that my model's prediction is consistent with studies for both pre-ZLB and ZLB periods.

Next, I conduct a crisis experiment, where the one-period nominal interest rate hits its zero lower bound and stays there for several periods. I also suppose that either a forward guidance policy or a LSAP program involving the purchase of long-term security is initiated in the wake of the shock. Because of nonlinearity, the state of the economy, the forward guidance horizon, and the level of the limits to arbitrage could impact the efficacy of unconventional monetary policy. I choose the parameters that govern the above conditions based on the observed data and previous literature. I obtain the impulse responses of short-term and long-term interest rates to each type of monetary policy.

Using a two-factor shadow rate model adapted from Wu & Xia (2016), I then interpolate the entire yield curve's responses to the two types of monetary policy shocks. I find that forward guidance affects Treasury yields at all maturities, with a peak effect at a maturity of about 20 months. In contrast, the effects of LSAP increase with maturity, with LSAP having its peak effect on the longest maturities. However, because of the feedback effect from the monetary policy rule, an easing LSAP program which boosts output gap and inflation will increase interest rates at short maturities in response.

My next step is to combine the model's prediction with the observed yield curve movement to separate the effects of forward guidance from the LSAP. In a daily window bracketing key FOMC announcement between November 2008 and December 2015, I look at the response of the yield curve to the announcement. I regress those changes of yields at all maturities in the data on the changes of yields at all maturities as a response to the monetary policy shocks predicted from the structural model. In this way, I can estimate the size of each type of monetary policy and decompose the changes of yields at all maturities into two components: one attributed to the forward guidance and the other attributed to the LSAP. For example, on December 16, 2008, the FOMC lowered the target for the federal funds rate to a range from 0 to 1/4 percent and indicated that it expected the target to remain there "*for some time*". In the same announcement, the Fed announced that it would continue to consider ways of using its balance sheet to further support credit markets and economic activity. The l0-year Treasury yield dropped 17.5 basis points on that day. My identification of forward guidance and LSAP shows that the forward guidance contributed 1.9 basis points, while the LSAP had an effect of 15.8 basis points.

Finally, I consider implications for the real economy. With the estimated size of each type of monetary policy, I examine the separated effects on real GDP and inflation rate using the structural model. The model predicts that the forward guidance shock on December 16, 2008 would increase the two-quarter ahead real GDP by 0.17 percent and the two-quarter ahead inflation by 0.25 percentage points. It also predicts the LSAP announcement on that day would raise the two-quarter ahead real GDP by 0.37 percent and the two-quarter ahead inflation by 0.26 percentage points.

Overall, my estimates imply that forward guidance has a bigger influence on short-run inflation while LSAP is more important in influencing output. My estimates indicate that the QE I program (November 2008 to March 2010) increased the real GDP by 2.94%. Other studies report similar findings. For example, Chung et al. (2012) estimate that QE I by itself boosted the level of real GDP almost 2% above baseline by early 2012, whereas the full program raises the level of real GDP almost 3% by the second half of 2012.

My paper contributes to the literature on assessing the effects of the unconventional monetary policies and especially to the those using event studies to investigate the impact on various interest rates (e.g. Gagnon et al. (2011), Krishnamurthy et al. (2011)). The identifying assumption in the literature is that unexpected changes in interest rates in a narrow window surrounding scheduled FOMC announcements arise from news about monetary policy.[4] However, most of the event studies identify the type of unconventional monetary policy by either looking at whether there are changes of words and sentences in the current FOMC statement with respect to the previous statement or whether the event date belongs to a certain period of policy implementation and assign the type

[4] Wright (2012) uses a structural VAR to identify the effects of monetary policy shocks on various long-term interest rates. The VAR is identified using the assumption that monetary policy shocks are heteroskedastic: monetary policy shocks have higher variance on days of FOMC meetings and certain speeches than the other days.

and the direction (easing or tightening) accordingly. This approach could only capture the changes in words, not the market expectation, which could even go in the opposite direction.[5] It also ignores the fact that Fed inaction may itself represent a policy surprise.[6] In contrast, I solve this problem by building a structural model to predict the effects on various interest rates conditioning on the type and direction of monetary policy. I then combine the observed high-frequency interest rates data with the model prediction, and let the data itself speak loud the type and size of the monetary policy. Furthermore, I find my estimates correspond closely to the narrative elements of the FOMC announcement while in the meantime shed light on the occasions of Fed inaction.

My paper is also related to the studies that investigate the impact of unconventional monetary policy on the economy. Gertler & Karadi (2015) use external instruments in a VAR to identify monetary shocks and study transmission mechanism of the monetary policy, especially the forward guidance policy, on credit costs and real activity. Chung et al. (2012) assume the term premium of long-term Treasury bonds is inversely proportional to the Fed's holdings of long-term securities and estimate the Federal Reserve Board's macroeconomic model. Baumeister & Benati (2013) employ a time-varying parameter structural vector autoregression (VAR) model, and the identification of monetary policy shocks is achieved assuming LSAP will lower the long-term yield spread while short-term interest rate unchanged. My paper provides micro-foundation for their identification assumptions. The responses of short-term and long-term interest rates are calculated from the structural model. Using a two-factor shadow rate model, I find that forward guidance affects Treasury yields at all maturities, with the peak around 2-year Treasury bond yield, which is the conceptually preferred policy indicator in Gertler & Karadi (2015). Although LSAP cannot lower the short-term rate due to the zero lower bound constraint, LSAP decreases the term premium of 10-year Treasury bonds as well as the interest rate spread. Furthermore, my estimates of the impacts of unconventional monetary policy on real activity and inflation rate are close to the above literature.

While the literature has mostly focused on the effects of monetary policy as a whole, a growing literature has begun to emphasize the different role that each type of monetary policy played in stimulating the economy. Campbell et al. (2012) distinguish between Odyssean forward guidance, which commits the Fed's future action, and Delphic forward guidance, which forecasts economic conditions. Nakamura & Steinsson (2018) provide evidence that the central bank information effects play an important role in the overall causal effect of monetary policy shocks. As far as I

[5]For example, on January 28, 2009, the FOMC statement was interpreted by some market participants as disappointing because of its lack of concrete language regarding the possibility and timing of purchases of longer-term Treasuries in the secondary market contrary to the other announcements (Gilchrist & Zakrajšek 2013, Bauer & Rudebusch 2014).

[6]For example, on September 18, 2013, the FOMC was widely expected to begin tapering its asset purchase while it turned out not to do so.

know, Swanson (2017) is only paper that also separately identifies the effects of forward guidance and LSAP program on the yield curve. He extends the methods of Gürkaynak et al. (2005) to estimate two dimensions of monetary policy, interpreted as forward guidance and LSAP, based on principal-component representations of the response of various interest rates to monetary policy announcements. Although there is a big difference between the identification method used by my paper and Swanson's paper, most of the shocks I have identified are qualitatively similar to the ones identified by Swanson (2017). For those different, I will discuss the reason based on the readings of the FOMC statement and market reports, and these details can be found in Section 4. One advantage and important contribution of my method is that once the size of each type of unconventional monetary policies has been identified, I can return to the structural model to make inferences about the other variables of interest. This makes my paper not only able to look at the announcement's effects on financial markets as Swanson (2017) and other event studies do but also the effects on the macroeconomic activity and inflation rate within one uniform framework.

Finally, my paper is also connected to empirical studies that explore the signaling channel for Fed bond purchases. Previous research, most notably the work of Bauer & Rudebusch (2014), has found that such purchases have important signaling effects that lower expected future short-term interest rates using an event study. In the context of this literature, my paper provides a theoretical explanation for their finding: whenever the Fed conducts a LSAP program, they will accompany it with forward guidance. An announcement of LSAP program which causes output and inflation to rise today implies, through the endogenous component in the central bank's policy rule, higher interest rates today. Thus, to keep short-term rates at a low level today, an additional expansionary policy is implemented at the same time.

The remainder of the paper proceeds as follows. I begin by describing a New Keynesian DSGE model based on Gertler & Karadi (2011, 2013) in section 1. In section 2, I calibrate of the model to match the key features of the data and calculate the state-dependent impulse responses under different scenarios. In section 3, I describe the shadow rate framework I use to interpolate the entire yield curve. Section 4 describes the regression methodology and results. Section 5 discusses the robustness of my methodology. Section 6 concludes. Appendix provides further details.

# 1 A DSGE Model

The framework is based on Gertler & Karadi (2011, 2013). It is a reasonably standard New Keynesian model modified to explicitly include financial market structure and financial balance sheets. The model has three main ingredients. First, financial intermediation is risky: banks' net worth varies over time mainly because banks finance long-term risky assets with short-term risk-less debt. Second, an agency problem between households and banks exists, and it generates a constraint in the borrowing ability of the latter. Third, the LSAP is introduced as central bank intermediation and can affect the economy to the extent there exist limits to arbitrage in private intermediation.

The first difference from GK is that central bank conducts its interest rate policy not only by adjusting the current short-term interest rate but also by announcing the future path of the interest rate. The second difference is that I assume the central bank follows a short-term shadow rate Taylor rule. The short-term nominal interest rate is constrained by the zero lower bound. The shadow rate is the short-term rate when the ZLB is not binding; otherwise, it is negative to account for unconventional policy tools. At last, I drop GK's assumption that the one-period short-term rate is pegged for certain periods. This allows me to look at the "pure" effects of forward guidance and LSAP when the ZLB is binding.

In this section I characterize the distinctive elements of the model, including the behavior of households, banks, producers, and the central bank. See Online Appendix[7] for thorough expositions of the model.

## 1.1 Households

The economy is populated by a continuum of households of measure unity. Within each household there are two types of members: workers and bankers. The fraction $1 - f$ of the household members are workers, and the fraction $f$ are bankers. Workers provide labor and earn wages. Each banker manages a financial intermediary and returns the profit back to the household. Within the family there is perfect consumption insurance.

A banker this period stays a banker next period with probability $\theta$; therefore, the average survival time for a banker in any given period is $1/(1-\theta)$. After the bankers exit, their retained earnings return to their respective household in the form of dividends. The bankers who exit become workers and are replaced by a similar number of workers randomly becoming bankers; thus the relative proportion of each type is fixed. New bankers will get startup funds equal to $X_t$ provided by the household.

The economy is cashless. Let $c_t$ be consumption and $l_t$ labor supply. Then the household's discounted utility $u_t$ is given by:

$$u_t = \mathrm{E}\sum_{j=0}^{\infty}\beta^j[\ln(c_{t+j} - hc_{t+j-1}) - \frac{\chi}{1+\phi}l_{t+j}^{1+\phi}] \tag{1}$$

where $\beta \in (0,1)$ denotes the household's subjective discount factor, $h \in (0,1)$ governs the strength

[7] The Online Appendix can be found at https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnx4dXowMzl8Z3g6MzNkNWE1YzBkMzdkMTgxZA

of habits, and $\chi, \phi > 0$. In this way the household's inter-temporal elasticity of substitution is unity, and its Frisch elasticity of labor supply is $1/\phi$.

There are three types of assets that the household can hold. First, households can borrow and lend in a default-free one-period nominal bond market at the nominal interest rate $i_t$. In addition, they can also make private loans to non-financial firms to finance capital, and they can hold a nominal long-term government bond. Let $Z_t$ be the net income flow to the bank from a loan that is financing a unit of capital, $Q_t$ be the real price of the private securities at time $t$, $\delta$ the depreciation rate of a unit of capital, and $\xi_t$ a random disturbance. Then the real rate of return to the bank on the loan $R_{kt}$ is given by

$$R_{kt} = \frac{Z_t + (1-\delta)Q_t}{Q_{t-1}}\xi_t$$

Following Woodford (2001) and other authors (e.g Arellano & Ramanarayanan (2012), Chen et al. (2012)), I model the nominal long-term government bond as a perpetuity that pays 1 dollar each period. Let $q_t$ be the real price of the nominal bond, $P_t$ the price level, $q_t^n \equiv P_t q_t$ the nominal price of the nominal bond, and $\pi_t \equiv \frac{P_t}{P_{t-1}} - 1$ the inflation rate. Then the real rate of return on the nominal bond $R_{bt}$ is given by

$$R_{bt} = \frac{1/P_t + q_t}{q_{t-1}} = \frac{1 + q_t^n}{q_{t-1}^n(1+\pi_t)}$$

The households face a holding cost for the private securities and long-term government bond. Let $S_{ht}$ be the amount of private securities that households have. The transaction cost is equal to the percentage $\frac{1}{2}\kappa_s(S_{ht} - S_h)^2/S_{ht}$ of the value of the securities in its respective portfolio for $S_{ht} > S_h$. Similarly, for government bonds there is a holding cost equal to the percentage $\frac{1}{2}\kappa_b(B_{ht} - B_h)^2/B_{ht}$ of the total value of government bonds held for $B_{ht} > B_h$, where $B_{ht}$ is the amount of long-term government bond that households have. Accordingly, there is a certain amount of each asset that the household can hold costlessly. Going above these levels involves transaction costs which are increasing at the margin. Limited participation in asset markets by households leads to incomplete arbitrage.

Accordingly, the household faces a flow budget constraint at time $t$:

$$P_t c_t + P_t D_{ht} + P_t Q_t[S_{ht} + \frac{1}{2}\kappa_s(S_{ht} - S_h)^2] + P_t q_t[B_{ht} + \frac{1}{2}\kappa_b(B_{ht} - B_h)^2] =$$
$$P_t W_t l_t + P_t \Pi_t - P_t T_t - P_t X_t + (1 + i_{t-1})P_{t-1}D_{ht-1} + R_{kt}P_{t-1}Q_{t-1}S_{ht-1} + R_{bt}P_{t-1}q_{t-1}B_{ht-1}. \tag{2}$$

where $D_{ht}$ is the quantity of one-period nominal bond held by household at time $t$, $W_t$ is the real wage, $\Pi_t$ are the payouts to the household from ownership of both non-financial and financial firms in real term, $T_t$ is the lump-sum taxes in real term, and $X_t$ is the total transfer the household gives to its members that enter banking at $t$.

The household's objective is to choose $c_t$, $l_t$, $D_{ht}$, $S_{ht}$ and $B_{h,t}$ to maximize (1) subject to (2). The first-order conditions are:

$$\begin{aligned}
\frac{\partial u_t}{\partial c_t} W_t &= \chi l_t^{\phi} \\
\mathrm{E}_t \Lambda_{t,t+1} R_t &= 1 \\
S_{ht} - S_h &= \frac{\mathrm{E}_t \Lambda_{t,t+1}(R_{kt+1} - R_t)}{\kappa_s} \\
B_{ht} - B_h &= \frac{\mathrm{E}_t \Lambda_{t,t+1}(R_{bt+1} - R_t)}{\kappa_b}
\end{aligned}$$

where the household's stochastic discount factor is $\Lambda_{t,t+1} \equiv \beta \frac{\partial u_t / \partial c_t}{\partial u_t / \partial c_{t+1}}$, and the link between nominal interest rate $i_t$ and real interest rate $R_t$ is given by the Fisher equation:

$$1 + i_t = R_t(1 + \mathrm{E}_t \pi_{t+1})$$

## 1.2 Banks

Banks lend funds obtained from households to non-financial firms and to the government. In addition to acting as specialists that assist in channeling funds from savers to investors, they engage in maturity transformation. They hold long-term assets and fund these assets with short-term liabilities (beyond their own equity capital). In addition, financial intermediaries in this model are meant to capture the entire banking sector, i.e., investment banks as well as commercial banks.

Let $n_t$ be the amount of net worth that a banker/intermediary has at the end of period $t$, $d_t$ the deposits the intermediary obtains from households, $s_{pt}$ the quantity of financial claims on non-financial firms that the intermediary holds, and $b_t$ the quantity of long-term government bonds. The intermediary balance sheet is then given by:

$$Q_t s_{pt} + q_t^n b_{pt} = n_t + d_t \tag{3}$$

Net worth is accumulated through retained earnings. It is thus the difference between the gross return on assets and the cost of liabilities:

$$n_t = R_{kt} Q_{t-1} s_{pt-1} + R_{bt} q_{t-1}^n b_{pt-1} - R_{t-1} d_t \tag{4}$$

The banker's objective is to maximize the discounted stream of payouts back to the household, where the relevant discount rate is the household's inter-temporal marginal rate of substitution. The terminal wealth is given by:

$$\mathrm{V}_t = \mathrm{E}_t \sum_{i=1}^{\infty} (1-\theta)\theta^{i-1} \Lambda_{t,t+i} n_{t+i} \tag{5}$$

To motivate a limit on the bank's ability to obtain deposits, the following moral hazard/costly enforcement problem is introduced: at the beginning of the period, the banker can choose to divert funds from the assets he holds and transfer the proceeds to the household of which he is a member. The cost to the banker is that the depositors can force the intermediary into bankruptcy and recover the remaining fraction of assets. However, it is too costly for the depositors to recover the funds that the banker diverted. It is assumed that it is easier for the bank to divert funds from its holdings of private loans than from its holding of government bonds: it can divert the fraction $\lambda$ of its private loan portfolio and the fraction $\lambda\triangle$ with $0 < \triangle < 1$ from its government bond portfolio. Therefore, for depositors to be willing to supply funds to the banker, the following incentive constraint must be satisfied:

$$V_t \geq \lambda Q_t s_{pt} + \lambda \triangle q_t^n b_{pt} \tag{6}$$

The left side is what the banker would lose by diverting a fraction of assets. The right side is the gain from doing so. The banker's maximization problem is to choose $s_t$, $b_t$, and $d_t$ to maximize (5) subject to (3), (4), and (6). Let $\lambda_t$ be the Lagrange multiplier associated with the incentive constraint. The first order conditions are:

$$\mathrm{E}_t \widetilde{\Lambda}_{t,t+1}(R_{kt+1} - R_t) = \frac{\lambda_t}{1+\lambda_t}\lambda$$
$$\mathrm{E}_t \widetilde{\Lambda}_{t,t+1}(R_{bt+1} - R_t) = \triangle \frac{\lambda_t}{1+\lambda_t}\lambda$$

with

$$\begin{aligned} \widetilde{\Lambda}_{t,t+1} &\equiv \Lambda_{t,t+1}\Omega_{t+1} \\ \Omega_t &= 1 - \theta + \theta \frac{\partial V_t}{\partial n_t} \\ \frac{\partial V_t}{\partial n_t} &= \widetilde{\Lambda}_{t-1,t}[(R_{kt} - R_{t-1})\phi_t + R_{t-1}] \end{aligned}$$

The constraints are:

$$\begin{aligned} Q_t s_{pt} + \triangle q_t^n b_t &= \phi_t n_t \quad \text{if} \quad \lambda_t > 0 \\ &< \phi_t n_t \quad \text{if} \quad \lambda_t = 0 \end{aligned}$$

where

$$\phi_t = \frac{\mathrm{E}_t \widetilde{\Lambda}_{t,t+1} R_t}{\lambda - \mathrm{E}_t \widetilde{\Lambda}_{t,t+1}(R_{kt+1} - R_t)}$$

### 1.3 Central bank's asset purchases

The central bank is allowed to purchase quantities of private loans $S_{gt}$ and long-term government bonds $B_{gt}$. For each each type of security, it pays the respective market prices $Q_t$ and $q_t$. However, when limits to arbitrage in the private market are operative, the central bank's acquisition of securities will have the effect of bidding up the prices on each of these instruments and down the excess returns. To finance these purchases, it issues risk-free short-term debt $D_{gt}$ that pays the safe market interest rate $i_t$. In particular, the central bank's balance sheet is given by

$$Q_t S_{gt} + q_t B_{gt} = D_{gt}.$$

### 1.4 Aggregation

Let $S_{pt}$ be the total quantity of loans that banks intermediate, $B_{pt}$ the total number of government bonds they hold, and $N_t$ their total net worth. Since neither component of the maximum adjusted leverage ratio depends on bank-specific factors, we can simply sum across the portfolio restriction on each individual bank to obtain

$$Q_t S_{pt} \leq \phi_t N_t - \triangle q_t^n B_{pt}$$

Total net worth evolves as the sum of the retained earnings by the fraction $\theta$ of surviving bankers and the transfers that new bankers receive, X, as follows:

$$\begin{aligned} N_t =& \theta[(R_{kt} - R_{t-1}) \frac{Q_{t-1} S_{pt-1}}{N_{t-1}} \\ & (R_{bt} - R_{t-1}) \frac{q_{t-1}^n B_{pt-1}}{N_{t-1}} + R_{t-1}] N_{t-1} + X \end{aligned}$$

Let $S_t$ and $B_t$ be the total supplies of private loans and long-term government bonds, respectively. Then by definition,

$$\begin{aligned} S_t &= S_{pt} + S_{ht} + S_{gt} \\ B_t &= B_{pt} + B_{ht} + B_{gt} \end{aligned}$$

We combine these identities with the balance constraint on the banks to obtain the following relation for the total value of private securities intermediated:

$$Q_t(S_t - S_{ht} - S_{gt}) \leq \phi_t N_t - \triangle q_t^n [B_t - (B_{gt} + B_{ht})] \tag{7}$$

## 1.5 The Production Sector

### 1.5.1 Intermediate goods firms

The economy also contains a continuum of infintely-lived monopolistically competitive firms indexed by $s \in [0, 1]$, each producing a single differentiated good. Each operates a constant returns to scale technology with capital and labor inputs and have identical Cobb-Douglas production functions:

$$Y_t(s) = A_t(\xi_t k_{t-1}(s))^\alpha l_t(s)^{1-\alpha}$$

where $\xi_t$ is a random disturbance that we refer to as a "capital quality" shock. The capital quality shock as a simple way to introduce an exogenous source of variation in the return to capital. It is best thought of as capturing some form of economic obsolescence, as opposed to physical depreciation.

To finance the new capital, the firm must obtain funding from a bank. Then by arbitrage, the value of the security is equal to the market price of the capital underlying security: $Q_t K_t = Q_t S_t$.

Let $P_{mt}(s)$ be the real marginal cost. Then the firm's demand for labor and labor is given by

$$\begin{aligned} W_t &= P_{mt}(s)(1-\alpha)\frac{Y_t(s)}{l_t(s)} \\ Z_t &= P_{mt}(s)\alpha\frac{Y_t(s)}{\xi_t k_{t-1}(s)} \end{aligned}$$

The capital accumulation equation is:

$$k_t(s) = \xi_t k_{t-1}(s)(1-\delta) + I_t(s)$$

Firms set prices optimally subject to nominal rigidities in the form of Calvo (1983) price contracts, which expire with probability $1-\gamma$ each period. Each time a Calvo contract expires, the firm sets a new contract price freely, which then remains in effect for the life of the new contract. When a firm's price contract expires, the firm $s$ chooses the new contract price $p_t^*(s)$ to maximize the value to shareholders of the firm's cash flows over the lifetime of the contract. In between these periods, the firm is able to partially index its price to the steady state rate of inflation. The objective function is:

$$\mathrm{E}_t \sum_{j=0}^{\infty}(1-\gamma)\gamma^j \Lambda_{t,t+j}[\frac{p_t^*(s)}{P_{t+j}}(1+\bar{\pi})^{j\gamma_p} - \frac{\epsilon}{\epsilon-1}P_{mt+j}(s)]Y_{t+j}(s)$$

The standard New Keynesian price optimality condition is

$$\mathrm{E}_t \sum_{j=0}^{\infty}(1-\gamma)\gamma^j \Lambda_{t,t+j}[\frac{p_t^*(s)}{P_{t+j}}(1+\bar{\pi})^{j\gamma_p} - \frac{\epsilon}{\epsilon-1}P_{mt+j}(s)]Y_{t+j}(s) = 0$$

### 1.5.2 Capital goods producers

Capital producers make new capital using input of final output and subject to adjustment costs. They sell the new capital to firms at the price $Q_t$. Given that households own capital producers, the objective function of a capital producer is

$$\mathrm{E}_t \sum_{j=0}^{\infty} \Lambda_{t,t+j}\{Q_{t+j}I_{t+j} - [1+f(\frac{I_{t+j}}{I_{t+j-1}})]I_{t+j}\}$$

The first order condition is:

$$Q_t = 1 + f(\frac{I_t}{I_{t-1}}) + \frac{I_t}{I_{t-1}}f'(\frac{I_t}{I_{t-1}}) - \mathrm{E}_t\Lambda_{t,t+1}(\frac{I_{t+1}}{I_t})^2 f'(\frac{I_{t+1}}{I_t})$$

### 1.5.3 Final goods firms

The output of each firm $s$ is purchased by a perfectly competitive final goods sector, which aggregates the differentiated goods into a single final good using a CES production technology:

$$Y_t = [\int_0^1 Y_t(s)^{\frac{\epsilon-1}{\epsilon}} ds]^{\frac{\epsilon}{\epsilon-1}}$$

where $Y_t$ denotes the quantity of the final good. Each intermediate firm $s$ thus faces a downward-sloping demand curve for its product with elasticity $1/(\epsilon-1)$. Then

$$Y_t(s) = (\frac{p_t(s)}{P_t})^{-\epsilon/(\epsilon-1)} Y_t$$

where $P_t$ is the CES aggregate price of the final good:

$$P_t = [\int_0^1 p_t(s)^{1/1-\epsilon} ds]^{1-\epsilon}$$

The evolution of the price level is:

$$P_t = [(1-\gamma)(P_t^*)^{1-\epsilon} + \gamma(\bar{\pi}^{\gamma_p} P_{t-1})^{1-\epsilon}]^{1/(1-\epsilon)}$$

### 1.6 Monetary Policy

This section describes the monetary policy by the central bank. There are two types of policies: the interest rate rule and the credit policy.

The central bank sets the one-period nominal interest rate $i_t$ according to the following policy rule,

$$i_t^* = r + \bar{\pi} + \kappa_\pi(\pi_t - \bar{\pi}) + \kappa_y(\log Y_t - \log Y_t^*) + z_t \quad (8)$$

$$i_t = \max\{\underline{\iota}, i_t^*\} \quad (9)$$

where $\underline{\iota}$ is the lower bound on the one-period nominal interest rate, $i_t^*$ is the rate the central bank would set if it was unconstrained, $r = -\log\beta$ denotes the steady-state one-period real interest rate, $Y_t^*$ is the natural (flexible-price equilibrium) level of output. For simplicity, we use minus the price markup as a proxy for the output gap. Based on the previous work of Laséen & Svensson (2011), Del Negro et al. (2015) and Keen et al. (2016), which use a combination of current and anticipated monetary policy shocks to model forward guidance shocks, I model $z_t$, the monetary policy deviation at time $t$ as

$$z_t = \varepsilon_{t,t}^m + \sum_{j=1}^{T} a_j \varepsilon_{t,t-j}^m \quad (10)$$

for a give $T \geq 0$, where $\varepsilon^{m,t} \equiv (\varepsilon_{t,t}^m, \varepsilon_{t+1,t}^m, \ldots, \varepsilon_{t+T,t}^m)'$ is a zero-mean i.i.d. random $(T+1)$-vector realized in the beginning of period t and called the innovation in period $t$. $\varepsilon^{m,t}$ can be interpreted as the new information the central bank announces in the beginning of period t about current and future periods.[8] $a_j$ governs the size of each shock.

[8] It follows that the dynamics of the deviation and the projection $z^t = (z_t, z_{t+1,t}, \ldots, z_{t+T,t})'$ can be written

$$z^{t+1} = A_z z^t + \varepsilon^{m,t+1}$$

In order to determine the magnitude of $a_j$, where $j > 0$, I follow the specification in Bundick & Smith (2016). They assume that the series of the size is an exponential decay process. In this case equation (10) could be rewritten as,

$$z_{t,t} = \varepsilon^m_{t,t} + \sum_{j=1}^{T} \rho_z^j \varepsilon^m_{t,t-j}.$$

In addition to the interest rate monetary policy, the central bank could conduct monetary policy through direct purchases of securities or bonds. During the crisis, the central bank purchases a fraction $\varphi_{st}$ of the outstanding stock of private securities and a fraction $\varphi_{bt}$ of the outstanding stock of long-term government bonds:

$$S_{gt} = \varphi_{st} S_t$$
$$B_{gt} = \varphi_{bt} B_t$$

Following Gertler & Karadi (2013), both $\varphi_{st}$ and $\varphi_{bt}$ obey second-order stationary stochastic processes to capture the cumulative buildup of asset purchases program.

$$\begin{aligned} \varphi_{st} &= \rho_{0s} + \rho_{1s}\varphi_{st-1} + \rho_{2s}\varphi_{st-2} + \varepsilon^s_t \\ \varphi_{bt} &= \rho_{0b} + \rho_{1b}\varphi_{bt-1} + \rho_{2b}\varphi_{bt-2} + \varepsilon^b_t \end{aligned}$$

The reason why the central bank's credit policy works is as follows. When the bank faces balance constraint shown in equation (7), given the total quantity of bank equity, an increase in the central bank's holding of long-term government bonds will increase the total demand for private securities. Since asset supplies are relatively inelastic in the short run, the enhanced asset demand pushes up the real price of capital $Q_t$ and pushes down the excess return on capital. Furthermore, the presence of inelastic household security demands will strengthen the effects.

One distinguishing feature of the policy experiments I perform from the GK paper is that in my model the number of periods spent at the zero lower bound is endogenous. GK assume that there exists some fixed periods where interest rate is pegged at the zero lower bound such as the nominal interest rate never goes below zero. Thus the monetary policy effects reported in their paper is the mixed impacts from interest rate peg as well as LSAP. In contrast, my shadow interest rate can be negative, and the interest rate is not pegged. The effects illustrated in the later parts of this paper

where the $(T+1) \times (T+1)$ matrix $A_z$ is defined as

$$A_z \equiv \begin{bmatrix} 0_{T\times 1} & I_T \\ 0 & 0_{1\times T} \end{bmatrix}.$$

is purely driven by forward guIdance or LSAP.

### 1.7 10-year Equivalent Treasury Yield

As in Gertler & Karadi (2013), 10-year bond yield $i_t^{(40)}$ is defined as the yield on a security that sells for the same price ($q_t^n$) as the perpetuity, pays \$1 per period for ten years, and then is redeemed at par value of $q_{ss}^n$, where $q_{ss}^n = 1/\bar{i}$ is the steady-state real price of the perpetuity and $\bar{i}$ is the steady-state short-term nominal interest rate. The nominal yield to maturity on the ten-year government bond $i_t^{(40)}$ is accordingly

$$q_t^n = \sum_{j=1}^{40} \frac{1}{(1+i_t^{(40)})^j} + \frac{q_{ss}^n}{(1+i_t^{(40)})^{40}} \tag{11}$$

### 1.8 Government, Resource Constraint and Equilibrium

Let $G_t$ be the government spending at time $t$, and $G_{ss}$ be the steady state level of government spending. The government budget constraint is

$$G_t + (R_{bt} - 1)B_t = T_t + (R_{kt} - R_{t-1})Q_{t-1}S_{gt-1} + (R_{bt} - R_{t-1})q_{t-1}^n B_{gt-1}$$

Equilibrium in the final goods market requires

$$Y_t = C_t + [1 + f(\frac{I_t}{I_{t-1}})]I_t + G_t$$

Market clearing in markets for private securities, long-term government bonds and labor. The supply of private securities at the end of period $t$ is given by the sum of newly acquired capital $I_t$ and leftover capital from last period:

$$S_t = I_t + (1-\delta)K_{t-1}$$

The supply of long-term government bonds is fixed by the government: $B_t = \bar{B}$. This completes the description of the model.

## 2 Calibration and Simulation of the Structrual Model

### 2.1 Calibration

Table 1 lists the choice of parameter values for the model.

I begin with the parameters that have the same value as in Gertler & Karadi (2013). They are shown in the Panel (A). The depreciation rate of capital $\delta$ is set to be 0.025, and the capital share $\alpha$ is 0.33. The price rigidity parameter $\gamma$ is 0.779, which implies firms resetting prices approximately every 13.6 months on average. The degree of price indexation $\gamma_p$ is assumed to be zero. The steady state government expenditure share $G_{ss}/Y$ is 0.2, and the steady state labor is 1/3. $\phi_y = -0.125$ for the Taylor rule coefficient on output gap. I set $\bar{K}_h$ so that in steady state, households hold half the quantity of private securities, and $\bar{B}_h$ so that households hold three-quarters of the outstanding stock of long-term government debt. $\bar{B}$ is set such as the ratio of the stock of long-term government bond to output in steady state is equal to its pre-crisis value of approximately 0.45.

However, some of the other parameters used by GK imply properties of the yield curve and the relation between bond and stock yields that are inconsistent with the observed data. Since interpreting the response of the yield curve to shocks is the focus of the present exercise, I have made a number of changes so that the predictions of the model better match the properties observed in financial data.

Panel (B) shows the parameters that are closely related to yield curve properties. I assign a quarterly value of 0.9945 to match an average of short-term real interest rate of 2.2%. GK use $\beta$ equal to 0.995, which implies a steady-state short-term real interest rate of 2 percent. GK assume an inflation target $\bar{\pi} = 0$. To match the average values of the nominal interest rate in the pre-ZLB data from Gürkaynak et al. (2007) dataset, I set $\bar{\pi} = 0.6$, corresponding to an annual inflation target of 2.4%. Thus the steady state value of nominal interest rate is 4.6%. GK assume a lower bound of 0 in their original calibration. But the short end of the yield curve was never literally zero, with excess reserves earning 0.25% interest from the Fed throughout this period. For this reason, I set $\underline{\iota} = 0.25\%$.

The following part of Panel (B) is the steady state bond excess return and equity excess return. GK set the steady state real excess return on long-term government bonds to be 50 basis points and real excess return on private securities 100 basis points. For the government bond, the data don't have the real federal funds rate for me to target the short-term real excess return, I use the 2-year inflation-indexed Treasuries (TIPS) yield instead. Taken from the updated Gürkaynak et al. (2010) online dataset, from 2004 to 2007 the average difference between a 10-year TIPS and a 2-year TIPS is 69 basis points[9], which is quite larger than GK's value[10]. Our new calibration has the real bond excess return of 103.8 basis points with the implication that 10-year and 2-year real rate spread is equal to 69 basis points exactly. For the private securities, I follow GK to use the information on pre-2008 spreads between mortgage rates and 10-year Treasury yield and between BAA corporate

[9] I use the 2004-2007 period to avoid both the low liquidity of TIPS in its first few years and the financial crisis and recession. Over this sample, real yields average between about 1.4% and 2.1%.

[10] Real excess return on long-term government bonds of 50 basis points as in GK's model will imply the spread of 10-year and 2-year real rate to be 33 basis points.

and 10-year Treasury yield. Using data from the St. Louis Federal Reserve Economic Database (FRED), I find that on average the former is 163 basis points and the latter is 353 basis points from January 1990 to November 2008.[11] Therefore, I set the steady state excess return on private securities to be 173 basis points, higher than the 100 basis points in GK.

The expected horizon for bankers, the steady-state leverage ratio, together with the two excess return values mentioned above, pin down the $\theta$, $\lambda$, $\Delta$, and $X$, where the parameter $\lambda$ is the percent of funds that a bank can divert to his household. Since I have adjusted the excess return values, I need to adjust the other targets to make the implied $\lambda$ still realistic. Therefore, I choose an expected horizon of 5.7 years instead of 8.77 years for bankers. I also change the steady-state leverage ratio to be 5 instead of 4 in their 2011 paper and 6 in their 2013 paper, but this latter change is not the most necessary. As a result, the implied value for $\lambda$ becomes 38.6%, close to the 38.1% in their 2011 paper and 34.5% in their 2013 paper.

The remaining part of Panel (B) is the household portfolio adjustment cost parameters $\kappa_s$ and $\kappa_b$, along with different values for the AR(2) coefficients for the LSAP shock. These parameters are chosen to make the predicted effects of LSAP on medium-term bond yields more consistent with the data in the crisis. Since I have made the above changes, I also have to make ajustment for those parameters.

Panel (C) presents other parameters used by GK differ substantially from previous studies and turn out to raise the possibility of some odd dynamics of the model. I have found that the model is much more realistic when more conventional values are used for these parameters. The habit parameter, $h$ is 0.615, close to the estimated value in Christiano et al. (2005), instead of 0.815 in Gertler & Karadi (2013). GK assume a value for $1/\phi$, the Frisch labor supply elasticity, equal to 3.6. I instead set $1/\phi = 2$. GK assume an elasticity of substitution $\varepsilon$ between goods of 4.167, implying a steady-state markup of 31.58%. My exercise sets $\varepsilon = 6$, implying a more realistic markup of 20%. GK assume an inverse elasticity of investment with respect to the price of capital, $\eta_i$, of 1.728. I instead use $\eta_i = 4.5$, close to the prior mean of the DSGE model estimated by Del Negro & Schorfheide (2008). The coefficient for the Taylor rule $\phi_\pi$ is taken from Coibion et al. (2012).

Finally, there is one parameter that is new to our model, $\rho_z$, which governs the decaying behavior of the forward guidance shock. In the crisis experiment below, we've chosen $\rho_z$ equal to 0.68 to match the evidence on the impact of forward guidance on the term structure. In Section 5, I discuss the effects of forward guidance persistence.

[11] Another way is look at the relative size of the two excess returns. The average ratio of the spread between 10-year Treasury yield and federal funds rate over the spread between BAA and federal funds rate is 0.29 while over the spread between 30-year mortgage rate and federal funds rate is 0.87. My calibration implies 0.6.

## 2.2 Solution Method

I solve the model using the OccBin toolkit developed by Guerrieri & Iacoviello (2015). The solution method constructs a piecewise linear approximation to the original nonlinear model. It allows us to model the occasionally-binding zero lower bound and solve for the short-term and long-term yields.

## 2.3 Crisis Experiment

I now explore how the unconventional monetary policy works in the context of a financial crisis as described in Gertler & Karadi (2011, 2013). The initiating shock for the crisis is a decline in capital quality. It forces the asset prices to decline and the excess return of capital to rise, which depresses real activity and in turn amplifies the downturn. Further, the drops of output and inflation are sufficiently sharp to push the economy to the point where the nominal interest rate hits the zero lower bound.

I suppose the the shock obeys a first-order autoregressive process with coefficient 0.88. We consider three scenarios:

(i) capital quality shock without central bank response,

(ii) capital quality shock with forward guidance,

(iii) capital quality shock with LSAP.

As discussed in Keen et al. (2016) and Bundick & Smith (2016), initial state of the economy matters for the performance of unconventional monetary policy. Swanson & Williams (2014) have examined the number of quarters until the private sector expected the funds rate to be 25 bp or higher from the the median "consensus" response to the monthly Blue Chip survey of professional forecasters. Their findings show that Blue Chip consensus expectation of the length of time fluctuated between two and five quarters before August 2011, and private-sector expectations of the time until lift-off jumped to seven or more quarters after that. In addition, most of the literature have chosen the length of zero lower to be between 1 and 7 quarters. I choose the size of the initial shock such as such that the model approximates the evidence on the impact of effect of LSAP on both real activity and the 10-year interest rate. In the baseline result we present here, the initial shock will have the annualized nominal shadow rate will fall to negative 121 basis points with the a total zero lower bound episode of 4 quarters. In the Section 5, we show the results when we have shallower (60 basis points) and deeper (180 basis points) shadow rates.

Figure 1 plots the the responses of capital quality, short-term nominal interest rate, output, inflation, the excess return of capital as well as the 10-year Treasury yield in the model to a negative capital quality shock. The solid red lines are the impulse responses not considering the zero lower bound; in contrast, the blue-dash lines with the zero lower bound constraint. The initial decrease of capital quality drives up the real excess return of capital. The process is amplified as the asset fire sale and decline in real activity further weaken bank's balance sheets. As Figure 1 shows, the existence of zero lower bound will make the recession more severe. The real output drops about 3.4 percent at the peak, and the annual inflation rate drops 2.2 percentage points in the initial.

The forward guidance horizon $T$ is set to last 7 quarters. On one hand, the horizon must be larger than the ZLB episode, which is four quarters in our baseline, otherwise the policy won't provide stimulus to the real economy. On the other hand, I limit the finite horizon to the diminishing influence of the central bank. In the Section 5, we show the results when we have shallower (60 basis points) and deeper (180 basis points) shadow rates.

I define that one unit of forward guidance shock will lower the nominal shadow rate by 25 basis points. As in Gertler & Karadi (2013), I assume that the LSAP policy is implemented as an AR(2) process. I define that one unit of LSAP shock will lower the 10-year yield by 5 basis points.[12] Figure 2 plots how much difference the unconventional monetary policy made to the response of the yield curve in addition to the negative capital quality shock. One unit easing forward guidance shock will decrease the annualized shadow short-term nominal interest rate by 25 basis points, the current output by 0.02 percent, and the current annualized inflation rate by 0.07 percentage points. One unit easing LSAP shock will raise the shadow short-term nominal interest rate by 40 basis points, the current output by 0.08 percent, and the current annualized inflation rate by 0.14 percentage points.

# 3 Interpolation of the Yield Curve

Given model-implied values for the shadow rate $i_t^*$ and yield on the ten-year equivalent government debt $i_{Nt}$, in this section I interpolate the yield on any maturity $i_{nt}$ under the ZLB using a flexible approximation to the shape of the yield curve.

[12] As a comparison, Swanson (2017) proposes one way of comparing magnitudes across the two types of policies: a "one-standard-deviation" change in forward guidance by the FOMC corresponded to a change of about 6bp in federal funds rate expectations one year ahead, while a "one-standard-deviation" change in LSAP corresponded to a roughly \$300 billion change in bond purchases. The nominal GDP in 2008 is 14,817.6 billion, so that the one-standard deviation of LSAP defined in Swanson (2017) is 2% increase of the bond-GDP ratio. Under the crisis experiment in scenario (i), the size of forward guidance shock set such as $\varepsilon_{t,t-j} = 0.11\%$. In terms of annualized basis points, the forward guidance shock series is (45, 29, 19, 13, 8, 5). At the peak of the LSAP shock, there is 4% increase in the real value of bond-real GDP ratio.

### 3.1 Solution Away from the ZLB

First I consider the case when the economy is far away from the ZLB, so that $i_t^* = i_t$, the observed one-period rate. Suppose there are two possibly unobserved factors, $(\xi_{1t}, \xi_{2t})$ that summarize everything that matters for determining interest rates. Their Q-measure dynamics are characterized by r edr e

$$\begin{aligned} \xi_{1t} &= \phi_1 \xi_{1t-1} + \varepsilon_{1t} \\ \xi_{2t} &= \phi_2 \xi_{2t-1} + \varepsilon_{2t} \end{aligned}$$

The one-period nominal interest rate $i_t$ is given by

$$i_t = \xi_{1t} + \xi_{2t} \tag{12}$$

Then the nominal forward rate at date $t$ at horizon $n$ is

$$f_{nt} = E_t^Q(i_{t+n}) = \phi_1^n \xi_{1t} + \phi_2^n \xi_{2t} \tag{13}$$

The yield at date $t$ with maturity $n$ is

$$i_{nt} = n^{-1} \sum_{j=0}^{n-1} f_{jt}$$

When $\phi_1 = 1$ and $|\phi_2| < 1$, this framework implies the Dynamic Nelson-Siegel model:

$$i_{nt} = \xi_{1t} + n^{-1} \frac{1-\phi_2^n}{1-\phi_2} \xi_{2t} \tag{14}$$

Equations (12) and (14) allow us to recover the two factors directly off the level of one-period rate $i_t$ and the long-term rate, $i_{Nt}$:

$$\begin{aligned} &\xi_{2t} = (N^{-1} \frac{1-\phi_2^N}{1-\phi_2} - 1)^{-1} (i_{Nt} - i_t) \\ &\xi_{1t} = i_t - \xi_{2t} \end{aligned}$$

Moreover, once $\xi_{1t}$ and $\xi_{2t}$ are known, I can interpolate the entire yield curve using equations (13) and (14).

### 3.2 Solution at the Lower Bound

Here I have $i_t^* = \xi_{1t} + \xi_{2t} < \underline{\iota}$, $i_t = \underline{\iota}$. Wu & Xia (2016) demonstrate that in equilibrium, the forward rates $f_{nt}$ can be approximated as

$$f_{nt}^* = \xi_{1t} + \phi_2^n \xi_{2t}$$
$$f_{nt} = \underline{\iota} + \sigma_n g(\frac{f_{nt}^* - \underline{\iota}}{\sigma_n})$$

where $g(z) = z\Phi(z) + \phi(z)$ for $\Phi(z)$ the cumulative distribution function for a standard Normal variable and $\phi(z)$ the density, and $\sigma_n$ is a parameter.

I have

$$i_{nt} = n^{-1} \sum_{j=0}^{n-1} f_{jt},$$

which along with $i_t^* = \xi_{1t} + \xi_{2t}$ give two equations in two unknowns to determine $(\xi_{1t}, \xi_{2t})$ from the model-implied interest rates $(i_t^*, i_{Nt})$.

### 3.3 Calibration

I use the pre-ZLB yield data to calibrate $\phi_2$. Gürkaynak et al. (2007) estimate zero-coupon nominal Treasury yields at various maturities, and data are available from the online version of their dataset. The first row of Table 2 reports average yields from January 1990 to November 2007, a span that excludes the Great Inflation as well as the Great Recession periods and I refer as pre-ZLB period. Over this sample, the average nominal 1-year Treasury yields is about 4.57 percent, and the average nominal 10-year Treasury yields is about 6 percent. I choose ($\xi_1$, $\xi_2$, $\phi_2$) such as the fitted yield curve best matched the average yield curve. It turns out that $\xi_1 = 7$, $\xi_2 = -2.77$, $\phi_2 = 0.979$.

Next, I use the same $\phi_2$ along with the model steady state values of the one-period and long term rates, $i_{ss}$ and $i_{Nss}$, to construct the yield curve implied by the model steady state. It turns out that $\xi_1 = 6.23$, $\xi_2 = -1.62$ are best fit. The second row of Table 2 reports the nominal yield curves implied by the model. The model is able to reproduce these features of the data quite well: the average level of nominal yields in the model between about 5.4 and 6.4 percent, with an upward slope of 109 bp.

I follow Krippner (2016) and set $\sigma_n$ as:

$$\sigma_n = \sqrt{\rho_1^2 n + \rho_2^2 G(2\phi_3, n) + 2\rho_{12}\rho_1\rho_2 G(\phi_3, n)}$$

where $\rho_1$, $\rho_2$, $\rho_{12}$ and $\phi_3$ are parameters estimated from an arbitrage-free Nelson & Siegel (1987) model with two state-variables (level and slope), and $G(\phi_3, n) = \frac{1}{\phi_3}[1 - \exp(-\phi_3 n)]$. $\rho_1$, $\rho_2$, $\rho_{12}$ and $\phi_3$ are estimated to be equal to 0.0111, 0.0142, -0.7390 and 0.2498 using 6 months, 1, 2, 5, 7, and 10 years monthly Treasury yield data from January 2009 to November 2015.

Next, I compute the implied yield curve during the ZLB period using the impulse responses of interest rates derived from the structural model. Panel B of Table 2 compares the yield data during the ZLB period with the interpolated data. Between November 2008 and November 2015, the average nominal 1-year Treasury yields was about 0.27 percentage points, and the average nominal 10-year Treasury yields was about 2.80 percentage points. Although the simulated model cannot capture the dramatic drop of the 10-year Treasury bond yield, it improves the GK's work.

Figure 3 illustrates the difference between the yield curves in scenarios (i) and (ii) and the difference between (i) and (iii). This is the paper's key identification assumption. As shown in the figure, one unit of easing forward guidance announcement lowers Treasury yields at all maturities, with a peak effect at a maturity of about 20 months; in contrast, one unit easing LSAP will increase the shortest-maturity Treasury yields because of the feedback of the interest rate rule but will lower medium-term and long-term yields, with the peak effect on the longest maturities.

# 4 The FOMC's Forward Guidance and LSAP Announcements

I now investigate the effects of forward guidance and LSAP announcements on each event date. First, I identify the separate contributions of each shock to the effects of the announcement by matching the change in the yield curve that the model predicts would arise from a linear combination of the two shocks with the observed change in the yield curve in a high-frequency window around the announcement. Second, given the size of each type of shocks, I use the theoretical model and obtain the model's prediction of the behavior of aggregate variables.

## 4.1 Regression Model

I look at how unconventional monetary policy affects interest rates when policy rates are stuck at the zero lower bound. To be more specific, I estimate models of the following form:

$$\triangle i_{nt} = \beta_{1t} \times \triangle i_n^{fg} + \beta_{2t} \times \triangle i_n^{lsap} + error_t, \text{for } n = 2, 3, \cdots, 10 \tag{15}$$

where $t$ indexes the FOMC announcement day, $\triangle i_{nt}$ is the daily change of yield curve observed at date $t$; $\triangle i_n^{fg}$ is the change in yield on a $n$-year Treasury bond if we have one unit forward guidance announcement during the crisis; $\triangle i_n^{lsap}$ is the change in yield on a $n$-year Treasury bond if we have one unit LSAP announcement during the crisis.

The parameters of interest in this model are $\beta_{1t}$ and $\beta_{2t}$. They represent how many units of each type of shocks are there on date $t$. $\beta_{1t} \times \triangle i_n^{fg}$ describes the effect of forward guidance monetary policy on the change of a $n$-year Treasury bond's yield on date $t$. $\beta_{2t} \times \triangle i_n^{lsap}$ describes the contribution of LSAP monetary policy on the change of a $n$-year Treasury bond's yield on date $t$.

I consider the event dates from November 2008 to December 2015. There are 63 dates in total, which consist of all the FOMC meetings as well as some important speeches during this period. The full list of the event dates could be found in the Appendix Table 11. For each of the announcement dates, I run a regression as in (15).

Figure 4 plots $\beta_{1t}$ and $\beta_{2t}$ over time. The upper panel is from November 2008 to September 2011, while the lower panel is from November 2011 to December 2015. The vertical axis is the size of shock measured in units, which I have defined as one unit of forward guidance shock will lower the nominal shadow rate by 25 basis points and one unit of LSAP shock will lower the 10-year yield by 5 basis points. Several notable announcements, which I will discuss later, are labeled in the figure for reference. Not surprisingly, forward guidance and LSAP policies announced on the same day always work in the same direction tightening or easing the market. Among all the event dates, the QE I announcements have the largest effects.

Figure 5 plots the time series of estimated contributions of the forward guidance and LSAP factors to the change of 10-year Treasury yields for each FOMC announcement day. Among the event dates, LSAP factor always has a larger effect than the forward guidance factor. However, on the short-term and medium-term yields, the two policies will have opposite effects because that an easing forward guidance lowers the shadow rate while an easing LSAP raises the shadow rate. The figures of the other maturities can be found in the Online Appendix.

## 4.2 Unconventional Monetary Policy on Several Key FOMC Announcement Days

Assessing the financial market effects of asset purchases is the first step in gauging the effectiveness of unconventional monetary policy actions. The next goal of this paper is to look at to what extent the monetary policy has fostered economic growth and inflation stability. Given $\beta_{1t}$ and $\beta_{2t}$, I return to the theoretical model described in section 1 and obtain the impulse responses of macroeconomic variables to $\beta_{1t}$ units of forward guidance shock and $\beta_{2t}$ units of LSAP shock, separately. In this way, the high-frequency yield data is used to figure out the sizes of each type of shocks while the structural model is to show the persistence of the monetary policy shocks on aggregate economy, which the standard event-study methodology cannot do.

I follow the literature and group the announcement dates into the following six groups: QE I phase (November 2008 to March 2010), QE II phase (November 2010 to June 2011), "Operation Twist" phase (September 2011 to August 2012), QE III phase (September 2012 to May 2013), "Tapering" phase (June 2013 to October 2014), and Post QE phase (December 2014 to December 2015), respectively.[13] One point need to be clarified here. Although some of the phases' names are associated with QE, there is forward guidance policy component in those periods as well. Among all the event days, there are several key announcements widely discussed in the literature. Tables 3 to 10 list those announcement dates, together with the separate contributions to the daily change in long-term yield, two-quarter hence GDP and two-quarter hence inflation. The bottom row of each table is the cumulative effect over the certain phase.

#### 4.2.1 QE I phase (November 2008 to March 2010)

The "QE1" program began on November 25, 2008, when the Federal Reserve Board announced it would purchase $600 billion of mortgage-backed securities and $100 billion of debt issued by the mortgage-related government-sponsored enterprises. In Figure 6, I plot the estimated effects on yield curve of the forward guidance and LSAP announcement for that day. The solid line in the upper left panel depicts the forward guidance effect on the yield curve, and the line in the upper right panel is the LSAP effect. 90% confidence intervals are shown in both cases. The middle left panel compares the observed change in yields with the fitted value. Even though there's no explicit words about the forward guidance policy, I argue, as in Bauer & Rudebusch (2014), LSAP announcements may signal to market participants that the central bank has changed its views on current or future economic conditions, which leads investors to alter their expectations of the future path of the policy rate. Based on the way yield curve responded, I have identified that there is also easing forward guidance on this day. The overall effect of the two types of policies is lowering the whole yield curve. The middle right panel and the lower left panel in Figure 6 show the impulse responses of output and inflation. Forward guidance has similar effect on current output compared to LASP, but LSAP is more effective afterwards. As for inflation, forward guidance plays an important role in lifting inflation rate path.

On December 16, 2008, the FOMC decreased the target for the policy rate to a range from 0 to 1/4 percent and indicated that it expected the target to remain there "for some time". Besides, it also stated that the Fed will continue to consider ways of using its balance sheet to further support credit markets and economic activity. My identification of forward guidance and LSAP effects shown in Figure 7 lowers both short-term and long-term interest rate as a whole with long-term end decreases by a larger amount.

On January 28, 2009, the FOMC restated that the Fed will continue to consider ways of using

[13]The categorization of QE I, QE II, "Operation Twist" and QE III comes from Wu (2014).

its balance sheet to further support credit markets and economic activity. However, the FOMC statement was interpreted by some market participants as disappointing because of its lack of concrete language regarding the possibility and timing of purchases of longer-term Treasuries in the secondary market. There my identification procedure finds contractionary forward guidance and LSAP shocks as in Figure 8.

As shown in Table 3, the cumulative drop in 10-year Treasury yield in the seven key announcement dates in QE I phase was 100.61 basis points, 11.86 basis points contributed by forward guidance while 94.30 basis points by LSAP. My estimates indicate that the QE I program increased the two-quarter hence real GDP by 2.94 percent, 1.02 percent from forward guidance and 1.92 percent from LSAP. Forward guidance raised the two-quarter hence inflation rate by 1.52 annualized percentage points, and LSAP has an effect of 1.29 annualized percentage points. Thus the total effects on inflation is 2.81 percentage points. I conclude that LSAP are more effective on output, while forward guidance is more effective on inflation in the short run.

#### 4.2.2 QE II phase (November 2010 to June 2011)

It's also interesting that the FOMC's subsequent QE II program, launched on November 3, 2010, has very small easing forward guidance and LSAP components, which are not significant at 10% level. A possible reason in the literature (e.g. Krishnamurthy et al. (2011), Bauer & Rudebusch (2014)) is that expectations of QE II were incrementally formed before official confirmation. The event study on the single QE II official announcement day may underestimate the full effect of the program. Therefore, I also include some important pre-announcement QE II news. For example, on September 21, 2010, the FOMC was "prepared to provide additional accommodation if needed", which was viewed as a setup statement to another round of asset purchases. As shown in Figure 4, I estimate a forward guidance factor and a LSAP factor in easing direction on this day.

#### 4.2.3 Mid-2013 phase (November 2010 to June 2011)

August 9, 2011 is another interesting date. This is the first announcement in which the FOMC gave explicit forward guidance about the likely path of the federal funds rate over the next several quarters. In that announcement, the FOMC stated that it expected the current level of the federal funds rate would be appropriate "at least through mid-2013". In Figure 9 I estimate that the forward guidance raises the two-quarter ahead output by 0.2 percent and the inflation by 0.3 annualized percentage points, and the LSAP raises the two-quarter ahead output by 0.45 percent and the inflation by 0.31 annualized percentage points.

#### 4.2.4 "Operation Twist" (September 2011 to August 2012)

September 21, 2011 is one of the dates when our results are different from Swanson (2017). It corresponds to "Operation Twist". The FOMC announced to purchase $400 billion of Treasury securities of median-and long maturities and to sell an equal amount of short-term Treasury securities. This program "should put downward pressure on longer-term interest rates and help make broader financial conditions more accommodative." Swanson (2017)'s identification procedure for forward guidance vs. LSAP announcements attributes the effects of this announcement to a tightening forward guidance and an easing LSAP factor. It is surprising for the two types of unconventional monetary polices implied from the same announcement to have different directions. However, as can be seen in Figure 10, my identification estimates this announcement to have both LSAP and forward guidance components in the easing direction. The forward guidance on that day decreased the l0-year Treasury yield by 0.5 basis points, while the LSAP had an effect of 7.4 basis points.

#### 4.2.5 QE III phase (September 2012 to May 2013)

The economy continued to disappoint policymakers and the Fed issued the statement on September 13, 2012 meeting promising to maintain a zero federal funds rate "at least through mid-2015". In addition, the Fed said it would continue to extend the average maturity of its holdings of securities and announced an open ended program purchasing additional agency mortgage-backed securities at a pace of $40 billion per month. This announcement put downward pressure on longer-term interest rates. The two-quarter hence real GDP was predicted to increase by 0.14 percent and the inflation by 0.12 annualized percentage points

On December 12, 2012, the FOMC again adjusted its forward guidance from the calendar-based language "at least through mid-2015" to forward guidance based on unemployment and expected inflation. The policy statement read: "...this exceptionally low range for the federal funds rate will be appropriate at least as long as the unemployment rate remains above 6-1/2 percent, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2 percent longer-run goal". This resulted in some concerns of the investors that the central bank would have to start tightening policy earlier than the time they anticipated before.[14] Therefore, the medium-term and long-term yields increase.

#### 4.2.6 Tapering (June 2013 to October 2014)

On June 19, 2013, there is little change in the FOMC statement on that date, but the FOMC released economic projections along with the statement that showed a substantial increase in the

[14] https://www.wsj.com/articles/SB10001424127887324481204578175112571119362

FOMC's economic outlook. Given earlier remarks by Chairman Ben Bernanke that the FOMC could begin tapering its asset purchases soon, markets interpreted this as a signal that a tapering was imminent. In addition, the FOMC statement says, "...14 of 19 FOMC participants indicated that they expect the first increase in the target for the federal funds rate to occur in 2015, and one expected the first increase to incur in 2016". Thus, this episode fits into the "taper tantrum" period, and I have identified a large tightening forward guidance factor and a medium size tightening LSAP factor. In Figure 11, I have estimated that the forward guidance would decrease the two-quarter ahead output by 0.16 percent and the inflation by 0.24 annualized percentage points, and the LSAP would decrease the two-quarter ahead output by 0.54 percent and the inflation by 0.45 annualized percentage points.

September 18, 2013 is the flip side of the above announcement. The FOMC was widely expected to begin tapering its asset purchase while it turned out not to do so. As shown in Table 9, the surprise decision by the FOMC not to taper its asset purchases is correctly identified in my estimates: the easing LSAP shock together with easing forward guidance shock had a result of 20 basis points drop of the 10-year yield. This in turn would raise the two-quarter ahead real GDP by 0.6 percent and the inflation by 0.56 annualized percentage points.

#### 4.2.7 Post QE phase (December 2014 to December 2015)

The statement on December 17, 2014 said the Fed would be "patient" before raising rates, adding that rates would stay low for a "considerable time." However, market expected that a hike in the federal funds rate would be coming after two meetings is possible and had confidence that the economy were on track.[15] Therefore, the whole yield curve was lifted up.

On March 18, 2015, the FOMC removed from its statement the pledge that it will be "patient" before raising interest rates. The Fed downgraded its forecasts for the U.S. growth outlook, significantly below what markets had expected. The revised forecast was read by financial markets as a sign that the central bank would take its time in raising borrowing costs for the economy.[16] My estimation appears to correctly identify this announcement as a substantial easing policy, and it lowers the medium-term yield most as shown in Figure 12.

On September 17, 2015, the FOMC decided not to raise its key interest rate. The Fed issued a statement that was widely regarded as more dovish than expected, and released interest rate forecasts that were substantially lower than before. The two-year Treasury yield posted its largest single-day decline since late December 2010. The 10-year Treasury yield dropped 9 basis points in the data, which forward guidance accounted for 1.1 basis points and LSAP for 7.5 basis points. It

[15] https://www.wsj.com/articles/fed-sticks-to-patient-tack-on-rates-1418843005?mg=prod/accounts-wsj

[16] https://www.wsj.com/articles/ten-year-u-s-government-bond-yield-falls-to-near-2-before-fed-statement-1426686629

increased the two-quarter hence real GDP by 0.29 percent and the two-quarter hence inflation by 0.28 percentage points.

Finally, on December 16, 2015, the FOMC raised the target range for the federal funds rate to 1/4 to 1/2 percent.

# 5 Discussion

I show how the state of the economy, the normalization of the monetary policy shocks, the forward guidance persistence and the forward guidance horizon nonlinearly impact the efficacy of the two types of monetary policies. Because of nonlinearity, different specification will change our result qualitatively, but my findings on the relative size of the two policies' effects on yield curves and macro economy won't be changed.

## 5.1 Role of the Initial Demand Shock

The initial capital quality shock decreases the shadow rate decreased to negative 121 bps, which the average shadow rate in the ZLB peirod. We illustrate how our calibration of the initial shock affects the main results.

Keeping everything else the same, Figure 13 plots the variation of the difference in yield curves when the initial shock changes from negative 60 bps to negative 180 bps. A weaker economy skews the LSAP more effective.

## 5.2 Role of Normalization

I define that one unit of forward guidance shock will lower the nominal shadow rate by 25 basis points and one unit of LSAP shock will lower the 10-year yield by 5 basis points. Now I illustrate how our estimate of the initial aggregate demand shock affects our main results. Keeping everything else the same, Figure 14 shows how the difference in yield curve varies when the normalization of one unit LSAP shock changes from 3 bps to 10 bps. Figure 15 plots the separate contribution of forward guidance and LSAP shocks. The main results change barely when we use different normalization.

## 5.3 Effects of Forward Guidance Shock Persistence

The persistence of forward guidance shock is set to be 0.65 in the baseline model. Figure 16 shows how the difference in yield curve varies when the persistence of forward guidance shock increases from 0.6 to 0.7. Intuitively, a more persistent forward guidance shock is more effective on the 10-year interest rate.

### 5.4 Effects of Forward Guidance Shock Horizon

The baseline model assumes forward guidance is effective for 7 quarters. Figure 17 shows how the difference in yield curve varies when the persistence of forward guidance shock increases from 5 to 8.

## 6 Conclusion

There are costs and benefits from every monetary policy action and inaction. In this paper, I show how to identify and estimate the forward guidance and large-scale asset purchase component of every FOMC announcement between 2008 and 2015. Building on earlier work by Gertler & Karadi (2013), the theoretical model shows that easing forward guidance announcement lowers Treasury yields at all maturities, with a peak effect at a maturity of about 20 months; in contrast, easing LSAP will increase the shortest-maturity Treasury yields because of the feedback of the interest rate rule and will lower medium-term and long-term yields, with the peak effect on the longest maturities.

I match the responses of the yield curve to a linear combination of the two shocks predicted by the model with the observed change in the yield curve in a high-frequency window around each Federal Reserve announcement. In this way, I estimate a time series for each type of unconventional monetary policy announcement and show that these series correspond closely to narrative elements of the FOMC announcements.

With the estimates of the shock series, I study the persistence of the monetary policy shocks on aggregate economy using the structural model. Our approach circuvments the limitations of the standard event-study methodology. Among the key announcement dates in QE I program I find that forward guidance was more effective at inflation, while LSAP was more important in influencing output.

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Table 1: Parameter Values

| | symbol | value | meaning | value in GK | meaning |
|---|---|---|---|---|---|
| (A) | | | | | |
| | $\delta$ | 0.025 | depreciation rate | | |
| | $\alpha$ | 0.33 | capital share in production function | | |
| | $\gamma$ | 0.779 | Calvo price-setting, resets every 13.6 months | | |
| | $\gamma^P$ | 0 | inflation indexation | | |
| | $G_{ss}/Y$ | 0.2 | steady state government spending-GDP ratio | | |
| | $\text{Ł}_{ss}$ | 1/3 | steady state labor supply | | |
| | $\phi_y$ | -0.125 | response of monetary policy to output gap | | |
| | $\bar{K}^h/K$ | 0.5 | prop. of ss. direct capital holdings of the hh. | | |
| | $\bar{B}^h/B$ | 0.75 | prop. of ss. direct Treasury holdings of the hh. | | |
| | $B/Y$ | 0.45 | ss. Treasury supply | | |
| (B) | | | | | |
| | $\beta$ | 0.9945 | ss. annual real interest rate = 2.2 percent | 0.995 | 2 percent |
| | $\bar{\pi}$ | 0.006 | annual inflation target = 2.4 percent | 0 | |
| | $\underline{\iota}$ | 0.25 | lower-bound of interest rate, annu. pp | 0 | |
| | $R_{k,ss} - R_{ss}$ | 173 | steady state excess return on capital, annu. bp. | 100 | |
| | $R_{b,ss} - R_{ss}$ | 103.8 | steady state excess return on bond, annu. bp. | 50 | |
| | $\phi$ | 5 | steady state leverage ratio | 4, 6 | |
| | $\theta$ | 0.956 | survival rate of the bankers, 5.7 years | 0.9715 | 8.77 years |
| | $\Delta$ | 0.6 | prop. advantage of gov. debt over divertible capital | 0.5 | |
| | $\lambda$ | 0.386 | fraction of capital that can be diverted | 0.381, 0.345 | |
| | $X$ | 0.0016 | transfer to the entering bankers | 0.002, 0.0062 | |
| | $\kappa_s$ | 28 | elasticity for hh. holdings of capital | 1 | |
| | $\kappa_b$ | 2 | elasticity for hh. holdings of bonds | 1 | |
| | $\rho_{1b}$ | 1.4 | AR(2) process governing LSAP | 1.5 | |
| | $\rho_{2b}$ | -.49 | AR(2) process governing LSAP | -0.55 | |
| (C) | | | | | |
| | $h$ | 0.615 | habit persistent | 0.815 | |
| | $\varphi$ | 1/2 | Frisch elasticity of labor supply =1/$\varphi$=2 | 0.276 | 3.6 |
| | $\epsilon$ | 6 | price mark-up 20% | 4.167 | 31.58% |
| | $\eta_i$ | 4.5 | quadratic investment cost parameter | 1.728 | |
| | $\phi_\pi$ | 2.5 | response of monetary policy to inflation | 1.5 | |
| (D) | | | | | |
| | $\rho_z$ | 0.65 | AR(1) process governing forward guidance | | |

Table 2: Data and model implied yield curve, in annualized percentage points

| | instant | 1-year | 2-year | 3-year | 4-year | 5-year | 6-year | 7-year | 8-year | 9-year | 10-year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (A) Normal time | | | | | | | | | | | |
| Jan. 1990-Nov. 2008 | 4.13 | 4.45 | 4.72 | 4.94 | 5.13 | 5.30 | 5.45 | 5.58 | 5.70 | 5.80 | 5.90 |
| model steady state | 4.37 | 4.60 | 4.81 | 4.98 | 5.14 | 5.27 | 5.39 | 5.49 | 5.58 | 5.66 | 5.73 |
| (B) Crisis | | | | | | | | | | | |
| Nov. 2008-Nov. 2015 | 0.27 | 0.28 | 0.54 | 0.89 | 1.24 | 1.58 | 1.89 | 2.16 | 2.40 | 2.62 | 2.80 |
| Nov. 2008-Jan. 2010 | 0.31 | 0.54 | 0.91 | 1.34 | 1.79 | 2.22 | 2.61 | 2.96 | 3.27 | 3.52 | 3.73 |
| scenario (i) | | 0.25 | 0.48 | 1.33 | 2.16 | 2.89 | 3.52 | 4.08 | 4.55 | 4.97 | 5.33 |
| scenario (ii) | | 0.25 | 0.40 | 1.23 | 2.06 | 2.81 | 3.46 | 4.03 | 4.52 | 4.95 | 5.32 |
| scenario (iii) | | 0.25 | 0.62 | 1.49 | 2.29 | 2.99 | 3.59 | 4.11 | 4.57 | 4.96 | 5.30 |

Table 3: QE I phase (November 2008 to March 2010)

| Date | $\triangle i_{10,t}$ | $\beta_{1t} \times \triangle i_{10}^{fg}$ | $\beta_{2t} \times \triangle i_{10}^{lsap}$ | FG: 2-q output | LSAP: 2-q output | FG: 2-q inflation | LSAP: 2-q inflation |
|---|---|---|---|---|---|---|---|
| 25-Nov-08 | -21.38 | -2.50 | -19.97 | 0.21 | 0.45 | 0.32 | 0.31 |
| 01-Dec-08 | -21.54 | -2.47 | -20.33 | 0.21 | 0.46 | 0.32 | 0.32 |
| 16-Dec-08 | -17.48 | -1.93 | -15.83 | 0.17 | 0.37 | 0.25 | 0.26 |
| 18-Mar-09 | -51.89 | -5.74 | -48.40 | 0.49 | 0.95 | 0.74 | 0.65 |
| 12-Aug-09 | 6.15 | 0.42 | 4.91 | -0.04 | -0.15 | -0.05 | -0.12 |
| 23-Sep-09 | -1.61 | -0.27 | -1.27 | 0.02 | 0.04 | 0.03 | 0.03 |
| 04-Nov-09 | 7.14 | 0.63 | 6.60 | -0.05 | -0.20 | -0.08 | -0.15 |
| Sum | -100.61 | -11.86 | -94.30 | 1.02 | 1.92 | 1.52 | 1.29 |

NOTES: Columns 2 to 4 show the decomposition of the change of 10-year Treasury yield $\triangle i_{10,t}$ (in annualised basis points) into the contribution of forward guidance and LSAP. Columns 5 to 8 show the effects of forward guidance and LSAP on 2-quarter ahead output and annualized inflation rate (in percentage points).

Table 4: Pre-QE II phase (August 2010 to October 2010)

| Date | $\triangle i_{10,t}$ | $\beta_{1t} \times \triangle i_{10}^{fg}$ | $\beta_{2t} \times \triangle i_{10}^{lsap}$ | FG: 2-q output | LSAP: 2-q output | FG: 2-q inflation | LSAP: 2-q inflation |
|---|---|---|---|---|---|---|---|
| 10-Aug-10 | -6.87 | -0.82 | -7.04 | 0.07 | 0.18 | 0.11 | 0.13 |
| 27-Aug-10 | 16.63 | 1.68 | 14.98 | -0.15 | -0.53 | -0.22 | -0.44 |
| 21-Sep-10 | -10.73 | -1.18 | -10.32 | 0.10 | 0.26 | 0.15 | 0.18 |
| 15-Oct-10 | 8.62 | 0.69 | 7.48 | -0.06 | -0.23 | -0.09 | -0.18 |
| Sum | 7.65 | 0.36 | 5.09 | -0.03 | -0.32 | -0.05 | -0.30 |

NOTES: Columns 2 to 4 show the decomposition of the change of 10-year Treasury yield $\triangle i_{10,t}$ (in annualised basis points) into the contribution of forward guidance and LSAP. Columns 5 to 8 show the effects of forward guidance and LSAP on 2-quarter ahead output and annualized inflation rate (in percentage points).

Table 5: QE II phase (November 2010 to June 2011)

| Date | $\triangle i_{10,t}$ | $\beta_{1t} \times \triangle i_{10}^{fg}$ | $\beta_{2t} \times \triangle i_{10}^{lsap}$ | FG: 2-q output | LSAP: 2-q output | FG: 2-q inflation | LSAP: 2-q inflation |
|---|---|---|---|---|---|---|---|
| 03-Nov-10 | 4.08 | -0.03 | 1.06 | 0.00 | -0.03 | 0.00 | -0.02 |
| 14-Dec-10 | 20.19 | 2.16 | 19.42 | -0.20 | -0.72 | -0.29 | -0.61 |
| 22-Jun-11 | 1.60 | 0.15 | 1.39 | -0.01 | -0.04 | -0.02 | -0.03 |
| Sum | 25.87 | 2.28 | 21.87 | -0.21 | -0.79 | -0.30 | -0.67 |

NOTES: Columns 2 to 4 show the decomposition of the change of 10-year Treasury yield $\triangle i_{10,t}$ (in annualised basis points) into the contribution of forward guidance and LSAP. Columns 5 to 8 show the effects of forward guidance and LSAP on 2-quarter ahead output and annualized inflation rate (in percentage points).

Table 6: Mid-2013 phase (November 2010 to June 2011)

| Date | $\triangle i_{10,t}$ | $\beta_{1t} \times \triangle i_{10}^{fg}$ | $\beta_{2t} \times \triangle i_{10}^{lsap}$ | FG: 2-q output | LSAP: 2-q output | FG: 2-q inflation | LSAP: 2-q inflation |
|---|---|---|---|---|---|---|---|
| 09-Aug-11 | -20.51 | -2.31 | -19.83 | 0.20 | 0.45 | 0.30 | 0.31 |

NOTES: Columns 2 to 4 show the decomposition of the change of 10-year Treasury yield $\triangle i_{10,t}$ (in annualised basis points) into the contribution of forward guidance and LSAP. Columns 5 to 8 show the effects of forward guidance and LSAP on 2-quarter ahead output and annualized inflation rate (in percentage points).

Table 7: "Operation Twist" (September 2011 to August 2012)

| Date | $\triangle i_{10,t}$ | $\beta_{1t} \times \triangle i_{10}^{fg}$ | $\beta_{2t} \times \triangle i_{10}^{lsap}$ | FG: 2-q output | LSAP: 2-q output | FG: 2-q inflation | LSAP: 2-q inflation |
|---|---|---|---|---|---|---|---|
| 21-Sept-11 | -8.37 | -0.46 | -7.14 | 0.04 | 0.18 | 0.06 | 0.13 |
| 25-Jan-12 | -8.02 | -1.02 | -8.47 | 0.09 | 0.21 | 0.13 | 0.15 |
| 31-Aug-12 | -7.02 | -0.77 | -6.46 | 0.07 | 0.17 | 0.10 | 0.12 |
| Sum | -23.41 | -2.26 | -22.07 | 0.19 | 0.56 | 0.29 | 0.40 |

NOTES: Columns 2 to 4 show the decomposition of the change of 10-year Treasury yield $\triangle i_{10,t}$ (in annualised basis points) into the contribution of forward guidance and LSAP. Columns 5 to 8 show the effects of forward guidance and LSAP on 2-quarter ahead output and annualized inflation rate (in percentage points).

Table 8: QE III phase (September 2012 to May 2013)

| Date | $\triangle i_{10,t}$ | $\beta_{1t} \times \triangle i_{10}^{fg}$ | $\beta_{2t} \times \triangle i_{10}^{lsap}$ | FG: 2-q output | LSAP: 2-q output | FG: 2-q inflation | LSAP: 2-q inflation |
|---|---|---|---|---|---|---|---|
| 13-Sep-12 | -2.92 | -0.42 | -3.63 | 0.04 | 0.10 | 0.05 | 0.07 |
| 12-Dec-12 | 5.70 | 0.47 | 4.84 | -0.04 | -0.15 | -0.06 | -0.11 |
| 22-May-13 | 9.60 | 0.98 | 9.15 | -0.08 | -0.28 | -0.13 | -0.21 |
| Sum | 12.38 | 1.03 | 10.35 | -0.09 | -0.33 | -0.13 | -0.25 |

NOTES: Columns 2 to 4 show the decomposition of the change of 10-year Treasury yield $\triangle i_{10,t}$ (in annualised basis points) into the contribution of forward guidance and LSAP. Columns 5 to 8 show the effects of forward guidance and LSAP on 2-quarter ahead output and annualized inflation rate (in percentage points).

Table 9: Tapering (June 2013 to October 2014)

| Date | $\triangle i_{10,t}$ | $\beta_{1t} \times \triangle i_{10}^{fg}$ | $\beta_{2t} \times \triangle i_{10}^{lsap}$ | FG: 2-q output | LSAP: 2-q output | FG: 2-q inflation | LSAP: 2-q inflation |
|---|---|---|---|---|---|---|---|
| 19-Jun-13 | 13.70 | 1.79 | 15.25 | -0.16 | -0.54 | -0.24 | -0.45 |
| 18-Sep-13 | -16.83 | -2.12 | -18.04 | 0.18 | 0.42 | 0.27 | 0.29 |
| 18-Dec-13 | 4.60 | 0.46 | 4.94 | -0.04 | -0.15 | -0.06 | -0.12 |
| 29-Jan-14 | -7.69 | -0.80 | -7.25 | 0.07 | 0.19 | 0.10 | 0.13 |
| 19-Mar-14 | 9.85 | 1.56 | 10.82 | -0.14 | -0.35 | -0.20 | -0.27 |
| 30-Apr-14 | -3.49 | -0.46 | -3.49 | 0.04 | 0.10 | 0.06 | 0.07 |
| 18-Jun-14 | -4.69 | -0.56 | -4.90 | 0.05 | 0.13 | 0.07 | 0.09 |
| 30-Jul-14 | 10.23 | 1.04 | 9.44 | -0.09 | -0.29 | -0.13 | -0.22 |
| 17-Sep-14 | 2.05 | 0.30 | 1.83 | -0.03 | -0.06 | -0.04 | -0.04 |
| 29-Oct-14 | 2.95 | 0.62 | 3.32 | -0.05 | -0.10 | -0.08 | -0.08 |
| Sum | 10.68 | 1.82 | 11.93 | -0.16 | -0.66 | -0.24 | -0.59 |

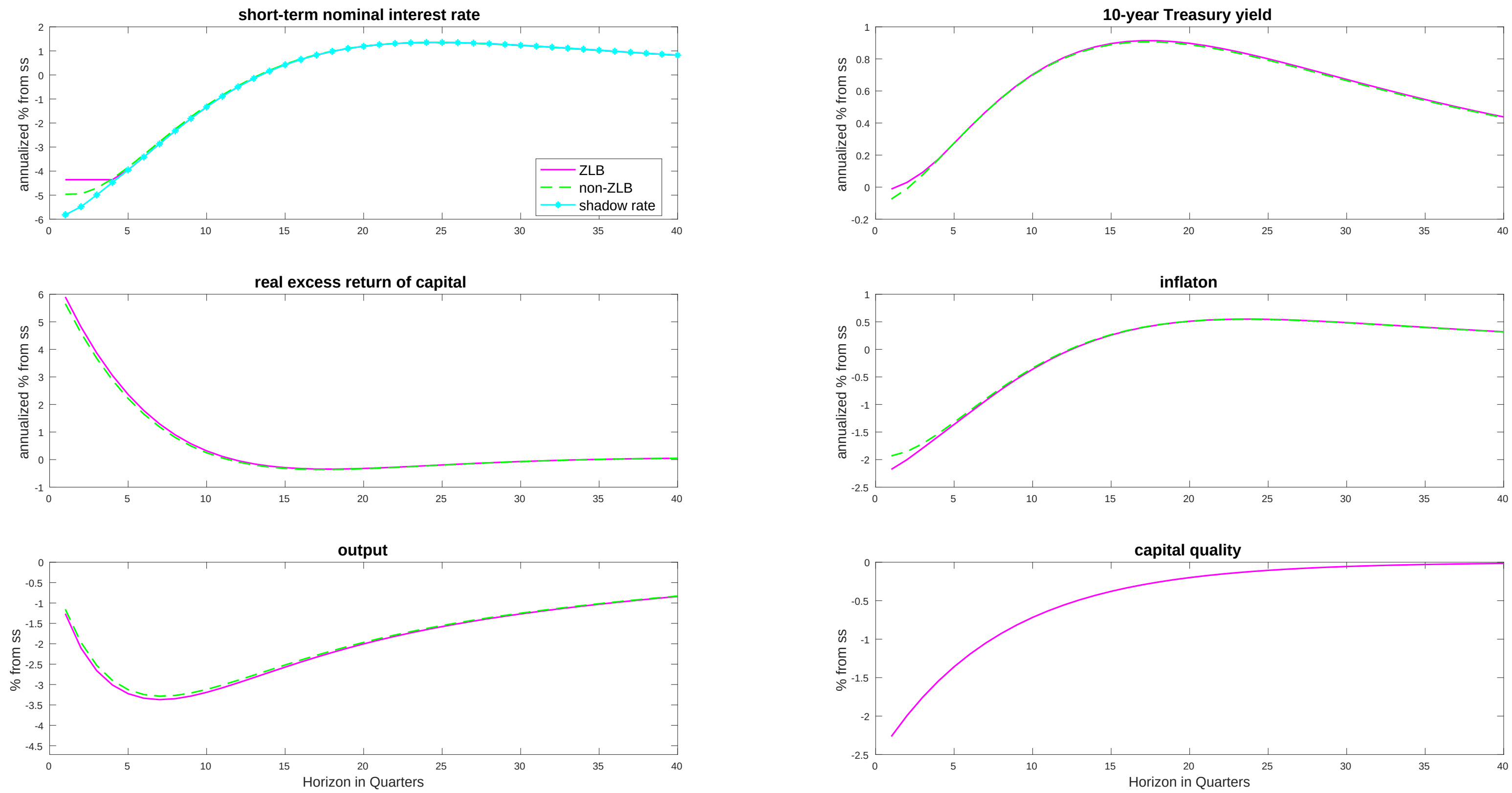
NOTES: Columns 2 to 4 show the decomposition of the change of 10-year Treasury yield $\triangle i_{10,t}$ (in annualised basis points) into the contribution of forward guidance and LSAP. Columns 5 to 8 show the effects of forward guidance and LSAP on 2-quarter ahead output and annualized inflation rate (in percentage points).

Table 10: Post QE phase (December 2014 to December 2015)

| Date | $\triangle i_{10,t}$ | $\beta_{1t} \times \triangle i_{10}^{fg}$ | $\beta_{2t} \times \triangle i_{10}^{lsap}$ | FG: 2-q output | LSAP: 2-q output | FG: 2-q inflation | LSAP: 2-q inflation |
|---|---|---|---|---|---|---|---|
| 17-Dec-14 | 7.80 | 0.92 | 7.33 | -0.08 | -0.23 | -0.12 | -0.17 |
| 18-Mar-15 | -11.89 | -1.51 | -10.88 | 0.13 | 0.27 | 0.19 | 0.19 |
| 29-Apr-15 | 6.75 | 0.63 | 6.04 | -0.05 | -0.19 | -0.08 | -0.14 |
| 17-Sep-15 | -8.96 | -1.12 | -7.46 | 0.10 | 0.19 | 0.14 | 0.14 |
| 16-Dec-15 | 2.94 | 0.43 | 2.69 | -0.04 | -0.08 | -0.05 | -0.06 |
| Sum | -3.36 | -0.65 | -2.28 | 0.06 | -0.03 | 0.08 | -0.05 |

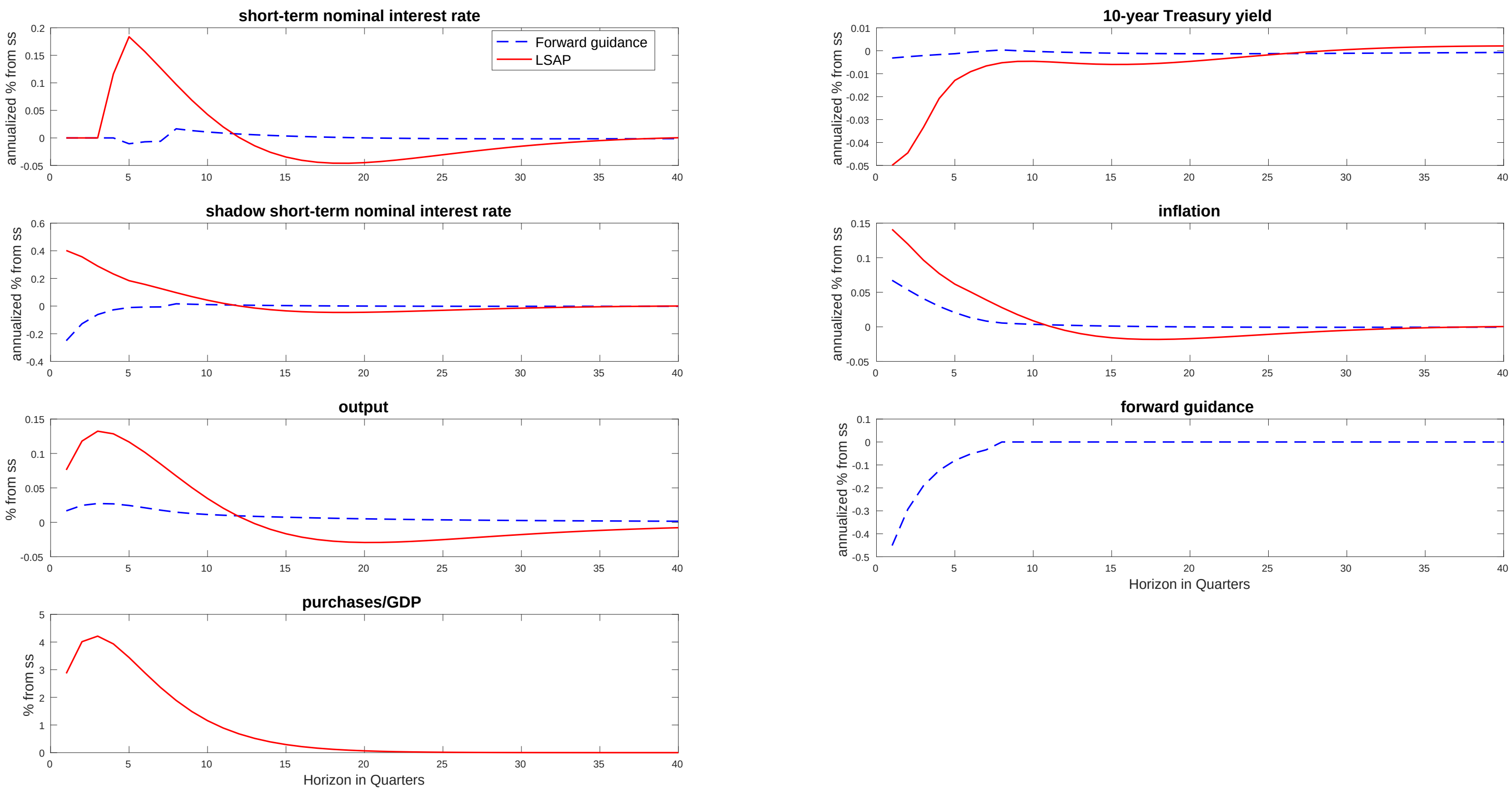
NOTES: Columns 2 to 4 show the decomposition of the change of 10-year Treasury yield $\triangle i_{10,t}$ (in annualised basis points) into the contribution of forward guidance and LSAP. Columns 5 to 8 show the effects of forward guidance and LSAP on 2-quarter ahead output and annualized inflation rate (in percentage points).

Figure 1: Crisis Experiment



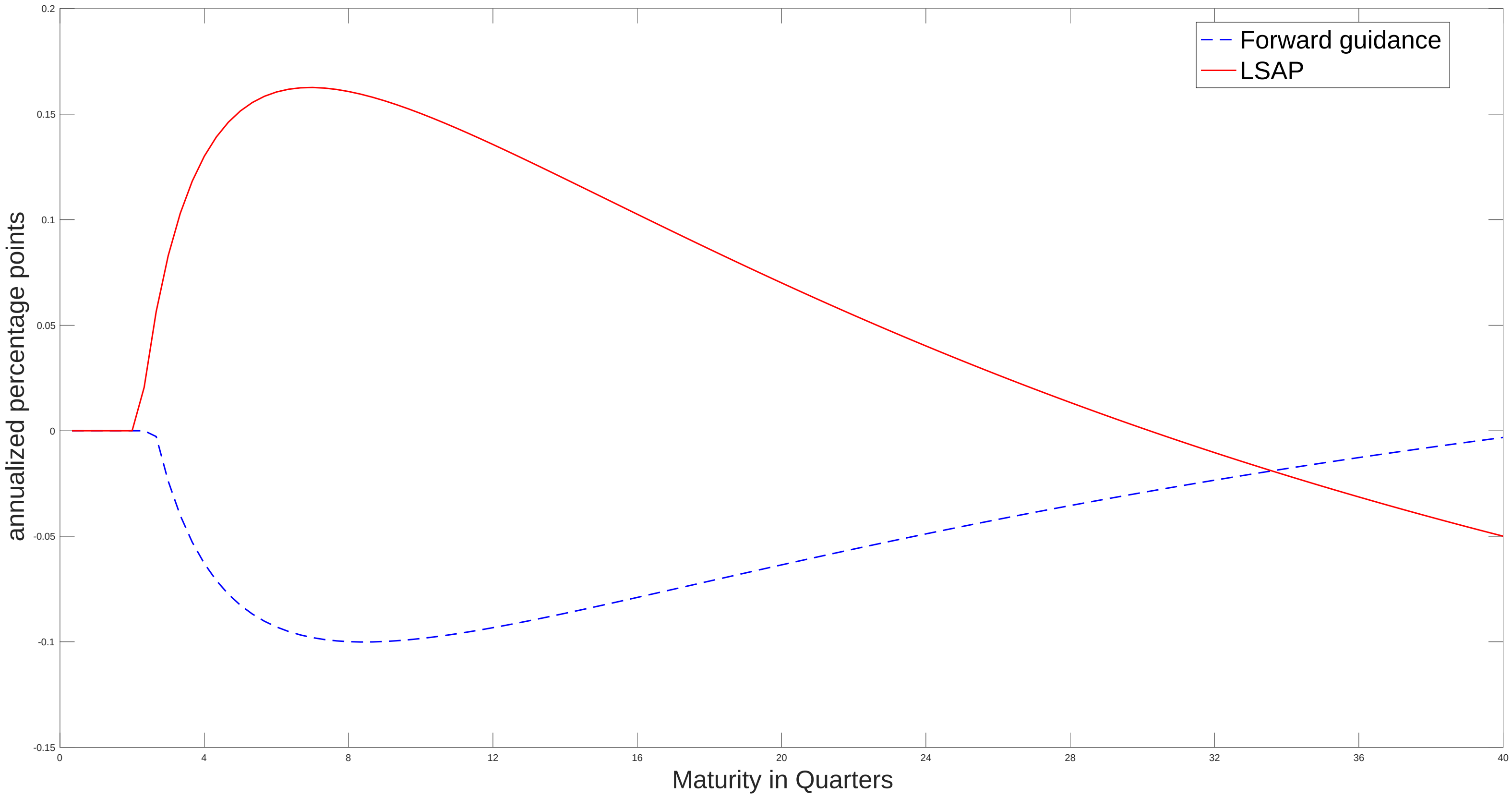

NOTES: Impulse responses to unexpected capital quality shock with and without the zero lower bound constraint. Shadow nominal interest rate is also plotted (solid cyan starred line).

Figure 2: Effects of Forward Guidance and LSAP Shocks




NOTES: Plot of the differences of the impulse responses from a no-policy-response case.

Figure 3: Difference Between Fitted Yield Curves




NOTES: Plot of the difference between fitted yield curves from a no-policy-response case.

Figure 4: Estimated Size of Each Shock Type

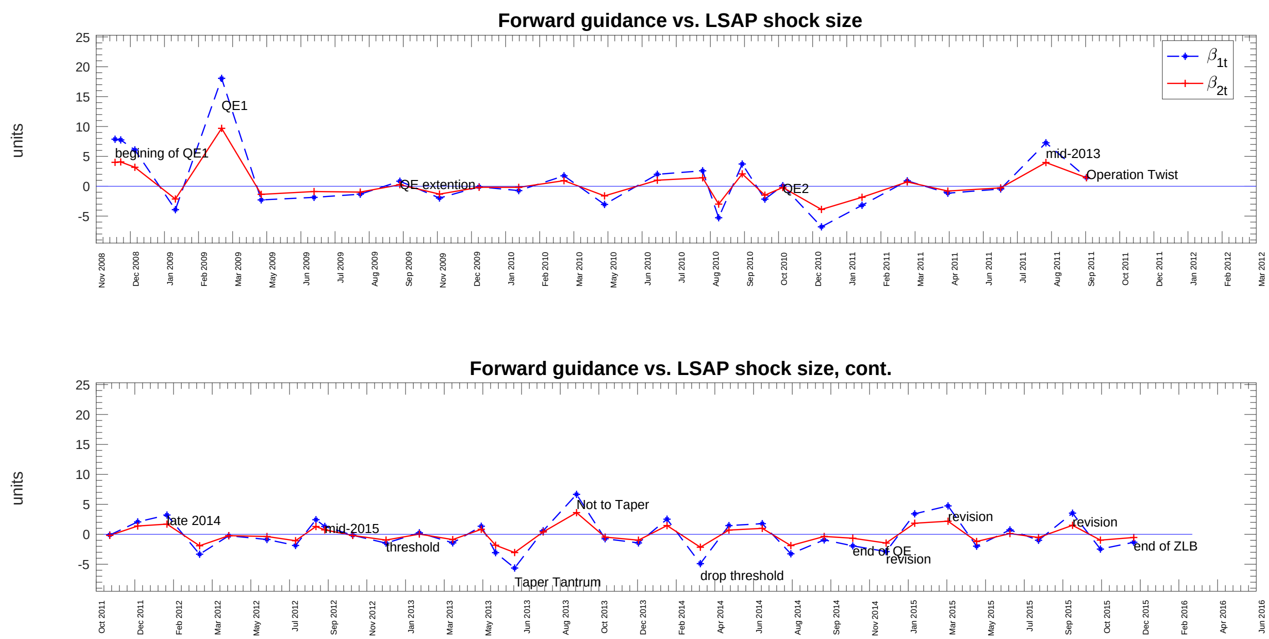
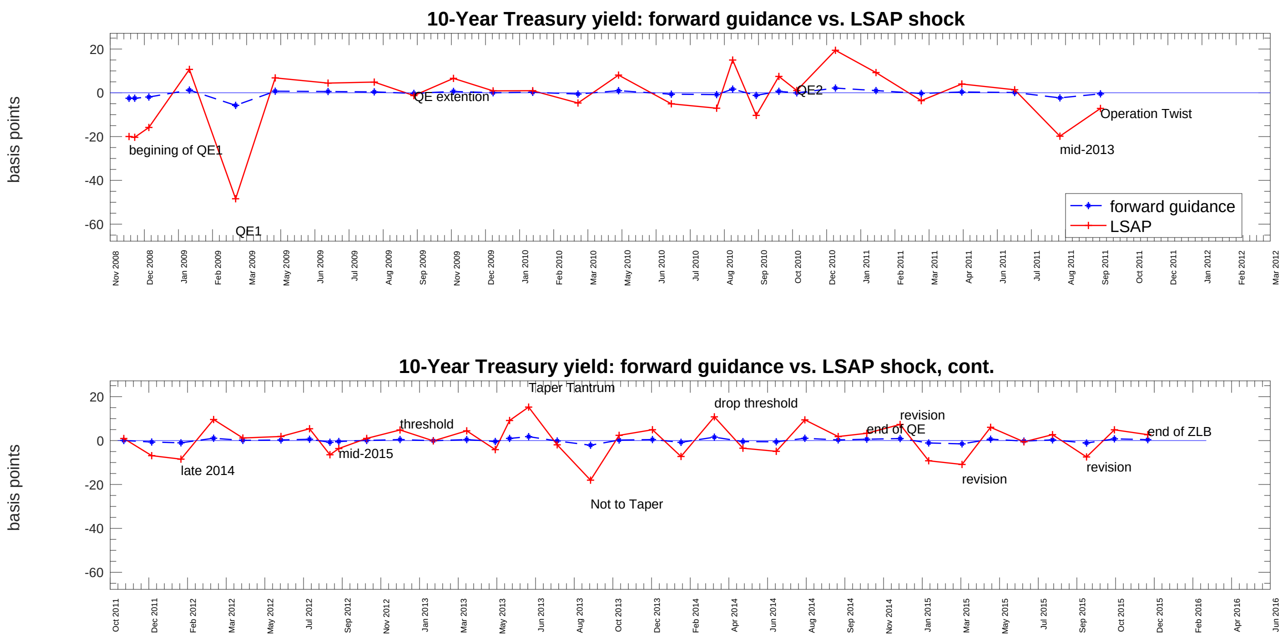
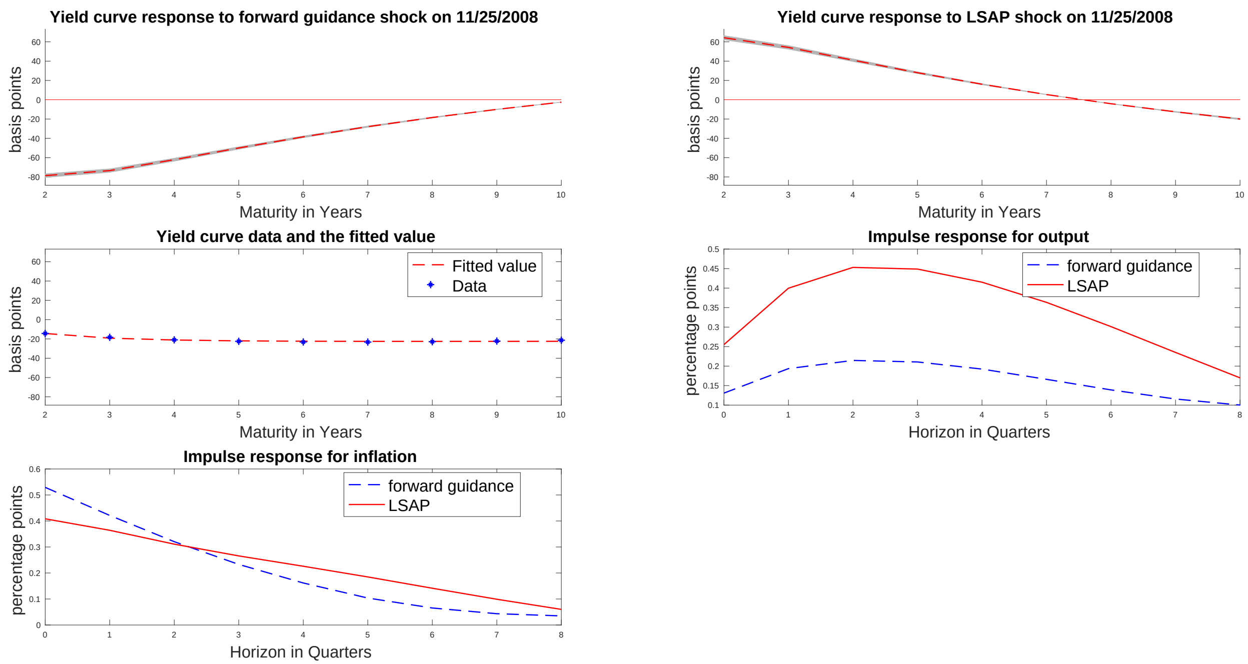


Figure 5: Estimated Effects on 10-year Treasury Yield



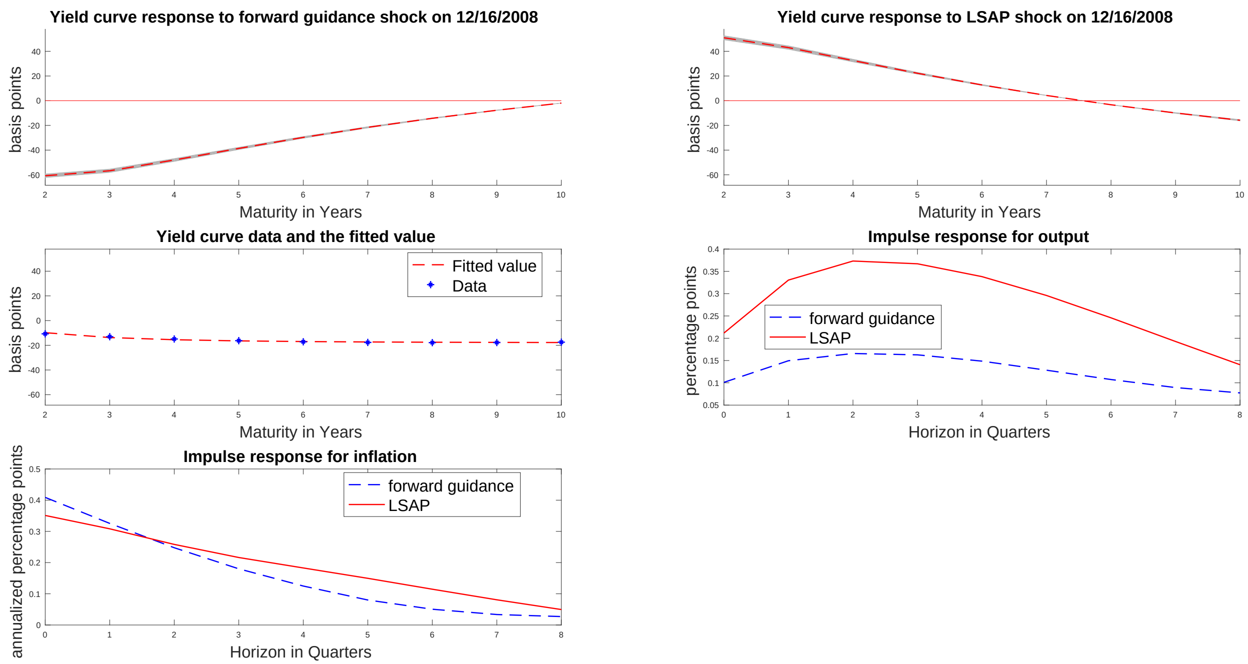

NOTES: Plot of estimated forward guidance (dashed blue line) and LSAP (solid red line) factors for 10-year Treasury yield for all the event dates. Notable announcements are labeled in the figure for reference. See text for details.

Figure 6: Estimated Effects on 11/25/2008



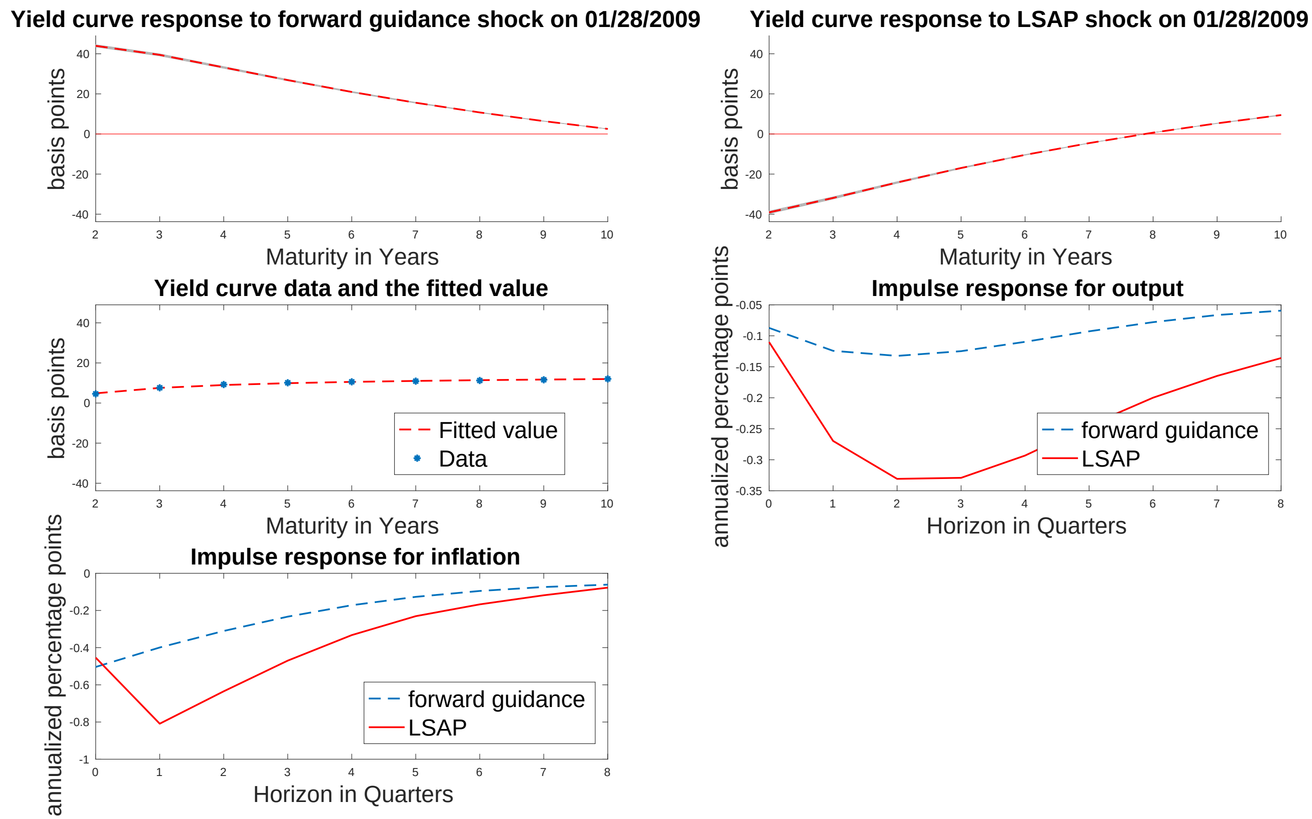

NOTES: Estimated effects on Treasury yield curve on Nov. 25, 2008. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 7: Estimated Effects on 12/16/2008



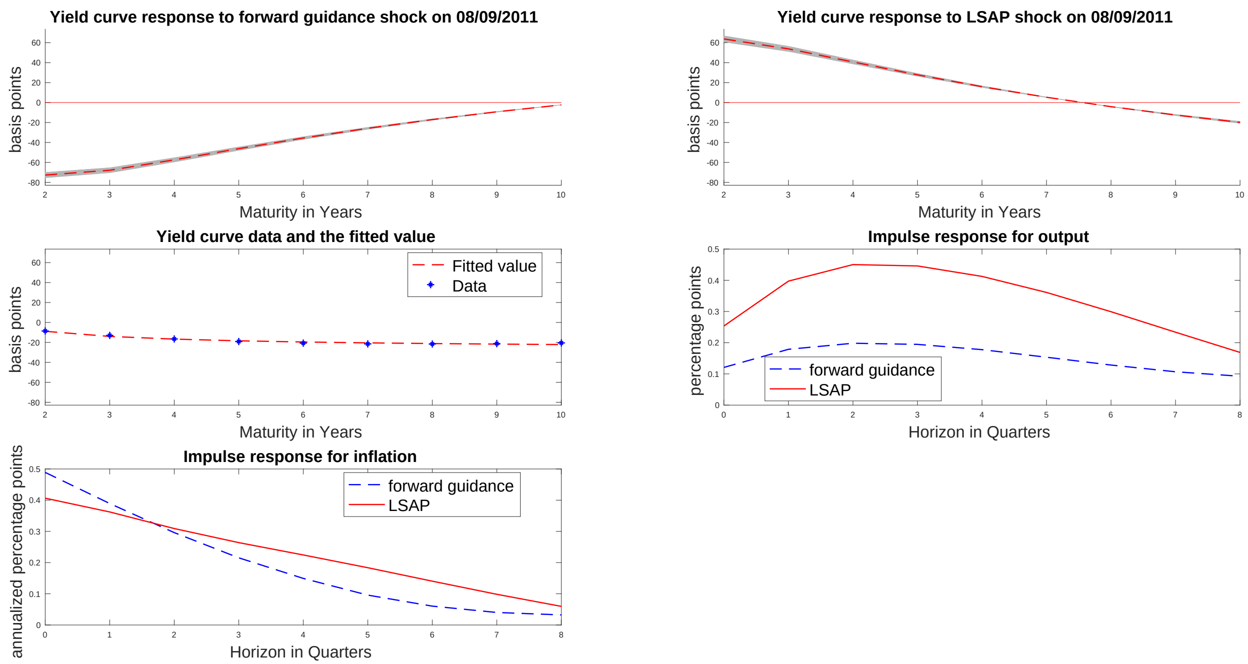

NOTES: Estimated effects on Treasury yield curve on Dec. 16, 2008. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 8: Estimated Effects on 01/28/2009



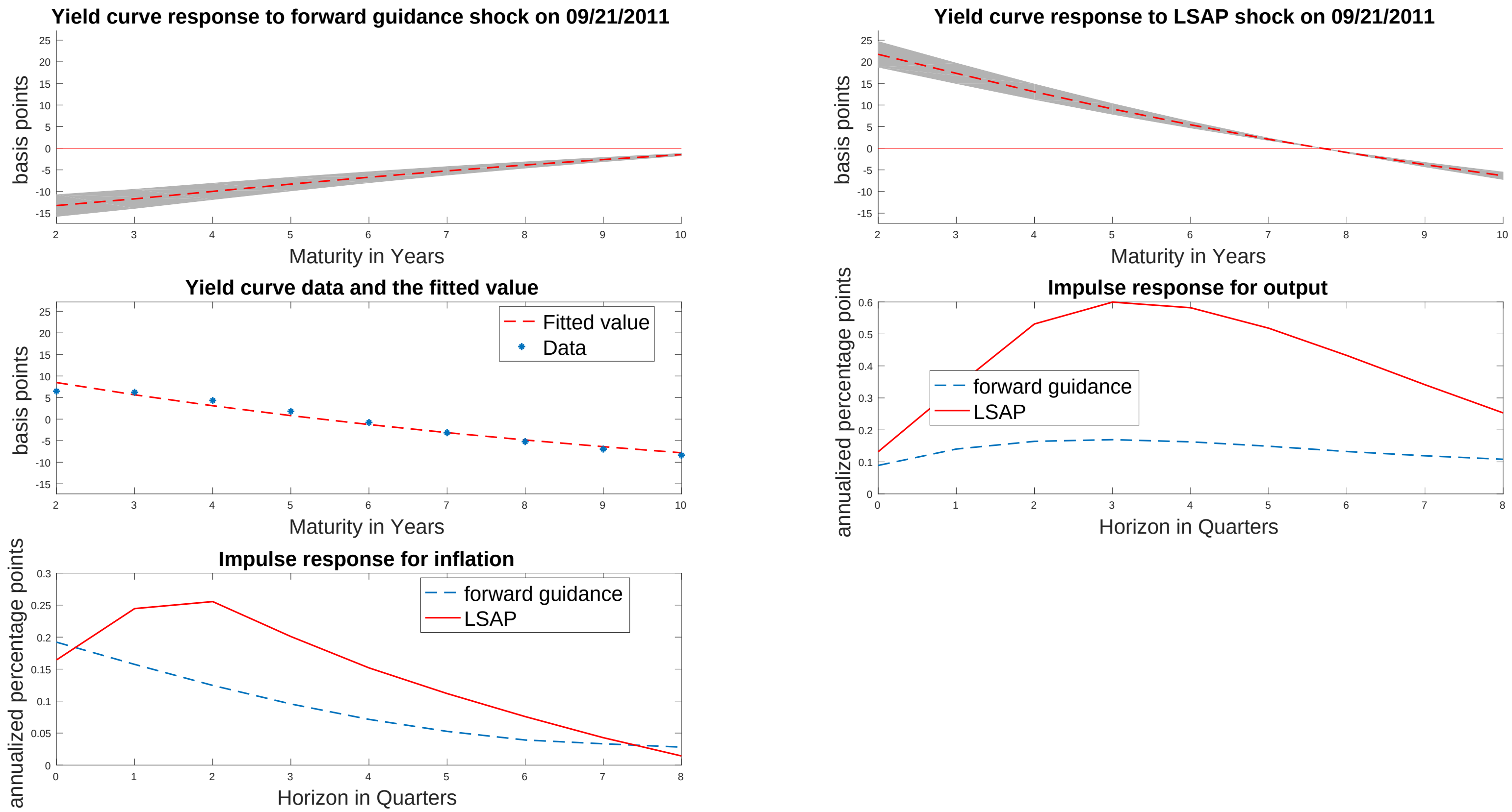

NOTES: Estimated effects on Treasury yield curve on Jan. 28, 2009. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 9: Estimated Effects on 08/09/2011



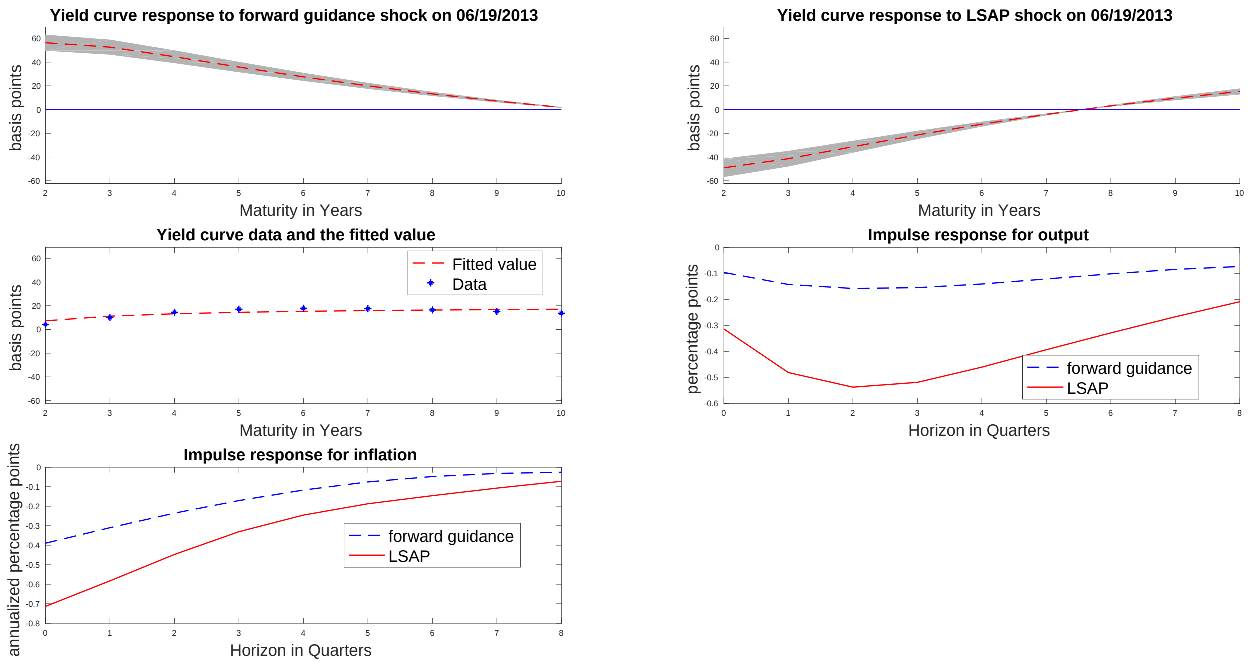

NOTES: Estimated effects on Treasury yield curve on Aug. 9, 2011. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 10: Estimated Effects on 09/21/2011



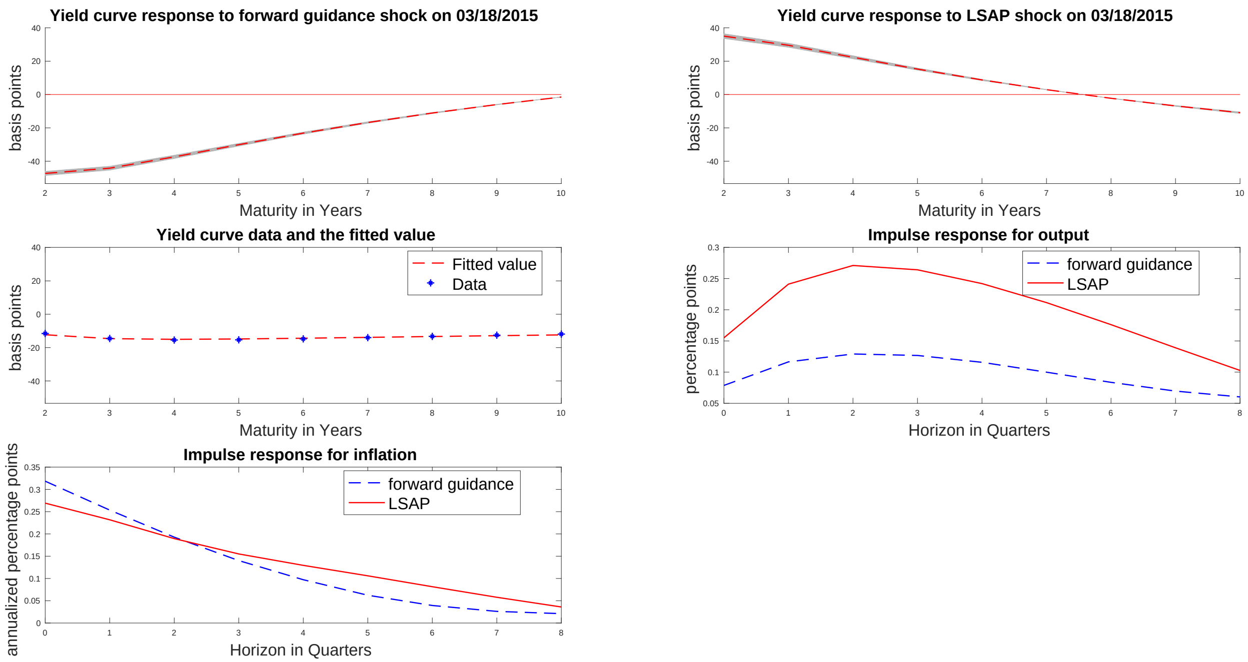

NOTES: Estimated effects on Treasury yield curve on Sept. 21, 2011. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 11: Estimated Effects on 06/19/2013



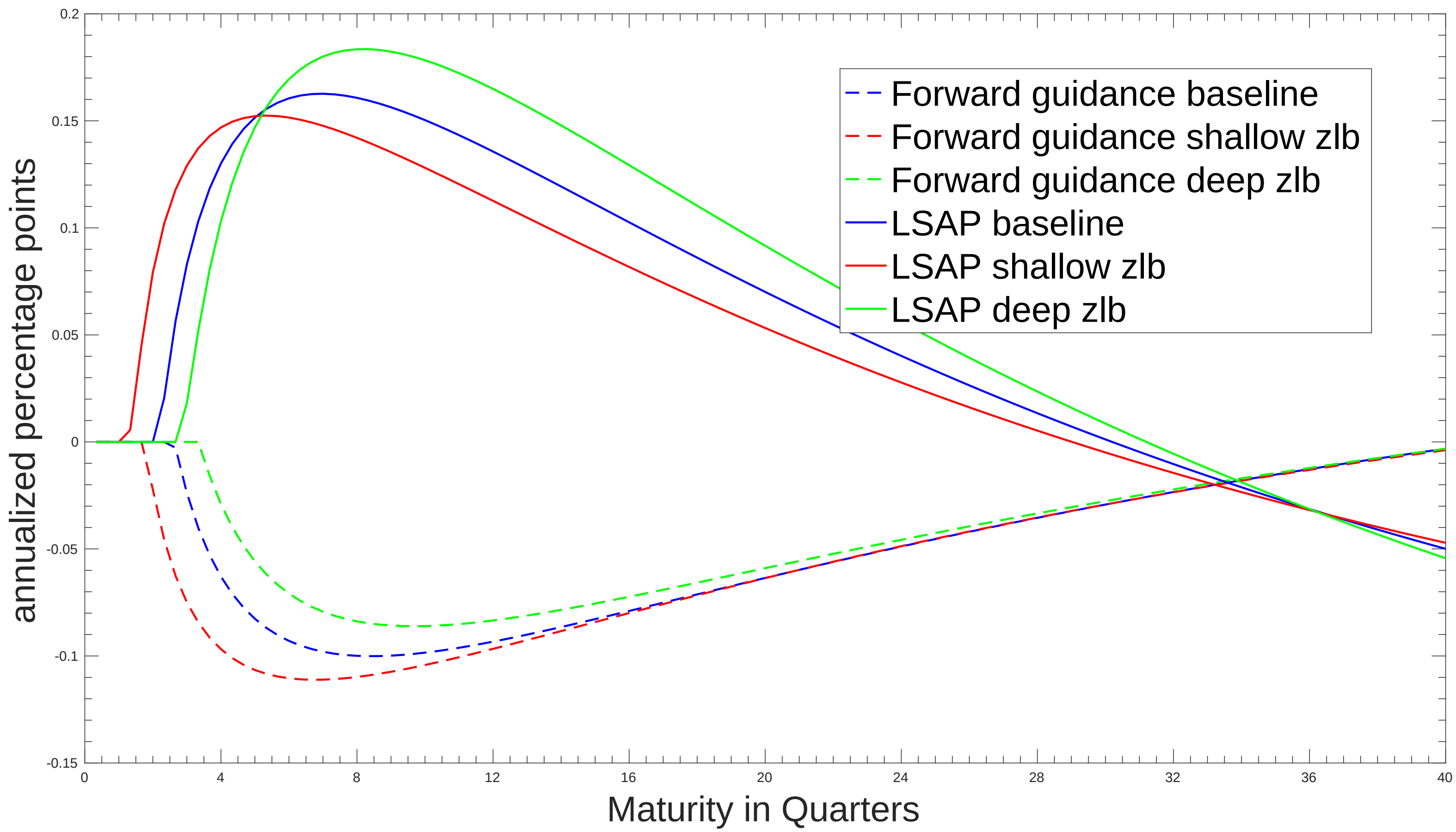

NOTES: Estimated effects on Treasury yield curve on June 19, 2013. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 12: Estimated Effects on 03/18/2015



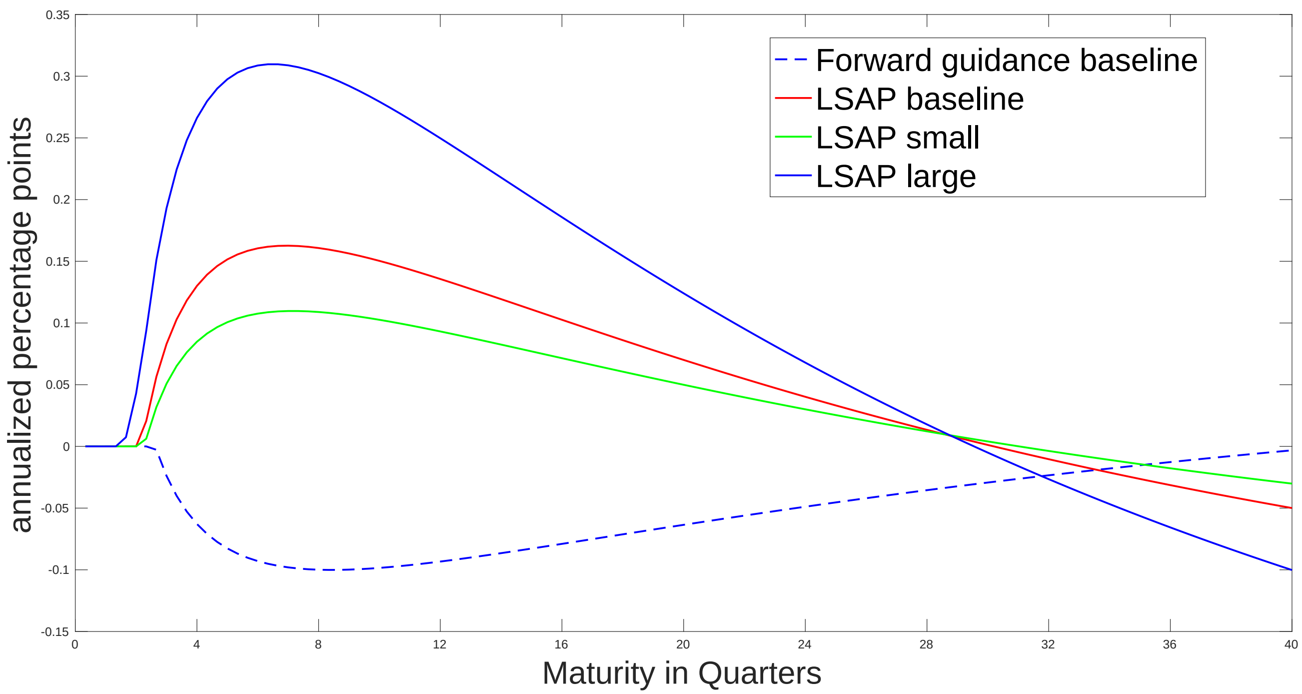

NOTES: Estimated effects on Treasury yield curve on March 18, 2015. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 13: Difference Between Fitted Yield Curves When Initial Condition Varies



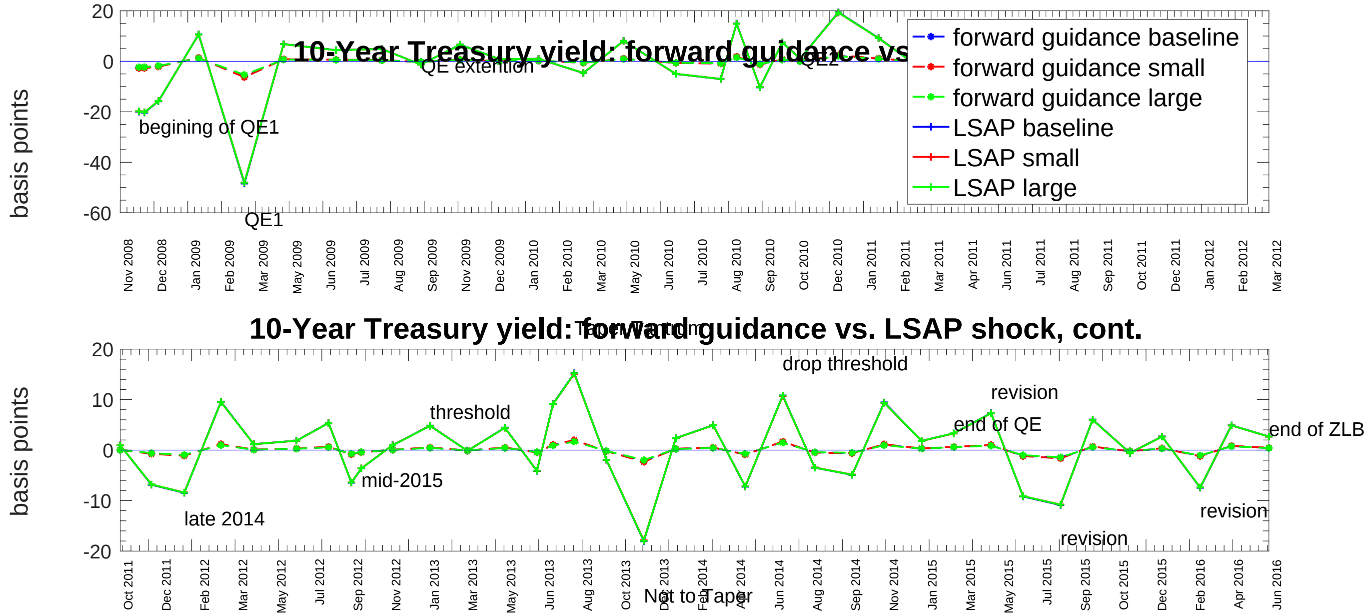

NOTES: Plot of the difference between fitted yield curves from a no-policy-response case.

Figure 14: Difference Between Fitted Yield Curves When Normalization Varies



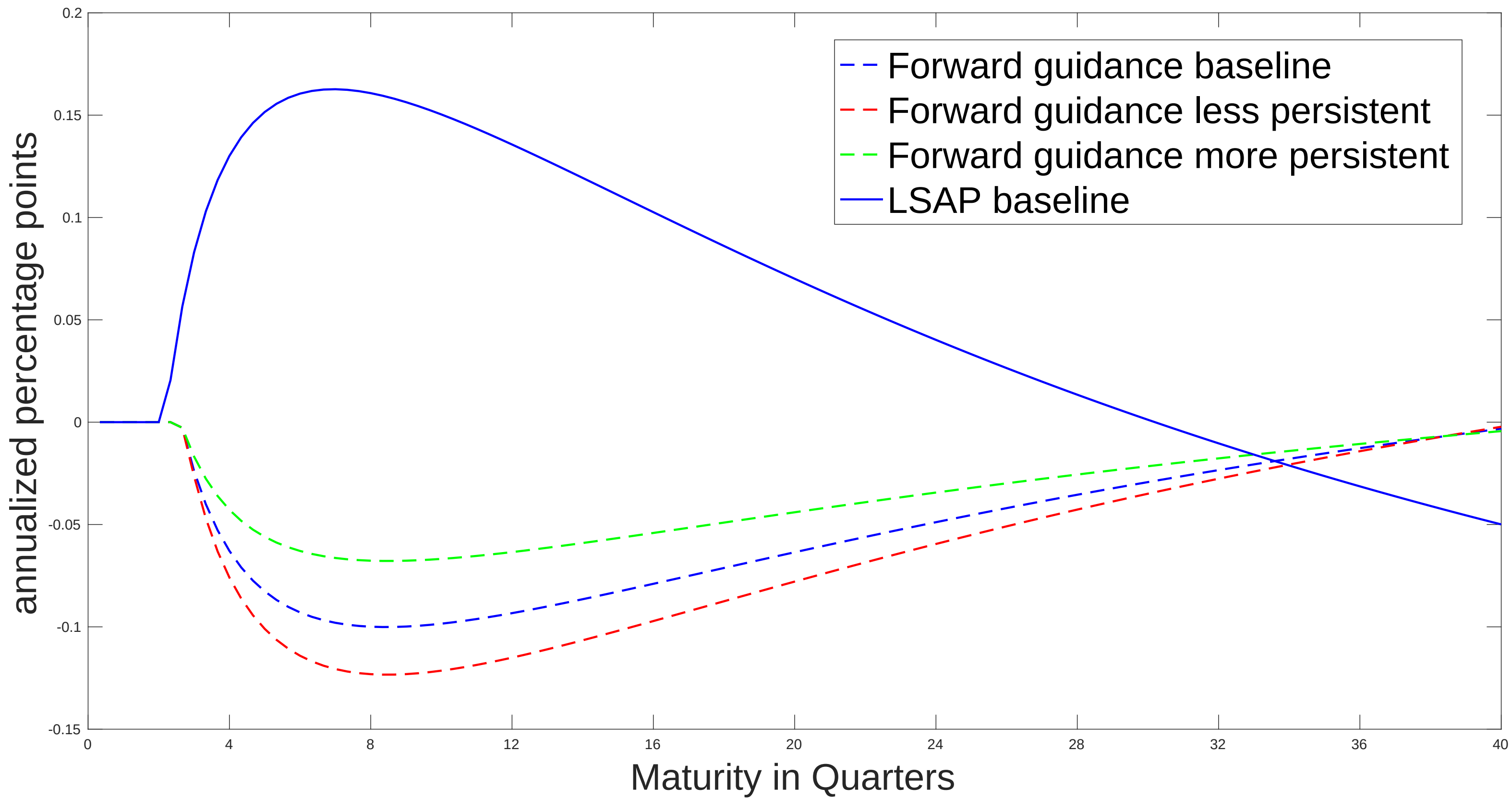

NOTES: Plot of the difference between fitted yield curves from a no-policy-response case.

Figure 15: Estimated Effects on 10-year Treasury Yield When Normalization Varies



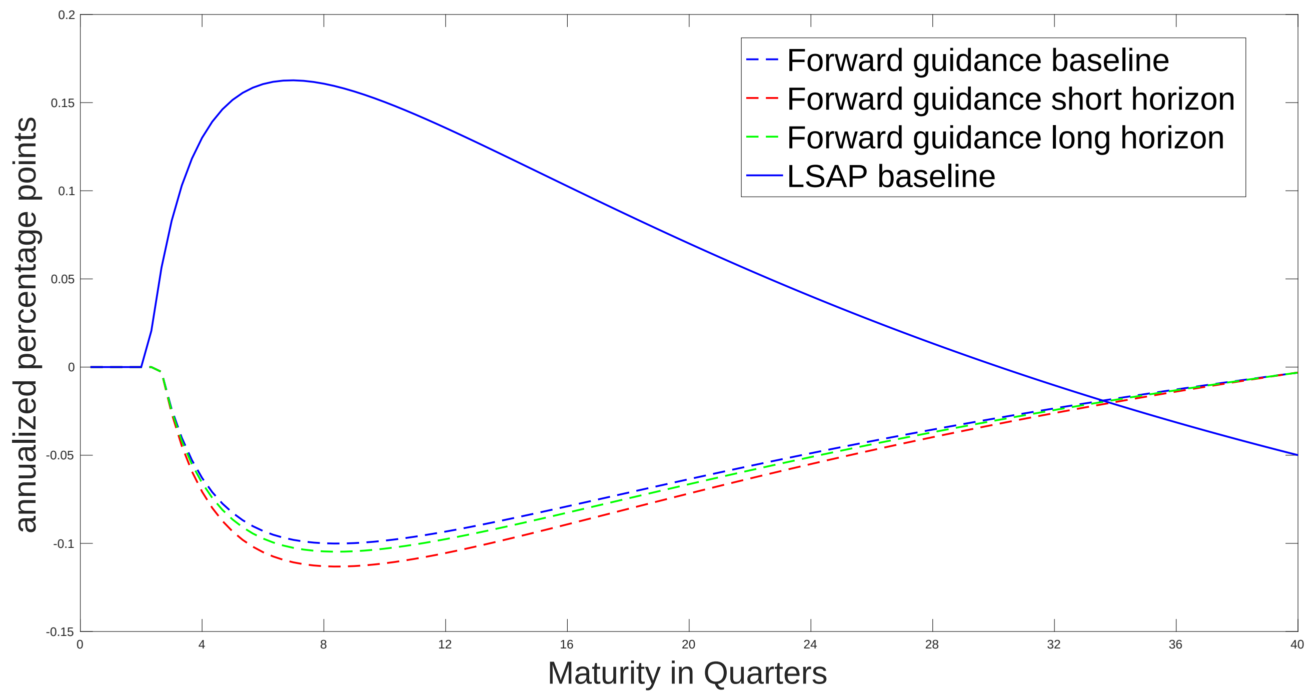

NOTES: Plot of estimated forward guidance (dashed line) and LSAP (solid line) factors for 10-year Treasury yield for all the event dates for different normalization. Notable announcements are labeled in the figure for reference. See text for details.

Figure 16: Difference Between Fitted Yield Curves When Forward Guidance Persistence Varies




NOTES: Plot of the difference between fitted yield curves from a no-policy-response case.

Figure 17: Difference Between Fitted Yield Curves When Forward Guidance Horizon Varies




NOTES: Plot of the difference between fitted yield curves from a no-policy-response case.

# Appendix

Table 11: List of Event Dates

| Date | Forward Guidance Announcement | LSAP Announcement |
|---|---|---|
| 25-Nov-08 | | The initial announcement that the Federal Reserve would purchase up to $100 billion of agency debt and up to $500 billion of agency MBS. |
| 1-Dec-08 | | Chairman Bernanke's speech on the Federal Reserve Policies in the Financial Crisis, which suggested that the Federal Reserve could purchase longer-term Treasury securities in substantial quantities in order to stimulate the economy. |
| 16-Dec-08 | ...anticipates that weak economic conditions are likely to warrant exceptionally low levels of the federal funds rate for some time. | The Federal Reserve will continue to consider ways of using its balance sheet to further support credit markets and economic activity. |
| 28-Jan-09 | | |
| 18-Mar-09 | ..for an extended period. | The FOMC statement, which announced purchases of Treasury securities of up to $300 billion and increased the size of purchases of agency MBS and agency debt to up to $1.2 trillion and $200 billion, respectively. |
| 29-Apr-09 | | |
| 24-Jun-09 | | |
| 12-Aug-09 | | FOMC statement dropped the up to in the language to quantify the amount of longer-term Treasury securities to be purchased. |
| 23-Sep-09 | | FOMC statement dropped the up to in the language to quantify the amount of agency MBS to be purchased. It also said that agency debt and MBS purchases would be slowed and finished by the end of 2010Q1, rather than the end of 2009. |

| Date | Forward Guidance Announcement | LSAP Announcement |
| --- | --- | --- |
| 4-Nov-09 | The Committee ... continues to anticipate that economic conditions, including low rates of resource utilization, subdued inflation trends, and stable inflation expectations, are likely to warrant exceptionally low levels of the federal funds rate for an extended period. | FOMC statement stated that the exact amount of agency debt to be purchased would be about $175 billion of agency debt, which is less than the previously announced maximum of $200 billion. |
| 16-Dec-09 | | |
| 27-Jan-10 | | |
| 16-Mar-10 | | |
| 28-Apr-10 | | |
| 23-Jun-10 | | |
| 10-Aug-10 | | To help support economic recovery in the context of price stability, the Committee will keep the Federal Reserve's holdings of securities at their current level by reinvesting principal payments from agency debt and agency mortgage-backed securities in longer-term Treasury securities. The Committee will continue to roll over the Federal Reserve's holdings of Treasury securities as they mature. |
| 27-Aug-10 | | In a speech, Chairman Bernanke announces that additional purchases of longer-term securities...would be effective in further easing financial conditions. |
| 21-Sep-10 | | The FOMC is prepared to provide additional accommodation if needed. |
| 15-Oct-10 | | Chairman Bernanke states the Fed will continue keeping interest rates low and mentions further quantitative easing. |
| 3-Nov-10 | | The FOMC intends to purchase a further $600 billion of longer term Treasury securities by the end of the second quarter of 2011, a pace of about $75 billion per month. |
| 14-Dec-10 | | |
| 26-Jan-11 | | |
| 15-Mar-11 | | |
| 27-Apr-11 | | |

| Date | Forward Guidance Announcement | LSAP Announcement |
|---|---|---|
| 22-Jun-11 | Modified the description of conditions likely to warrant low rates, to including low rates of resource utilization and a subdued outlook for inflation over the medium run. | |
| 9-Aug-11 | The Committee currently anticipates that economic conditions ... are likely to warrant exceptionally low levels of the federal funds rate at least through mid-2013. | |
| 21-Sep-11 | | The FOMC intends to purchase, by the end of June 2012, $400 billion of Treasury securities with remaining maturities of 6 years to 30 years and to sell an equal amount of Treasury securities with remaining maturities of 3 years or less. |
| 2-Nov-11 | | |
| 13-Dec-11 | | |
| 25-Jan-12 | ... at least through late 2014. | |
| 13-Mar-12 | | |
| 25-Apr-12 | | |
| 20-Jun-12 | | The FOMC decided to continue through the end of the year its program to extend the average maturity of its holdings of securities. An accompanying statement by the Federal Reserve Bank of New York clarifies that this continuation will result in the purchase, as well as the sale and redemption, of about $267 billion in Treasury securities by the end of 2012. |
| 1-Aug-12 | | |
| 31-Aug-12 | | Chairman Bernanke hints at QE3: The Federal Reserve will provide additional policy accommodation as needed to promote a stronger economic recovery and sustained improvement in labor market conditions in a context of price stability. |

| Date | Forward Guidance Announcement | LSAP Announcement |
|---|---|---|
| 13-Sep-12 | ...decided today to keep the target range for the federal funds rate at 0 to 1/4 percent and currently anticipates that exceptionally low levels for the federal funds rate are likely to be warranted at least through mid-2015 . | The FOMC agreed today to increase policy accommodation by purchasing additional agency mortgage-backed securities at a pace of $40 billion per month. The Committee also will continue through the end of the year its program to extend the average maturity of its holdings of securities as announced in June, and it is maintaining its existing policy of reinvesting principal payments from its holdings of agency debt and agency mortgage-backed securities in agency mortgage-backed securities. These actions, which together will increase the Committee's holdings of longer-term securities by about $85 billion each month through the end of the year, should put downward pressure on longer-term interest rates, support mortgage markets, and help to make broader financial conditions more accommodative. |
| 24-Oct-12 | | |
| 12-Dec-12 | | The FOMC will continue purchasing additional agency mortgage-backed securities at a pace of $40 billion per month. The Committee also will purchase longer-term Treasury securities after its program to extend the average maturity of its holdings of Treasury securities is completed at the end of the year, initially at a pace of $45 billion per month. |
| 30-Jan-13 | | |
| 20-Mar-13 | | |
| 1-May-13 | | |
| 22-May-13 | | Chairman Bernanke's testimony before the Joint Economic Committee indicated that the central bank may reduce its stimulus at some point: If we see continued improvement, and we have confidence that that is going to be sustained, in the next few meetings we could take a step down in our pace of purchases. |

| Date | Forward Guidance Announcement | LSAP Announcement |
|---|---|---|
| 19-Jun-13 | ...14 of 19 FOMC participants indicated that they expect the first increase in the target for the federal funds rate to occur in 2015, and one expected the interest increase to incur in 2016. | |
| 31-Jul-13 | | |
| 18-Sep-13 | | |
| 30-Oct-13 | | |
| 18-Dec-13 | ...anticipates, based on its assessment of these factors, that it likely will be appropriate to maintain the current target range for the federal funds rate well past the time that the unemployment rate declines below 6-1/2 percent, especially if projected in ation continues to run below the Committee's 2 percent longer-run goal. | Beginning in January, the Committee will add to its holdings of agency mortgage-backed securities at a pace of $35 billion per month rather than $40 billion per month, and will add to its holdings of longer-term Treasury securities at a pace of $40 billion per month rather than $45 billion per month. The Committee is maintaining its existing policy of reinvesting principal payments from its holdings of agency debt and agency mortgage-backed securities in agency mortgage-backed securities and of rolling over maturing Treasury securities at auction. The Committee's sizable and still-increasing holdings of longer-term securities should maintain downward pressure on longer-term interest rates, support mortgage markets, and help to make broader financial conditions more accommodative, which in turn should promote a stronger economic recovery and help to ensure that inflation, over time, is at the rate most consistent with the Committee's dual mandate. |
| 29-Jan-14 | | Beginning in February, the Committee will add to its holdings of agency mortgage-backed securities at a pace of $30 billion per month rather than $35 billion per month, and will add to its holdings of longer-term Treasury securities at a pace of $35 billion per month rather than $40 billion per month. |

| Date | Forward Guidance Announcement | LSAP Announcement |
|---|---|---|
| 19-Mar-14 | With the unemployment rate nearing 6-1/2 percent, the Committee has updated its forward guidance. | Beginning in April, the Committee will add to its holdings of agency mortgage-backed securities at a pace of $25 billion per month rather than $30 billion per month, and will add to its holdings of longer-term Treasury securities at a pace of $30 billion per month rather than $35 billion per month. |
| 30-Apr-14 | | Beginning in May, the Committee will add to its holdings of agency mortgage-backed securities at a pace of $20 billion per month rather than $25 billion per month, and will add to its holdings of longer-term Treasury securities at a pace of $25 billion per month rather than $30 billion per month. |
| 18-Jun-14 | | Beginning in July, the Committee will add to its holdings of agency mortgage-backed securities at a pace of $15 billion per month rather than $20 billion per month, and will add to its holdings of longer-term Treasury securities at a pace of $20 billion per month rather than $25 billion per month. |
| 30-Jul-14 | | Beginning in August, the Committee will add to its holdings of agency mortgage-backed securities at a pace of $10 billion per month rather than $15 billion per month, and will add to its holdings of longer-term Treasury securities at a pace of $15 billion per month rather than $20 billion per month. |
| 17-Sep-14 | | Beginning in October, the Committee will add to its holdings of agency mortgage-backed securities at a pace of $5 billion per month rather than $10 billion per month, and will add to its holdings of longer-term Treasury securities at a pace of $10 billion per month rather than $15 billion per month. |
| 29-Oct-14 | the Committee today reaffirmed its view that the current 0 to 1/4 percent target range for the federal funds rate remains appropriate. | Accordingly, the Committee decided to conclude its asset purchase program this month. |
| 17-Dec-14 | the Committee judges that it can be patient in beginning to normalize the stance of monetary policy. | |

| Date | Forward Guidance Announcement | LSAP Announcement |
|---|---|---|
| 28-Jan-15 | | |
| 18-Mar-15 | the Committee judges that an increase in the target range for the federal funds rate remains unlikely at the April FOMC meeting. The Committee anticipates that it will be appropriate to raise the target range for the federal funds rate when it has seen further improvement in the labor market and is reasonably confident that inflation will move back to its 2 percent objective over the medium term. This change in the forward guidance does not indicate that the Committee has decided on the timing of the initial increase in the target range. | |
| 29-Apr-15 | | |
| 17-Jun-15 | | |
| 29-Jul-15 | | |
| 17-Sep-15 | | |
| 28-Oct-15 | | |
| 16-Dec-15 | Given the economic outlook, and recognizing the time it takes for policy actions to affect future economic outcomes, the Committee decided to raise the target range for the federal funds rate to 1/4 to 1/2 percent. | |