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

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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. We 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. We 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 us to identify the separate contributions of each shock to the effects of the announcement. Our estimates correspond closely to narrative elements of the FOMC announcements. Our estimates imply that forward guidance was more effective at inflation, while LSAP was more important in influencing output.

1 Introduction

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) has turned to use 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 from a dynamic stochastic general equilibrium (DSGE) model and the 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 et al. (2003) show that lowering the expected path of policy rates can be highly effective in increasing economic activity and inflation. 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. For the empirical side, most research has focused on analyzing the effects of LSAP on, for example, interest rates, output, inflation, term premia and corporate credit 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, the current literature is silent on determining 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

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

[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), Kapetanios et al. (2012), Bauer & Rudebusch (2014).

paper, we estimate the size of each type of monetary policy by combining the impulse response of yield curve to monetary policy shocks from a structural model with the movement of yield curve in the data. Given that, we use the structural model to derive the impulse responses of macroeconomic variables to different type of monetary policy shocks. In this way, we are able to overcome some key limitations of the event studies of the Fed's unconventional monetary policy. Our method provides an analysis beyond the very short-run response of financial variables and provides direct evidence on aggregate effects within a unified framework.

First, I build a New Keynesian DSGE model, based on Gertler & Karadi (2011, 2013), and investigate the impact of forward guidance and LSAP policies on real activities and interest rates. In their model, Gertler and Karadi 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. The new features of the model are: the one-period nominal short-term interest rate has a zero lower bound (ZLB); the one-period shadow nominal short-term interest rate follows a Taylor rule; forward guidance 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 (Keen et al. (2016)). We calibrate the model to match the key features of the data. We also show that our model's prediction is consistent with studies for both pre-ZLB and ZLB periods.

Next, we conduct a crisis experiment, where the one-period nominal interest rate hits its zero lower bound and stays there for several periods. We 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. We choose the parameters that govern the above conditions based on the observed data and from the literature. We obtain the impulse responses of one-period shadow nominal interest rate and perpetuity rate to one unit of each type of monetary policy.

Using a two-factor shadow rate model adapted from Wu & Xia (2016), we can then interpolate the entire yield curve's responses to the two types of monetary policy shocks. We find that forward guidance affect Treasury yields at all maturities, with a peak effect at a maturity of about 16 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 the interest rates at short maturities at the same time.

Our next step is to combine the model's prediction with the observed yield data 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 how Treasury bond yields respond to the Fed's policy. We regress those changes of yields at all maturities in the data on the changes of yields at all maturities predicted from the structural model. In this way, we are able to estimate the size of each of the two types of monetary policy and decompose the changes of yields at all maturities into two components: one caused by the forward guidance and the other caused by 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". Meanwhile, the Fed announced that it would continue to consider ways of using its balance sheet to further support credit markets and economic activity. As shown in Figure 14, the unconventional monetary policy lowers both short-term and long-term interest rate as a whole. 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, we consider implications for the real economy. With the estimated size of each type of monetary policy, we examine the separated effects on output and inflation rate using the structural model. The theoretical model predicts the forward guidance shock on December 16, 2008 would increase the two-quarter ahead 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 increase the two-quarter ahead GDP by 0.37 percent, and the two-quarter ahead inflation by 0.26 percentage points. Our overall estimates imply that forward guidance is more effective at short-run inflation, while LSAP is more important in influencing output during the QEI period.

Another way in the literature to figure out the size of unconventional monetary policy is to look at the changes of words and sentences in the current FOMC statement with respect to the previous statement and assigns the type and the direction (easing or tightening) of monetary policy accordingly. The drawback of this approach is that it only captures the changes in words, not the market expectation. It also ignores the case that the FOMC can surprise markets through its inaction rather than its actions. For example, on June 19, 2013, there is little change in the FOMC statement, but the FOMC released economic projections along with the statement that showed a substantial increase in the FOMC's economic outlook. Given earlier remarks by then-Chairman Ben Bernanke that the FOMC could begin tapering its asset purchases soon, markets interpreted this as a signal to a tapering process (Swanson 2017). 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 during the summer of 2013. Figure 26 shows that the unconventional monetary policy increases the yield at all maturities. My identification of forward guidance and LSAP shows that both of them are in the tightening direction. The forward guidance on that day increased the 10-year Treasury yield by 1.8 basis points, while the LSAP has an effect of 15.3 basis points. The theoretical model predicts the forward guidance shock on that day would decrease the two-quarter ahead GDP by 0.16 percent, the two-quarter ahead inflation by 0.24 percentage points. It also predicts the LSAP announcement on that day would decrease the two-quarter ahead GDP by 0.54 percent, and the two-quarter ahead inflation by 0.45 percentage points.

One paper, Swanson (2017), also provides methods to determine the size and the type of monetary policy. He extends the methods of Gürkaynak et al. (2005) to estimate two dimensions of monetary policy during the zero lower bound period. These two dimensions are interpreted as forward guidance and LSAP. He finds that forward guidance has relatively small effects on the longest-maturity Treasury yields and essentially no effect on corporate bond yields, while LSAP has large effects on those yields but essentially no effect on short-term Treasuries.

There is a big difference between the identification method used by this paper and Swanson's paper. We start from a theoretical model, calibrate it to fit the behavior of the economy before and during the zero lower bound period, then match the impulse responses the model predicted to the observed yield curve data. However, some of the shocks we identified are qualitatively similar to the ones identified by Swanson (2017). For example, on September 23, 2009, the FOMC stated it would extend its asset purchase program by an additional three months, through 2010Q1 rather than 2009Q4. Swanson (2017)'s identification characterizes this announcement as forward guidance, based on the way financial markets responded. Our identification, shown in Figure 18, attributes the easing effects mainly to the forward guidance, and the short-term maturities decrease more than the long-term end.

September 21, 2011 is one of the dates when our results are different from Swanson (2017). It corresponds to "Operation Twist", a program where the FOMC sold about $400 billion of short-term Treasury securities in its portfolio and used the proceeds to purchase a like quantity of long-term Treasuries. 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 22, 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.

One advantage and important contribution of our methodology is that once we have identified the size of each type of unconventional monetary policies on the event date, we can return to the structural model to make inferences about the other variables of interest. This makes our paper not only able to look at the announcement's effects on financial markets as Swanson (2017) and the event studies do but also the effects on the macroeconomic activity and inflation rate. Again, take September 21, 2011 as an example. The theoretical model predicts the forward guidance shock on that day would increase the two-quarter ahead GDP by 0.04 percent and the two-quarter ahead inflation by 0.06 percentage points. It also predicts the LSAP announcement on that day would boost the two-quarter ahead GDP by 0.18 percent and the two-quarter ahead inflation by 0.13 percentage points.

Our estimate indicates that the QE I program (November 2008 to March 2010) will increase 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.

The remainder of the paper proceeds as follows. In section 2, I describe a New Keynesian DSGE model based on Gertler & Karadi (2011, 2013) with forward guidance shocks. In section 3, I discuss the calibration of the model and present the state-dependent impulse responses under different scenarios. In section 4, I describe the shadow rate framework we use to interpolate the entire yield curve. In section 5, I describe the regression methodology and results. Section 6 discusses the robustness of our methodology. Section 7 concludes. Appendix provides further details.

2 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 riskless debt. Second, an agency problem between households and banks generates a constraint in the borrowing ability of the latter. Third, the LSAP is used as central bank intermediation that 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. In the model, the short-term nominal interest rate faces the zero lower bound, and the second difference is that we assume the central bank follows a short-term shadow rate Taylor rule. The shadow rate is the short-term rate when the ZLB is not binding; otherwise, it is negative to account for unconventional policy tools.

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

2.1 Households

The economy is populated by a continuum of household 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 θ; 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.

As in Woodford (2011), we consider the limit of the economy as it become cashless and ignore the convenience yield to the household from real money balances. Let c_t be consumption and l_t labor supply. Then the household's discounted utility u_t is given by:

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

where $\beta \in (0,1)$ denotes the household's subjective discount factor, $h \in (0,1)$ governs the strength 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 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, δ the depreciation rate of a unit of capital, and ξ_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

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

We suppose that for private securities a household faces a holding cost. 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:

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

where D_{ht} is the quantity of one-period nominal bond held by household at time t, W_t is the real wage, Π_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:

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

2.2 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. We assume 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 λ 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 λ_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:

$$\begin{aligned}Q_t s_{pt}+\triangle q_t^n b_t &= \phi_t n_t \quad \text{if} \quad \lambda_t>0\\ &< \phi_t n_t \quad \text{if} \quad \lambda_t=0\end{aligned} \tag{7}$$

where

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

2.3 Central bank's asset purchases

We allow the central bank 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

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

2.4 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 (14) 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 θ 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:

$$Q_t(S_t - S_{ht} - S_{gt}) \leq \phi_t N_t - \triangle q_t^n [B_t - (B_{gt} + B_{ht})] \tag{8}$$

2.5 The Production Sector

2.5.1 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 ξ_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 $p_t^i(s)$ 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:

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

The standard New Keynesian price optimality condition is

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

2.5.2 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

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

First order condition is:

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

2.5.3 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:

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

2.6 Monetary Policy

This section we describe 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,

$$i_t^* = r + \bar{\pi} + \kappa_\pi(\pi_t - \bar{\pi}) + \kappa_y(\log Y_t - \log Y_t^*) + z_t \quad (9)$$

$$i_t = \max\{\underline{\iota}, i_t^*\} \quad (10)$$

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, we define z_t, the monetary policy deviation at time t as

$$z_t = \varepsilon_{t,t}^m + \sum_{j=1}^{T} a_j \varepsilon_{t,t-j}^m \tag{11}$$

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 receives in the beginning of period t about those deviations.[4] a_j governs the size of each shock.

In order to determine the magnitude of a_j, where $j > 0$, we follow the specification in Bundick & Smith (2016). They assume that the series of the size is an exponential decay process. Therefore, our specification in equation (11) could be rewritten as,

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

One distinguishing feature of the policy experiments we perform from the GK paper is that the number of periods the zero lower bound binds 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. In contrast, our shadow interest rate can be negative, and the interest rate is not pegged.

Besides the interest rate monetary policy, the central bank could conduct monetary policy through direct pruchases of securities of bonds. During the crisis, the central bank purchases a fraction φ_{st} of the outstanding stock of private securities and a fraction φ_{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 φ_{st} and φ_{bt} obey second-order stationary stochastic

[4] 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

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

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

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

processes to capture the cumulative buildup of asset purchases program.

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

The reason why the central bank's credit policy works is as follows. When the bank faces balance constraint shown in equation (8), 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.

2.7 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

$$
q_t^n = \sum_{j=1}^{40} \frac{1}{(1+i_t^{(40)})^j} + \frac{q_{ss}^n}{(1+i_t^{(40)})^{40}} \tag{12}
$$

2.8 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.

3 Calibration and Simulation of the Theoretical Model

3.1 Calibration

However, some of the other parameters used by Gertler and Karadi 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, we have made a number of changes so that the predictions of the model better match the properties observed in financial data.

Table 1 shows the key features of the data and compares the performance of the new calibrated model with the GK model. There are three aspects for comparison. First one is the steady state. The difference between a 10-year inflation-indexed Treasuries (TIPS) and a 2-year TIPS is 69 basis points, taken from the updated Gürkaynak et al. (2010) online dataset. We use the 2004-07 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 percent. Our new calibration will result in a 10-year and 2-year real rate spread equal to 69 basis points. However, GK's model will have the spread as 33 basis points.

The second way to compare the performance is to look at the behavior of the model during the ZLB period. The average 10-year Treasuries yield dropped a lot at the in-between 2007 and 2008 is around 200 to 300 bps. According to Wu & Xia (2016), the average shadow rate in the ZLB period is negative 121 bps. The initial capital quality shock will decrease the interest rate to the zero lower bound. It will have the shadow rate decreased to negative 121 bps and 10-year yield lowered by 4 bps, while the one conducted in GK will increase the 10-year Treasury yield by 51 bps.

Table 2 lists the choice of parameter values for the model.

We begin with the parameters that we use the same value as in Gertler & Karadi (2013). They are shown in the Panel (A). The depreciation rate of capital δ is set to be 0.025, and the capital share α is 0.33. The price rigidity parameter γ is 0.779, which implies firms resetting prices approximately every 13.6 months on average. The degree of price indexation γ_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. We use the same conventional Taylor rule parameters $\phi_\pi = 1.5$ for the feedback coefficient on inflation and $\phi_y = -0.125$ for the coefficient on output gap. We 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.

As shown in the Panel (B) of Table 2, for the discount factor β, we assign a quarterly value of 0.9945 to match an average of short-term real interest rate of 2.21 percent. GK use β 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, we set $\bar{\pi} = 0.6$, corresponding to an annual inflation target of 2.4%. 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, we set $\underline{\iota} = 0.25\%$.

GK choose θ, λ, Δ, and X to imply an expected horizon of 8.77 years for bankers, a steady-state excess return on government bonds of 50 basis points, a steady-state excess return on private securities of 100 basis points, and a steady-state leverage ratio for banks of 4 in their 2011 paper and 6 in their 2013 paper. The values of these premiums observed in the data, e.g., Adrian et al. (2013) appear to be much higher. The values of θ, λ ,Δ, and X in Table 2 target an expected horizon of 5.7 years for bankers, a bond premium of 98 basis points, an equity premium of 173 basis points, and a steady-state leverage ratio for banks of 5. Therefore, the implied value for λ becomes 38.6% instead of 38.1% in their 2011 paper and 34.5% in their 2013 paper, and the implied value for X becomes 0.16% instead of 0.2% in their 2011 paper and 0.62% in their 2013 paper. We also used different values from GK for the household portfolio adjustment cost parameters κ_s and κ_b, along with different values for the AR(2) coefficients for the LSAP shock. These changes make the predicted effects of LSAP on medium-term bond yields more consistent with the data as discussed above.

A number of other parameters used by GK differ substantially from previous studies and turn out to raise the possibility of some odd dynamics of the model. We 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. We instead set $1/\phi = 1/2$. GK assume an elasticity of substitution ε between goods of 4.167, implying a steady-state markup of 31.58%. As shown in Panel (C) of Table 2, our 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, η_i, of 1.728. We 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 ϕ_π is taken from Coibion and Gorodnichenko (2011).

Finally, there is one parameter that is new to our model, ρ_z, which governs the decaying behavior of the forward guidance shock. In the crisis experiment below, we've chosen ρ_z equal to 0.68 to match the evidence on the impact of forward guidance on the term structure.

3.2 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.

3.3 Crisis Experiment

We 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. Most of the literature, simulate a large decline in household demand by the increase of discount factor β, which generates a zero lower bound episode. However, to capture the increase of excess return during the Great Recession, and examine the effects of LSAP via its transmission through excess return (relative to a friction-less benchmark), the driven force of the economy hitting the zero lower bound is from the quality of capital.

We 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. We 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 6, 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 otherwise the policy won't provide stimulus to the real economy. On the other hand, we limit the finite horizon to the diminishing influence of the central bank.

We define that one unit of forward guidance shock will lower the nominal shadow rate by 25 basis points. As in Gertler & Karadi (2013), we assume that the LSAP policy is implenmented as an AR(2) process. We define that one unit of LSAP shock will lower the 10-year yield by 5 basis points.[5] Figure 2 reports how much difference the unconventional monetary policy made to the response of the model economy with zero lower bound constraint. A unit forward guidance shock will decrease the annualized shadow short-term nominal interest rate by 25 basis points, increase the current output by 0.02 percentage points, and the current annualized inflation rate by 0.07 percentage points. A unit LSAP shock will increase the shadow short-term nominal interest rate by 40 basis points, increase the current output by 0.08 percentage points, and the current annualized inflation rate by 0.14 percentage points.

[5] 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.

4 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 we interpolate the yield on any maturity i_{nt} under the ZLB using a flexible approximation to the shape of the yield curve.

4.1 Solution Away from the ZLB

First we 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, (ξ_{1t}, ξ_{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

$$i_t = \xi_{1t} + \xi_{2t} \tag{13}$$

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

$$f_{nt} = E_t^Q(i_{t+n}) = \phi_1^n \xi_{1t} + \phi_2^n \xi_{2t} \tag{14}$$

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:

$$i_{nt} = \xi_{1t} + n^{-1} \frac{1 - \phi_2^n}{1 - \phi_2} \xi_{2t} \tag{15}$$

Equations (13) and (15) allow us to recover the two factors directly off the level of one-period rate i_t and the long-term rate, i_{Nt}:

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

Moreover, once we know ξ_{1t} and ξ_{2t}, we can interpolate the entire yield curve using equations (14) and (15) .

4.2 Solution at the Lower Bound

Here we 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 σ_n is a parameter.

We have

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

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

4.3 Calibration

We use the pre-ZLB yield data to calibrate ϕ_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 3 reports average yields from January 1990 to November 2007, a span that excludes the Great Inflation as well as the Great Recession periods and we 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. We choose (ξ_1, ξ_2, ϕ_2) such as the fitted yield curve best matched the average yield curve. It turns out that $\xi_1 = 7$, $\xi_2 = -2.77$, $\phi_2 = 0.979$.

We next use the same ϕ_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 $\xi_1 = 6.23$, $\xi_2 = -1.62$. The second row of Table 3 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. Figure 3 compares the approximated normal time yield curve with the data. The solid line is the average yield curve over the pre-ZLB period. The dashed line is calculated using the model-implied steady state values i_{ss} and i_{Nss} as well as the above estimated ϕ_2.

We follow Krippner (2016) and set σ_n as follows:

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

where ρ_1, ρ_2, ρ_{12} and ϕ_3 are parameters estimated from an arbitrage-free Nelson & Siegel (1987) model with two state-variables (level and slope), and $G(\phi_3, n) = \frac{1}{\phi_3}[1 - \exp(-\phi_3 n)]$. ρ_1, ρ_2, ρ_{12} and ϕ_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, with the impulse responses from the above theoretical model, we compute the implied yield curve during the ZLB period. The upper left panel of Figure 4 compares the approximated yield curve when there is capital quality shock with the yield curve implied by the model's steady state. The upper right panel illustrates the yield curve when there is capital quality shock without central bank response, capital quality shock with one unit of forward guidance shock, and capital quality shock with one unit of LSAP shock. The horizontal axis is in maturity in quarters. The short-term end of these yield curves is shown in the lower left panel, and the long-term end is shown in the lower right panel. The horizontal axis in both of them is in maturity in months. As shown by the solid line, because of the capital quality shock, the nominal short-term interest rate drops to 0, so does the 1-month interest rate. With the forward guidance, i.e. the dashed line, the 2-month interest rate drops to 0, and the 10-year interest rate decreases too. With the LSAP, i.e. the dotted line, the short-term interest rates increase, while the 10-year interest rate drops.

Figure 5 illustrates the difference between the yield curves in scenarios (i) and (ii) and the difference between (i) and (iii). One unit of easing forward guidance announcement lowers Treasury yields at all maturities, with a peak effect at a maturity of about 24 months; in contrast, one unit 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.

5 The FOMC's Forward Guidance and LSAP Announcements

We now investigate the effects of forward guidance and LSAP announcements on each event date. First, we 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, we return to the theoretical model and obtain the model's prediction of the behavior of aggregate variables.

5.1 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:

$$\triangle i_{nt} = \beta_{1t} \times \triangle i_n^{fg} + \beta_{2t} \times \triangle i_n^{lsap} + error_t, \text{for } n = 2, 3, \cdots, 10 \tag{16}$$

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 β_{1t} and β_{2t}. They tell us 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, and most of them consist of the FOMC meetings, but some important speeches and other events are included as well. The full list of the event dates could be found in the appendix table 12. For each of the announcement dates, I run a regression as in (16).[6] Figure 6 plots β_{1t} and β_{2t} over time.

Given β_{1t} and β_{2t}, we return to the theoretical model described in section 2 and obtain the impulse responses of macroeconomic variables to β_{1t} units of forward guidance shock and β_{2t} units of LSAP shock, separately. In this way, we use the high-frequency yield data to figure out the sizes of each type of shocks and use the structural model to show the persistence of the monetary policy shocks on aggregate economy, which the standard event-study methodology cannot do.

[6] Since each of the regression has the same set of regressors on the right-hand-side, running a 63-system seemingly unrelated regression will have the same estimates as running an OLS regression for each equation/system.

5.2 Unconventional Monetary Policy on Several Key FOMC Announcement Days

Figures 7 to 9 plot the time series of estimated values of the forward guidance and LSAP factors for each FOMC announcement for 5-year, 9-year and 10-year Treasury yields, respectively, for all the event dates. Among all the event days, there are 35 key announcements widely discussed in the literature. Some of them are labelled on the figures and will be analyzed individually below. Not surprisingly, forward guidance and LSAP policies announced on the same day always work in the same direction tightening or easing the market. However, on the short-term and medium-term yields, the two policies have opposite effects, but on the long-term yield both policies have effect in the same direction. This is because that an easing forward guidance will lower the shadow rate while an easing LSAP will raise the shadow rate through the Taylor rule. Among the event dates, forward guidance factor usually is larger than the LSAP factor for the short-term and medium-term yields, while LSAP factor usually is larger than the forward guidance factor for the long-term yield.

Figure 10 shows the time series of estimated effects of the forward guidance and LSAP on the two-quarter hence output for all the event dates. The LSAP is the dominant force. Similarly, Figure 11 plots the time series of estimated effects of the forward guidance and LSAP on the two-quarter hence annualized inflation rate over time. For the current output, most of the dates have forward guidance more powerful than LSAP.

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.[7] 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.[8]

5.2.1 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 12, 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

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

[8] The first 8 days in the following paragraphs are identified by Gagnon et al. (2011).

left panel compares the observed change in yields with the fitted value. Even though there's no explicit words about the forward guidance policy, we 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, we have identified that there is also 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 12 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 1, 2008, Chairman Bernanke's speech on the Federal Reserve Policies in the Financial Crisis suggested that the Fed could purchase longer-term Treasury securities in substantial quantities in order to stimulate the economy. Figure 13 shows that this implies a slightly smaller size of forward guidance factor and a similar size of LSAP factor, compared to November 25, 2008.

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 14 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 its balance sheet to further support credit markets and economic activity. 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 identifies contractionary forward guidance and LSAP shocks as in Figure 15.

On March 18, 2009, the FOMC decided to purchase "up to an additional $750 billion of agency-backed securities", decided to increase "its purchases of agency debt this year by up to $100 billion", and purchase "up to $300 billion of longer-term Treasury securities over the next six months". In addition, the Committee changed the language about the expected duration of a near-zero policy rate to "for an extended period". Hence there was forward guidance policy announced at the same time as LSAP policy. Figure 16 plots the estimated effects of the forward guidance and LSAP announcements. Both short-term and long-term yields decreased a lot. The LSAP is more powerful that increases the two-quarter ahead output by 0.74 percent and increases two-quarter ahead inflation by 0.65 annualized percentage points.

On August 12, 2009, FOMC statement dropped the up to in the language to quantify the amount of longer-term Treasury securities to be purchased, and said that it would end its purchases of long-dated Treasury bonds in October. That announcement boosted investors' confidence that the Fed governors believe the recession is winding down.[9] Based on the way yield curve responded, there are both tightening forward guidance and tightening LSAP on this day as in Figure 17. The LSAP has a bigger effect.

The next major event, on September 23, 2009, is shown in Figure 18. The FOMC statement said that agency debt and MBS purchases would be slowed and finished by the end of 2010Q1, rather than the end of 2009. In addition, the statement also dropped the "up to" language qualifying the maximum amount of agency MBS purchases. From the text of the FOMC statement alone, it's about the extension of QE program. However, an extension of the end date of the LSAP program was also taken by markets to imply a correspondingly later liftoff date for the federal funds rate; thus it has forward guidance effect. The effects from the LSAP component is relatively small such that the long-term-end moves smaller than the short-term end. We estimate that the forward guidance raises the two-quarter ahead output by 0.03 percent and the two-quarter ahead inflation by 0.05 annualized percentage points.

On November 4, 2009, the FOMC reduced the planned purchase of agency debt from $200 billion to $175 billion. As shown in Figure 19, the forward guidance and LSAP are both tightening, and the yield curve becomes steeper.

5.2.2 QE II phase (November 2010 to June 2011)

It's also interesting that the FOMC's subsequent "QE2" program, launched on November 3, 2010, has both forward guidance and LSAP components as shown in Figure 20. However, the effects are not significant at 10% level.

5.2.3 Mid-2013 phase (November 2010 to June 2011)

August 9, 2011 is another interesting date. That announcement marked the first time the FOMC gave explicit (rather than implicit) 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 (essentially zero) level of the federal funds rate would be appropriate "at least through mid-2013". Reassuringly, I estimate the announcement on this date as a forward guidance component, with a bigger LSAP component. The reason could be that the announcement decreased the term premia, and thus has a bigger effects on the long-term end. In Figure 21 we estimate that the forward guidance raises the two-quarter ahead output by 0.2 percent and the inflation by 0.3 annualized

[9] See details in McKay & Rogow (2009).

percentage points, and the LSAP raises the two-quarter ahead output by 0.45 percent and the inflation by 0.31 annualized percentage points.

5.2.4 "Operation Twist" (September 2011 to August 2012)

The next FOMC announcement, on September 21, 2011, corresponds to "Operation Twist", a program where the FOMC sold about $400 billion of short-term Treasury securities in its portfolio and used the proceeds to purchase a like quantity of long-term Treasuries. As can be seen in Figure 22, this announcement is estimated to have easing forward guidance and LSAP components. This forward guidance effect is due to the fact that shorter-maturity interest rates rose in response to the FOMC announcement presumably due to a change in risk premia on those securities resulting from the large increase in expected sales by the Fed. (Swanson (2017))

The next change in forward guidance occurs in the statement released after the January 25, 2012 FOMC meeting. It states that the federal funds rate was expected to remain at zero was updated to read "... at least through late 2014," which was an increase of six quarters. I estimate the announcement on this date as a forward guidance component and a LSAP component, both in the easing direction. Figure 23 shows that the forward guidance has a smaller effect on two-quarter ahead output and a larger effect o n inflation compared to LSAP, and the long maturities decreases more than the short maturities.

5.2.5 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", a 6-month extension. In addition, the statement said the Fed would add $85 billion to the Fed's balance sheet every month until the labor market significantly improved. Figure 24 shows a small size of both types of policies.

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, and longer-term inflation expectations continue to be well anchored." 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.[10] Therefore, the medium-term and long-term yields increase. See Figure 25 for details.

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

5.2.6 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 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 during the summer of 2013, and appears to be correctly identified by my procedure as tightening policies. In Figure 26 we estimate that the forward guidance will decrease the two-quarter ahead output by 0.16 percent and the inflation by 0.24 annualized percentage points, and the LSAP will 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. The surprise decision by the FOMC not to taper its asset purchases seems to be correctly identified in my estimates: the easing LSAP shock together with easing forward guidance shock result in the 20 basis points drop of the 10-year yield, shown in Figure 27.

On December 18, 2013, the policy statement said 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 inflation continues to run below the Committee's 2 percent longer-run goal." Evidence shows the labor market had improved and as a result, the FOMC decided to begin tapering their monthly asset purchases. The new language on unemployment was probably added to prevent the market from moving up the date in which they expect the federal funds rate to rise. Figure 28 show that the overall effect is contractionary.

At its March 19, 2014 meeting, the Fed decided to drop the 6.5 percent unemployment threshold and pledged it would rely on a wide range of measures in deciding when to raise interest rates. The Fed also announced a further $10 billion cut in its monthly bond purchases. The tightening effects are shown in Figure 29.

The Fed ended its bond purchase program on October 29, 2014. However, in the meantime, the FOMC statement said, "The committee judges that it can be patient in beginning to normalize the stance of monetary policy", and "The committee sees this guidance as consistent with its previous statement". According to the response of the yield curve, the market takes this decision as an tightening policy, with a larger size of forward guidance effect shown in Figure 30.

5.2.7 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." Market expected that a hike in the federal funds rate would be coming after two meetings is possible, and moved, taken together, amounted to a vote of confidence that the economy were on track. [11] As shown in Figure 31, both forward guidance and LSAP are contractionary, and the overall effect is that the whole yield curve is 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. [12] 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 32.

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. Figure 33 showed the effects of expansionary forward guidance and LSAP shocks.

Finally, on December 16, 2015, the FOMC raised the target range for the federal funds rate to 1/4 to 1/2 percent. The tightening effect is shown in Figure 34 with a bigger component of forward guidance compared to LSAP.

Given their effects on the output and inflation discussed in previous section, we can conclude that in most announcement days, LSAP are more effective on output, while forward guidance is more effective on inflation in the short run.

6 Discussion

We 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.

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

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

6.1 Role of the Initial Demand Shock

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

Keeping everything else the same, Figure 35 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.

6.2 Role of Normalization

We 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. We illustrate how our estimate of the initial aggregate demand shock affects our main results. Keeping everything else the same, Figure 36 shows how the difference in yield curve varies when the normalization of one unit LSAP shock changes from 3 bps to 10 bps. Figure 37 plots the separate contribution of forward guidance and LSAP shocks. The main results change barely when we use different normalization.

6.3 Effects of Forward Guidance Shock Persistence

The persistence of forward guidance shock is set to be 0.65 in the baseline model. Figure 38 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.

6.4 Effects of Forward Guidance Shock Horizon

The baseline model assumes forward guidance is effective for 7 quarters. Figure 39 shows how the difference in yield curve varies when the persistence of forward guidance shock increases from 5 to 8.

7 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 16 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, we 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 all the announcement dates we find that forward guidance was more effective at inflation, while LSAP was more important in influencing output.

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Table 1: Key features of the data

Key features		Data	GK	My paper
Steady state				
	10-y - 2-y real rate	69 bp	33 bp	69 bp
	inflation rate		0	2.4 percent
ZLB behavior				
	initial shock's effect on 10-y rate	around -200 bp	+51.6 bp	-4 bp
	avg. shadow rate	-121 bp		-121bp

Table 2: Parameter Values

	symbol	value	meaning	value in GK	meaning
(A)					
	δ	0.025	depreciation rate		
	α	0.33	capital share in production function		
	γ	0.779	Calvo price-setting, resets every 13.6 months		
	γ^P	0	inflation indexation		
	G_{ss}/Y	0.2	steady state government spending-GDP ratio		
	Ł_{ss}	1/3	steady state labor supply		
	ϕ_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)					
	β	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	
	θ	0.956	survival rate of the bankers, 5.7 years	0.9715	8.77 years
	$R_{k,ss} - R_{ss}$	1.73	steady state excess return on capital, annu. pp.	1	
	Δ	0.6	prop. advantage of gov. debt over divertible capital	0.5	
	ϕ	5	steady state leverage ratio	4, 6	
	λ	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	
	κ_s	28	elasticity for hh. holdings of capital	1	
	κ_b	2	elasticity for hh. holdings of bonds	1	
	ρ_{1b}	1.4	AR(2) process governing LSAP	1.5	
	ρ_{2b}	-.49	AR(2) process governing LSAP	-0.55	
(C)					
	h	0.615	habit persistent	0.815	
	φ	1/2	Frisch elasticity of labor supply $=1/\varphi=1$	0.276	3.6
	ϵ	6	price mark-up 20%	4.167	31.58%
	η_i	4.5	quadratic investment cost parameter	1.728	
	ϕ_π	2.5	response of monetary policy to inflation	1.5	
(D)					
	ρ_z	0.65	AR(1) process governing forward guidance		

Table 3: 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
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
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 4: 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 5: 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 6: 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 7: 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 8: "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 9: 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 10: 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-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	27.51	3.94	29.96	-0.34	-1.07	-0.51	-0.88

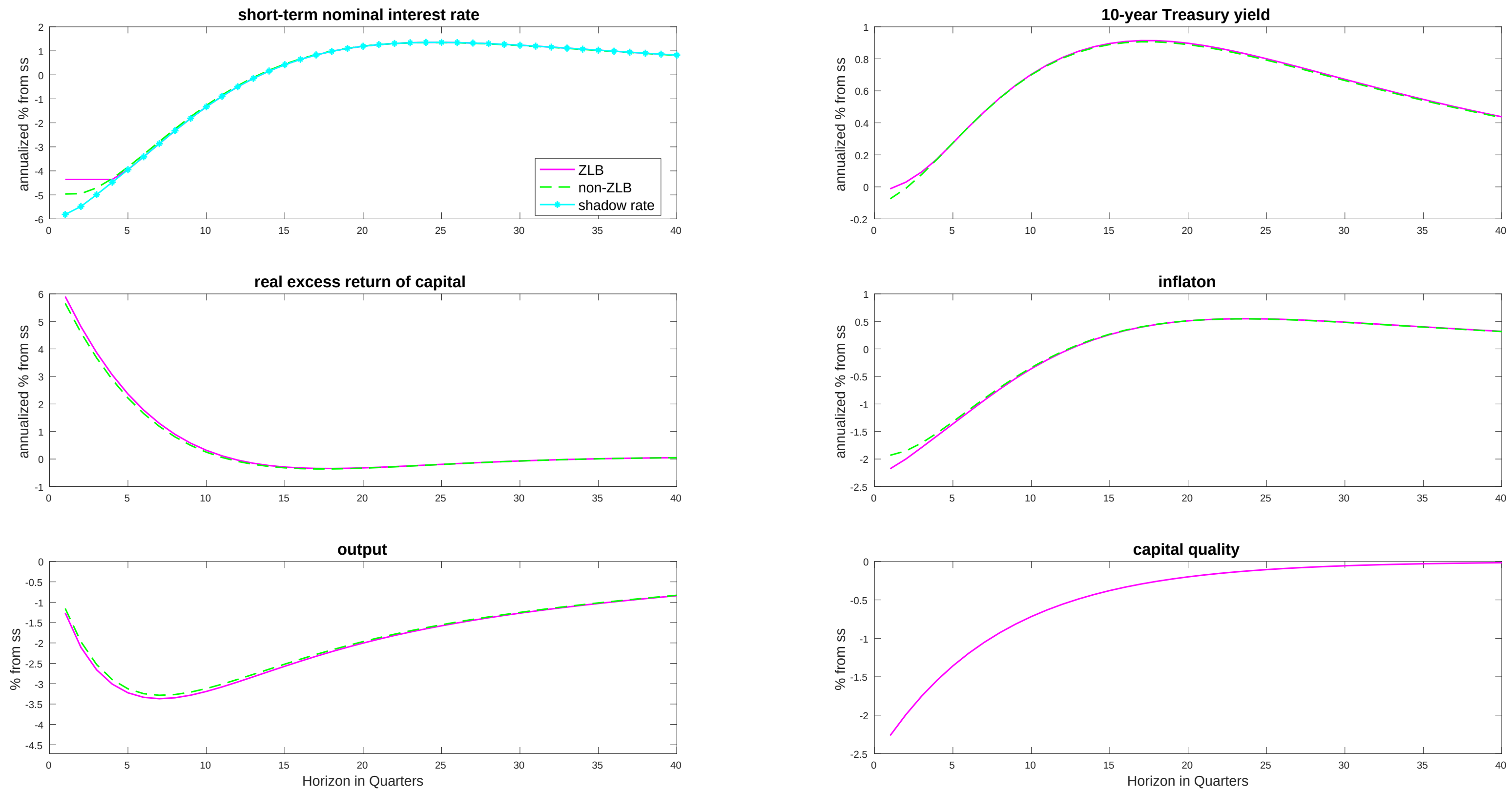
NOTES: Columns 2 to 4 show the decomposition of the change of 10-year Treasury yield $\triangle i_{10,t}$ (in annualised basis points) into the contribution of forward guidance and LSAP. Columns 5 to 8 show the effects of forward guidance and LSAP on 2-quarter ahead output and annualized inflation rate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

Table 11: 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

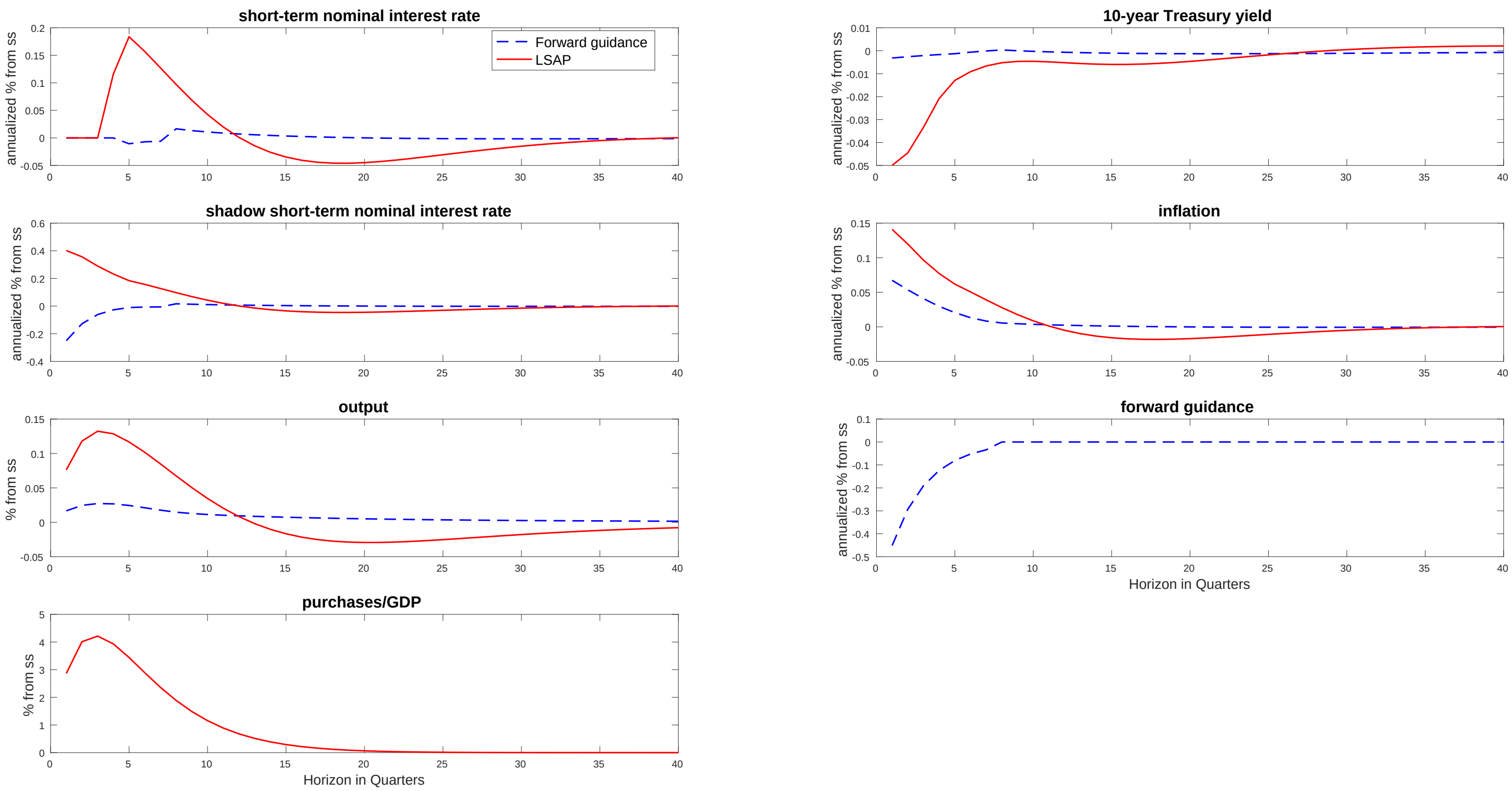
NOTES: Columns 2 to 4 show the decomposition of the change of 10-year Treasury yield $\triangle i_{10,t}$ (in annualised basis points) into the contribution of forward guidance and LSAP. Columns 5 to 8 show the effects of forward guidance and LSAP on 2-quarter ahead output and annualized inflation rate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

Figure 1: Crisis Experiment



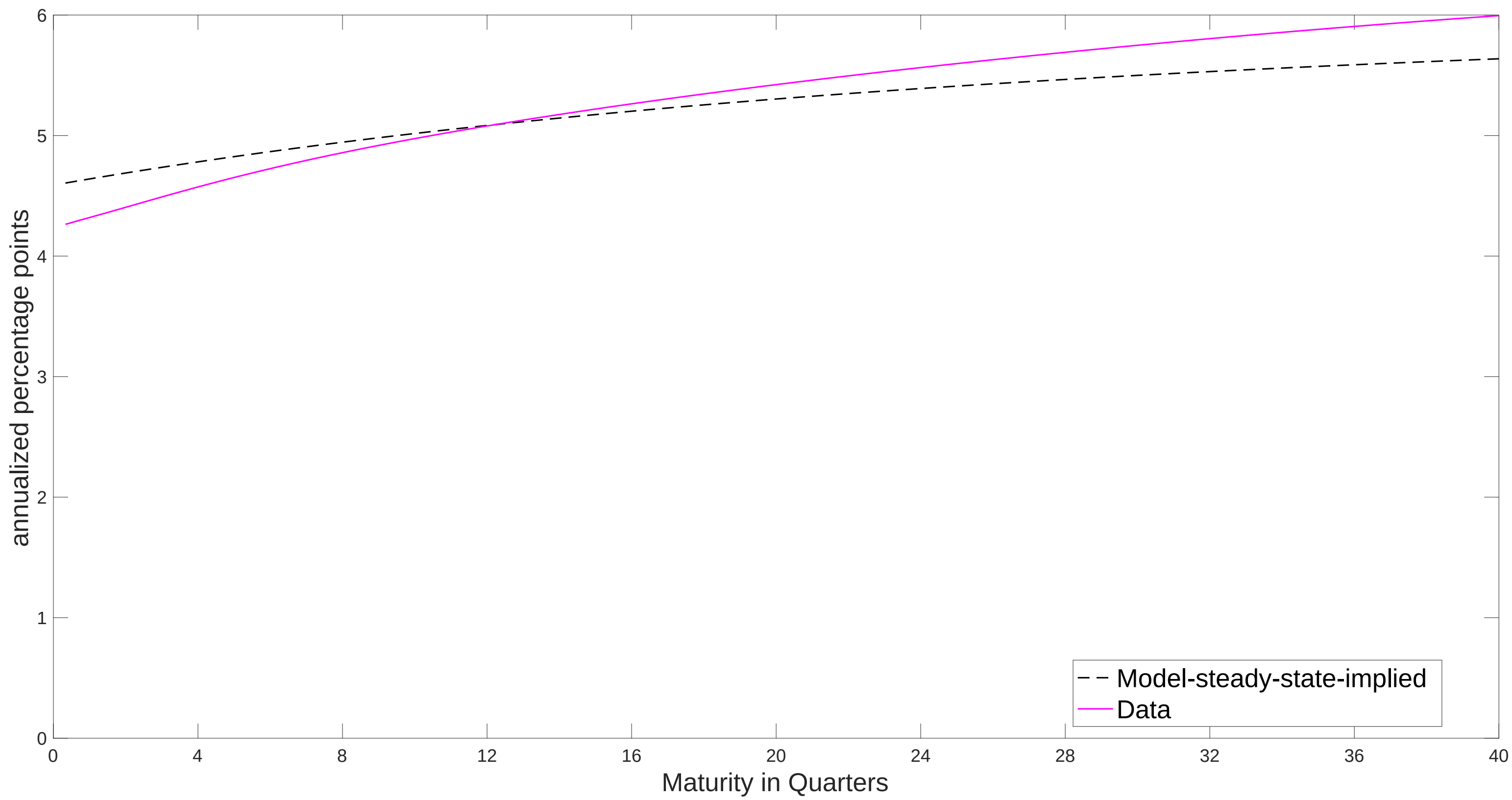
NOTES: Impulse responses to unexpected capital quality shock with and without the zero lower bound constraint. Shadow nominal interest rate is also plotted (solid cyan starred line).

Figure 2: Effects of Forward Guidance and LSAP Shocks



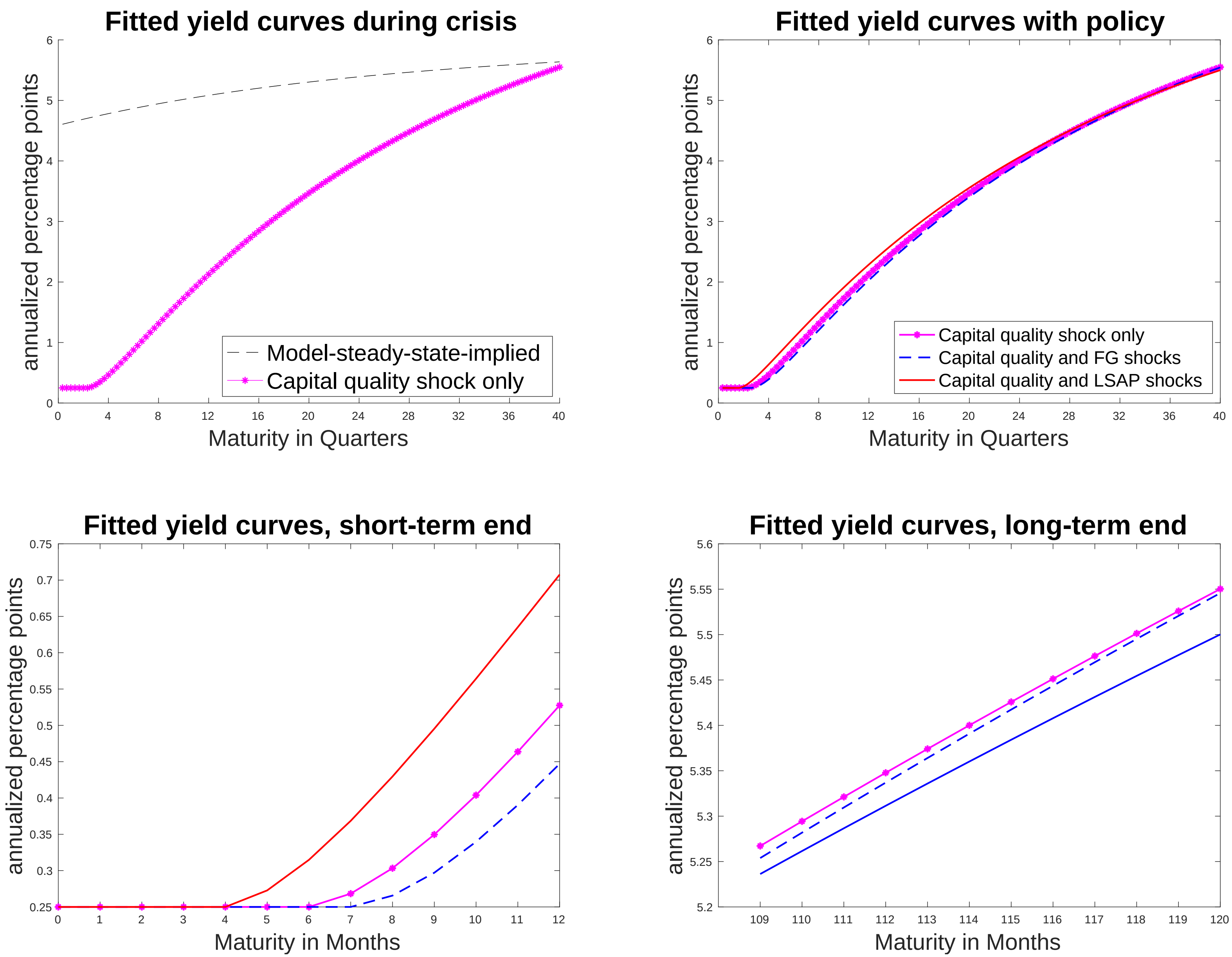
NOTES: Plot of the differences of the impulse responses from a no-policy-response case.

Figure 3: Observed and Fitted Yield Curves During Pre-ZLB period



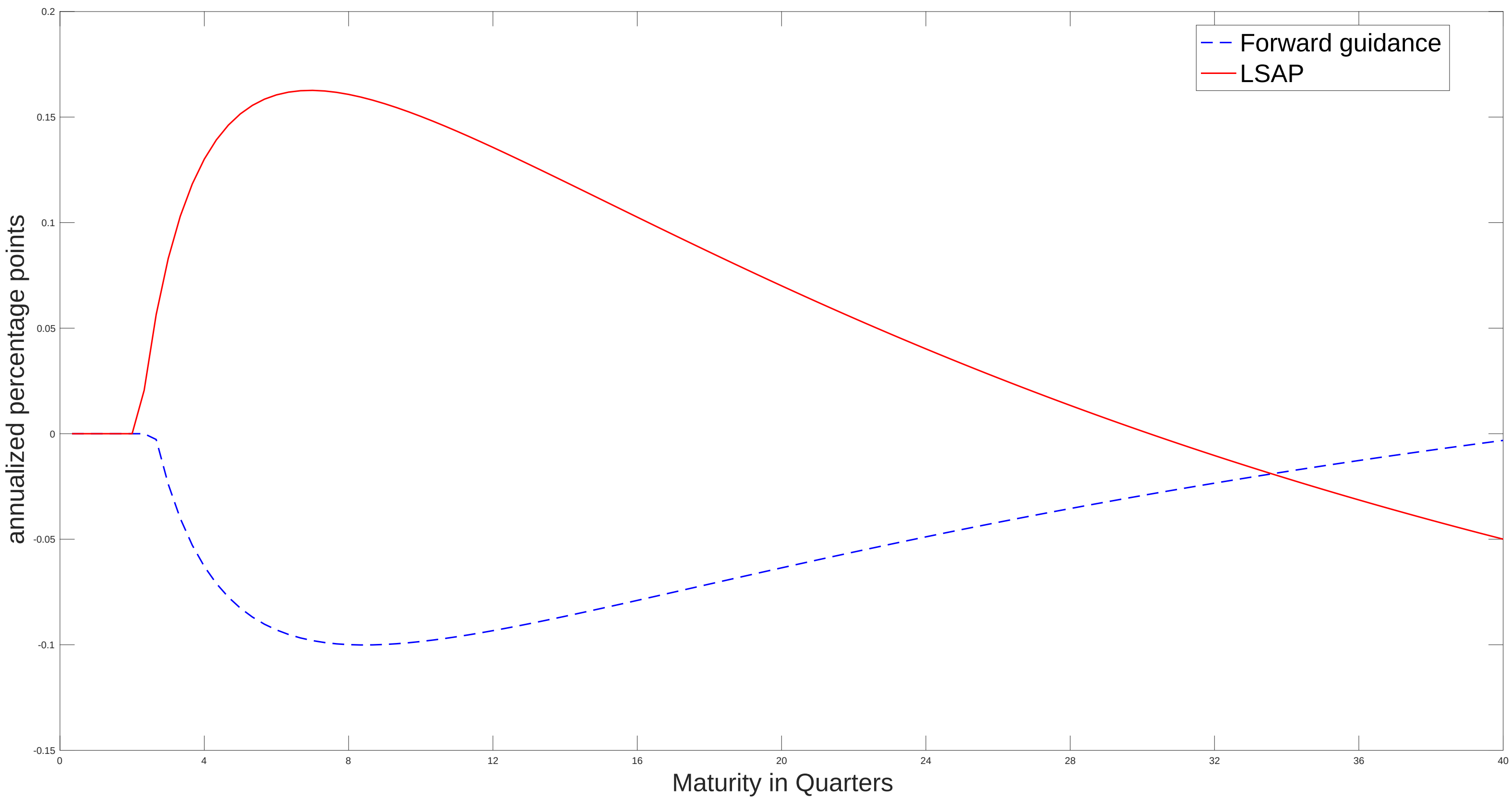
NOTES: Plot of the yield curves in the model steady state (blue dashed line) and the data (red solid line).

Figure 4: Fitted Yield Curves During Crisis



NOTES: There are three scenarios: (i) capital quality shock without central bank response (solid blue line with stars), (ii) capital quality shock with forward guidance (dashed blue line) (iii) capital quality shock with LSAP (solid red line). Upper left panel plots the scenario (i), and the upper right panel compares these three scenarios. The lower panels plot the short-term end and long-term end of the yield curves under three scenarios.

Figure 5: Difference Between Fitted Yield Curves



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

Figure 6: Estimated Size of Each Shock Type

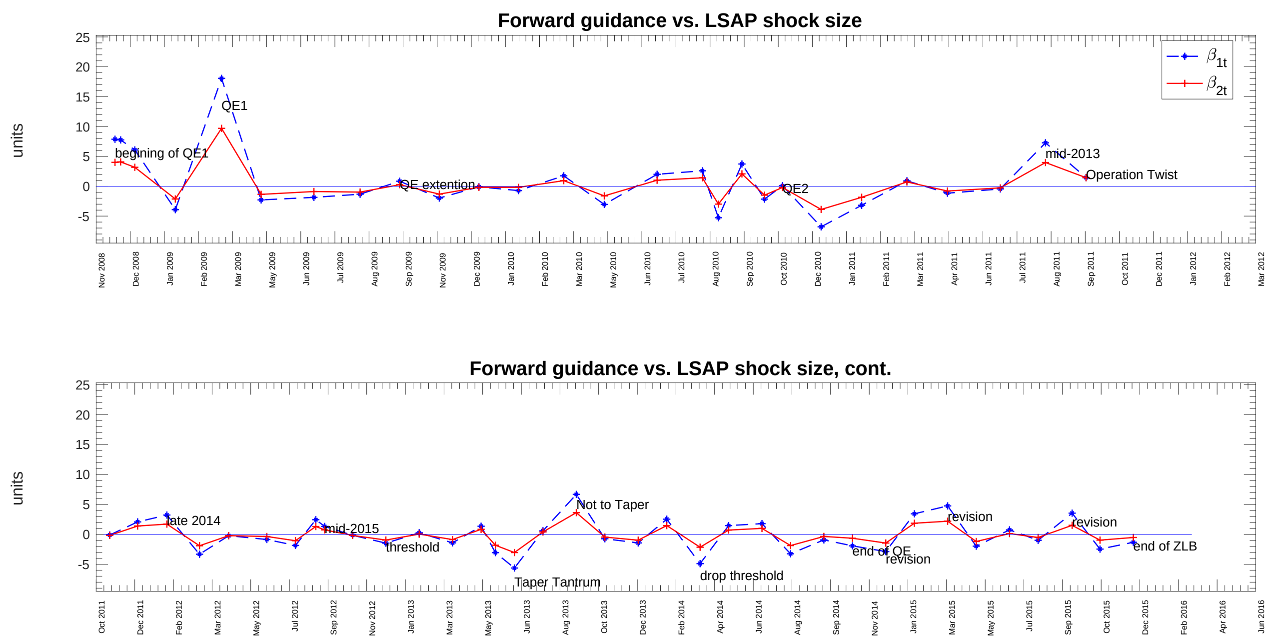
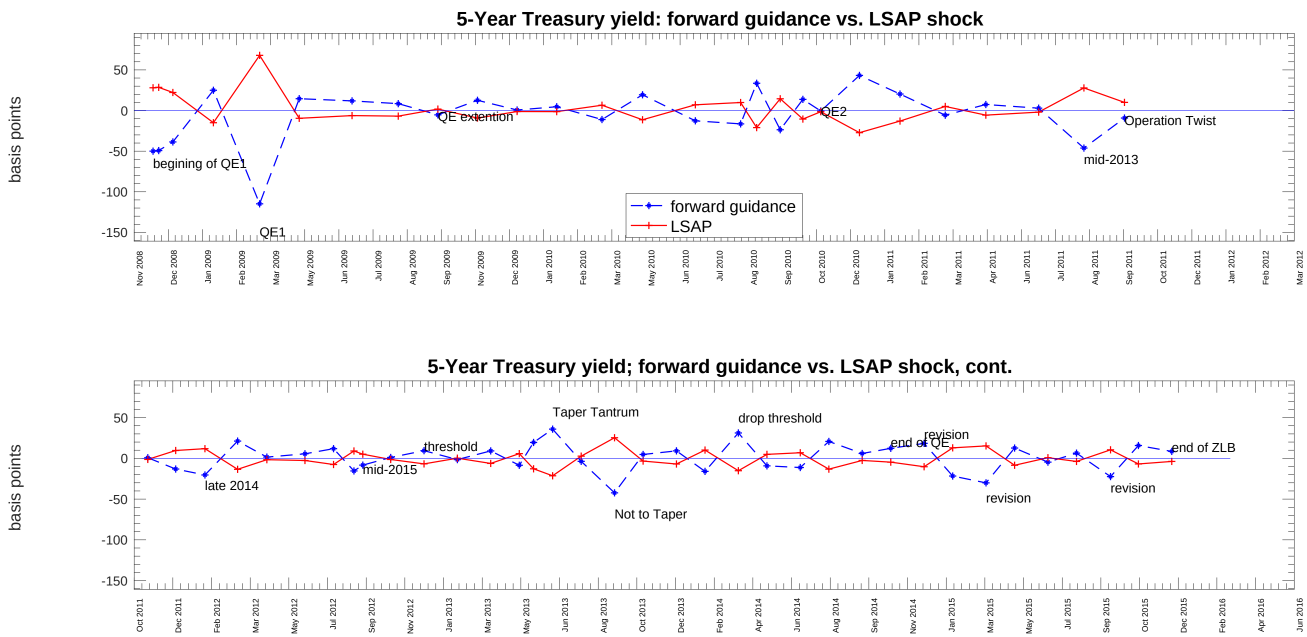
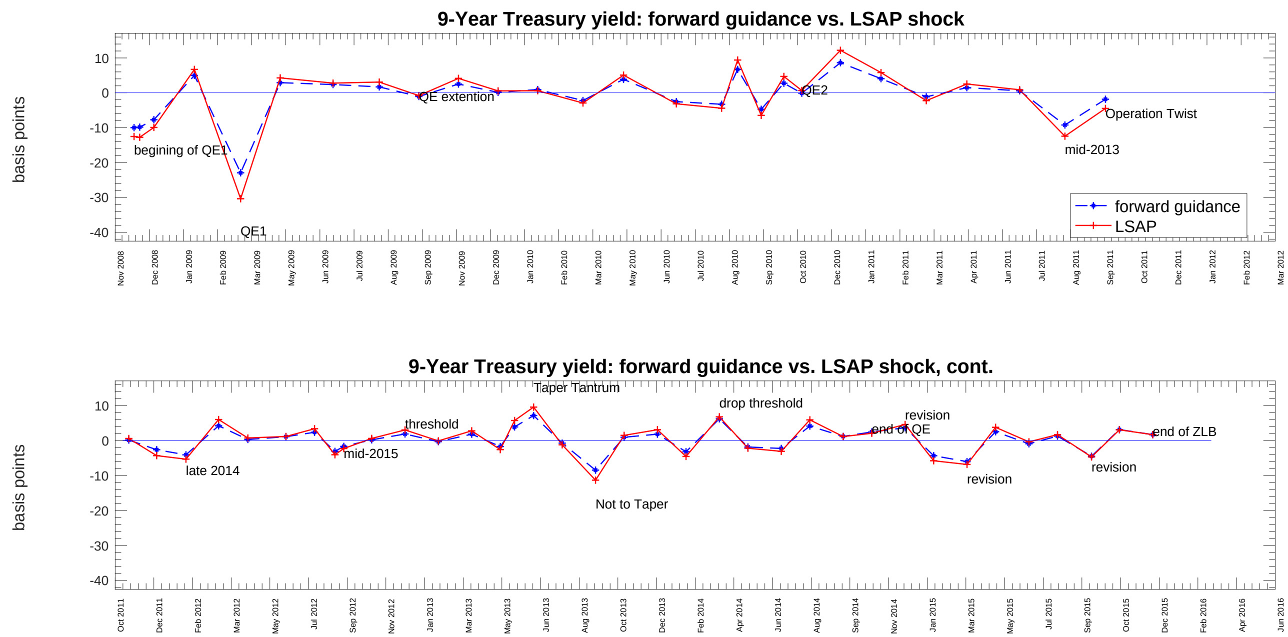


Figure 7: Estimated Effects on 5-year Treasury Yield



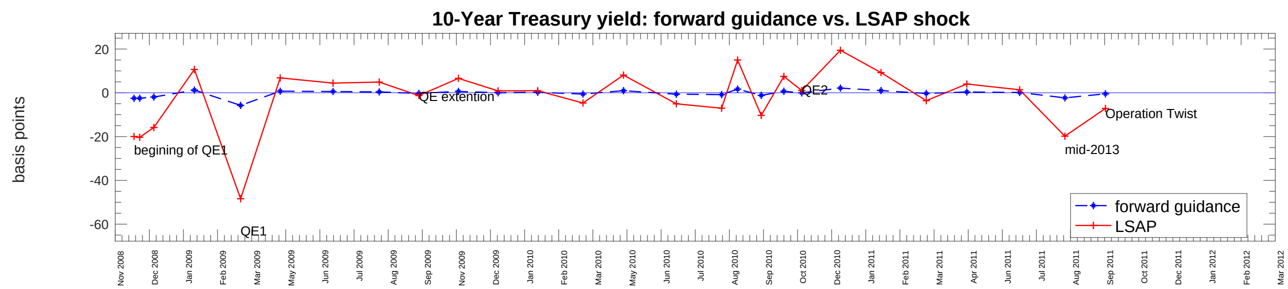
NOTES: Plot of estimated forward guidance (dashed blue line) and LSAP (solid red line) factors for 5-year Treasury yield for all the event dates. Notable announcements are labeled in the figure for reference. See text for details.

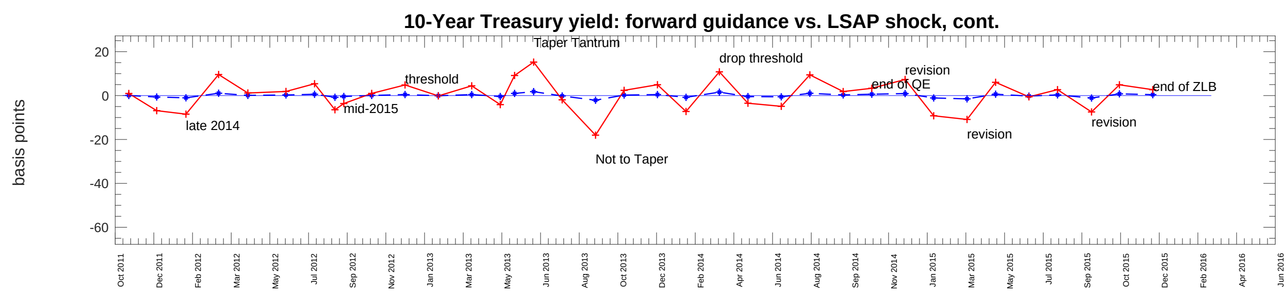
Figure 8: Estimated Effects on 9-year Treasury Yield



NOTES: Plot of estimated forward guidance (dashed blue line) and LSAP (solid red line) factors for 9-year Treasury yield for all the event dates. Notable announcements are labeled in the figure for reference. See text for details.

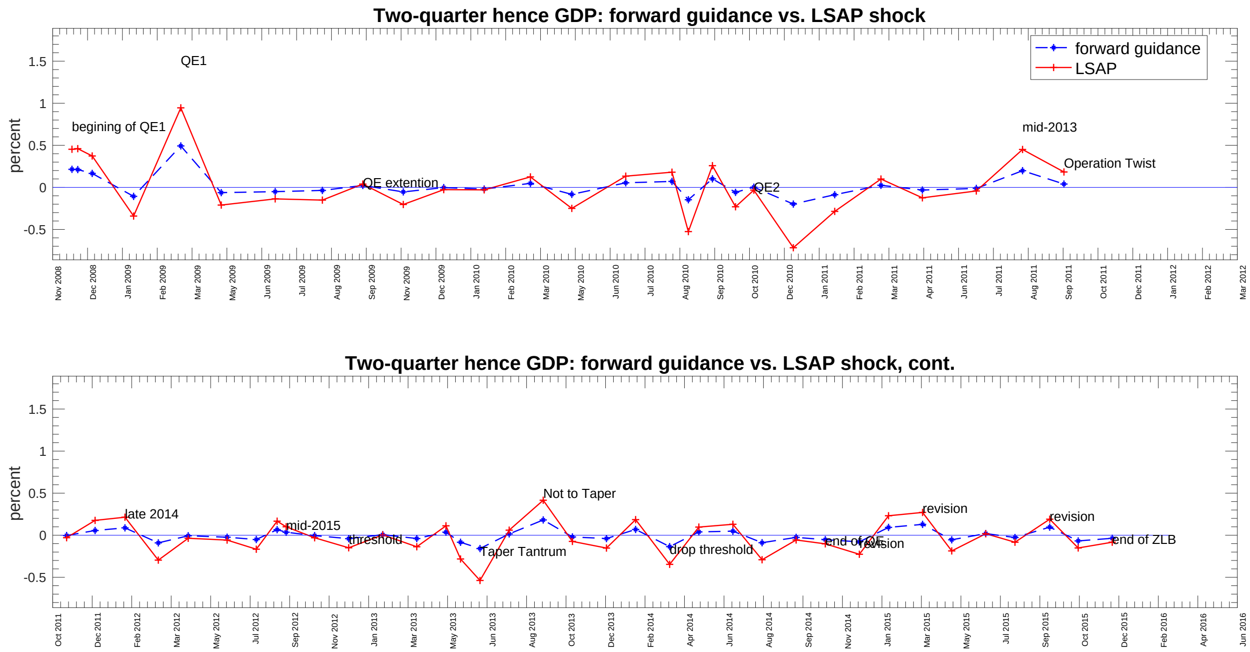
Figure 9: Estimated Effects on 10-year Treasury Yield





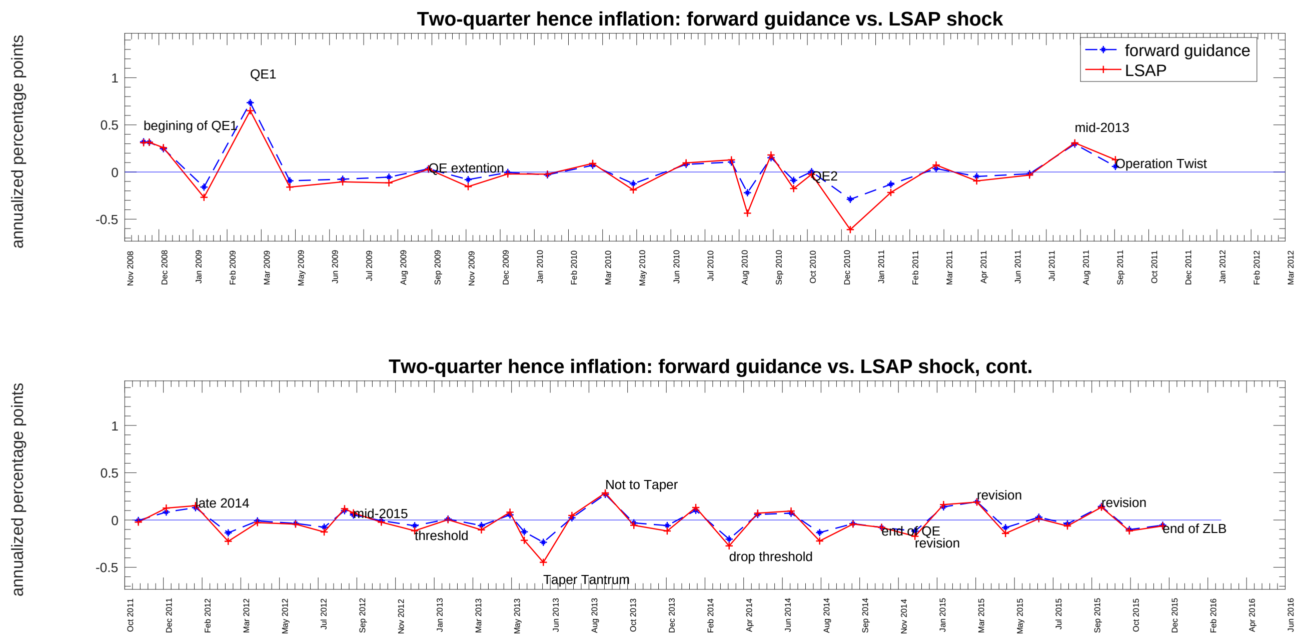
NOTES: Plot of estimated forward guidance (dashed blue line) and LSAP (solid red line) factors for 10-year Treasury yield for all the event dates. Notable announcements are labeled in the figure for reference. See text for details.

Figure 10: Estimated Effect on Two-quarter Hence GDP



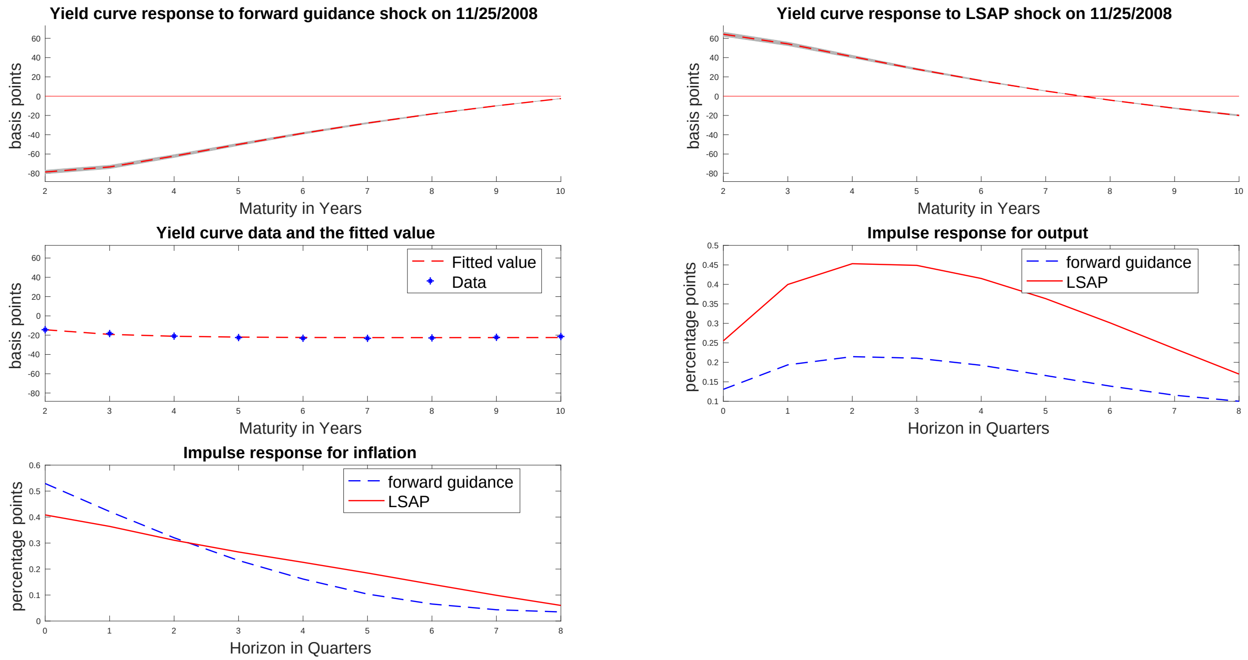
NOTES: Plot of estimated effect of forward guidance (dashed blue line) and LSAP (solid red line) policies on two-quarter hence GDP for all the event dates. Notable announcements are labeled in the figure for reference. See text for details.

Figure 11: Estimated Effect on Two-quarter Hence Inflation



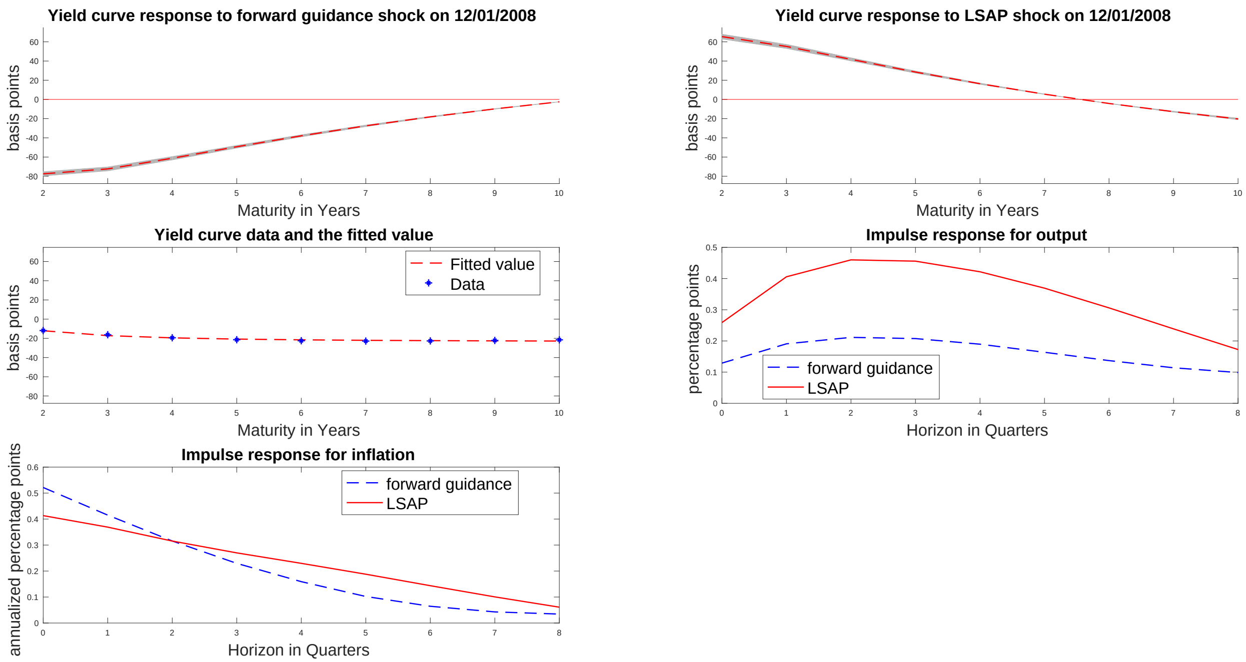
NOTES: Plot of estimated effect of forward guidance (dashed blue line) and LSAP (solid red line) policies on two-quarter hence inflation for all the event dates. Notable announcements are labeled in the figure for reference. See text for details.

Figure 12: Estimated Effects on 11/25/2008



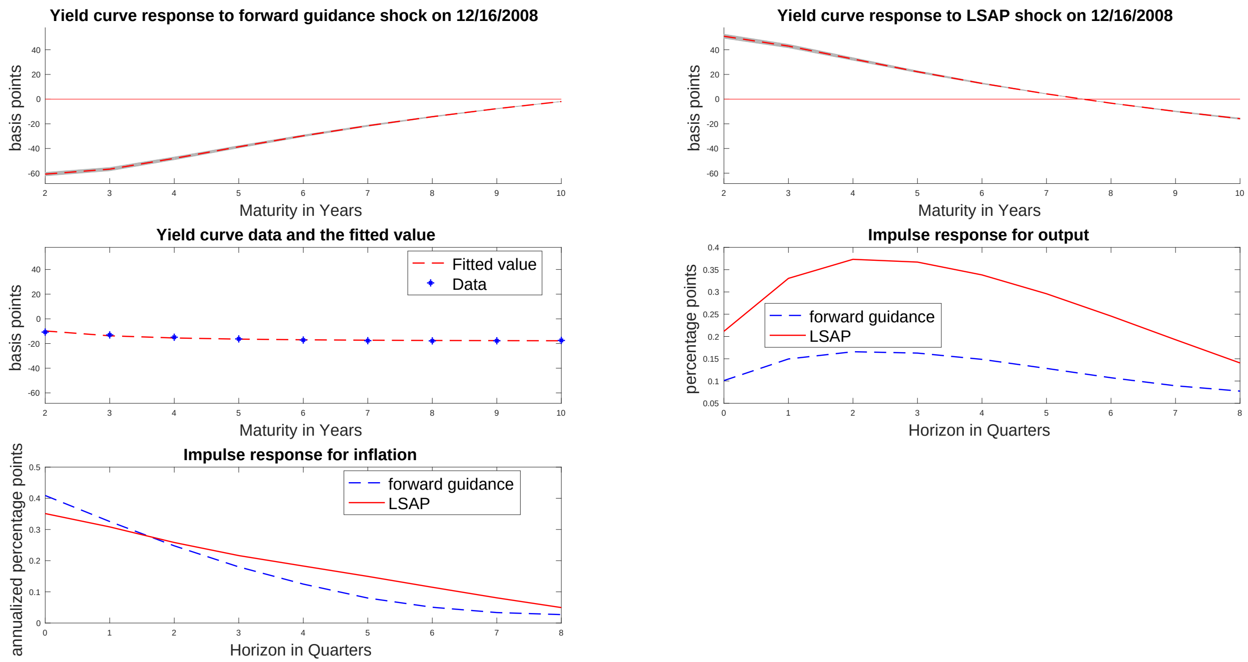
NOTES: Estimated effects on Treasury yield curve on Nov. 25, 2008. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value.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

Figure 13: Estimated Effects on 12/01/2008



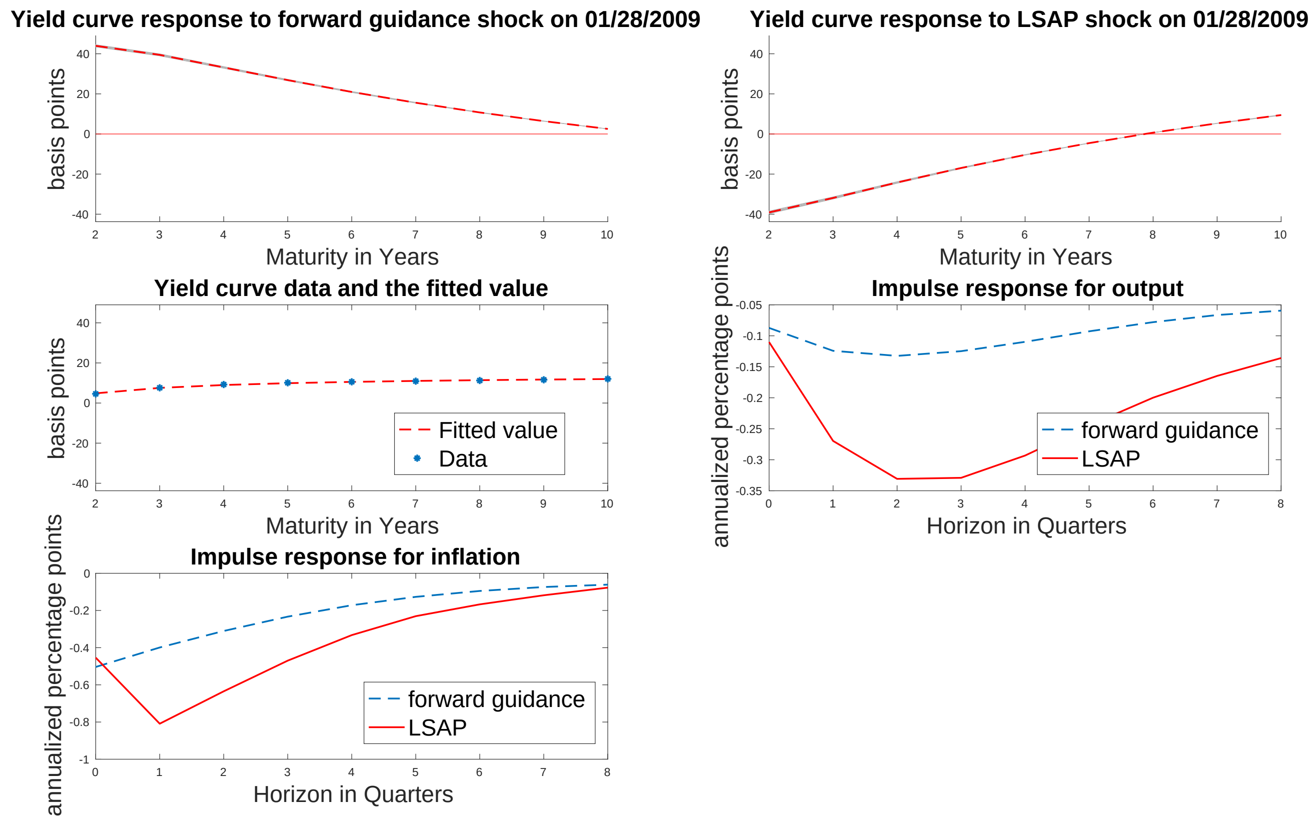
NOTES: Estimated effects on Treasury yield curve on Dec. 01, 2008. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 14: Estimated Effects on 12/16/2008



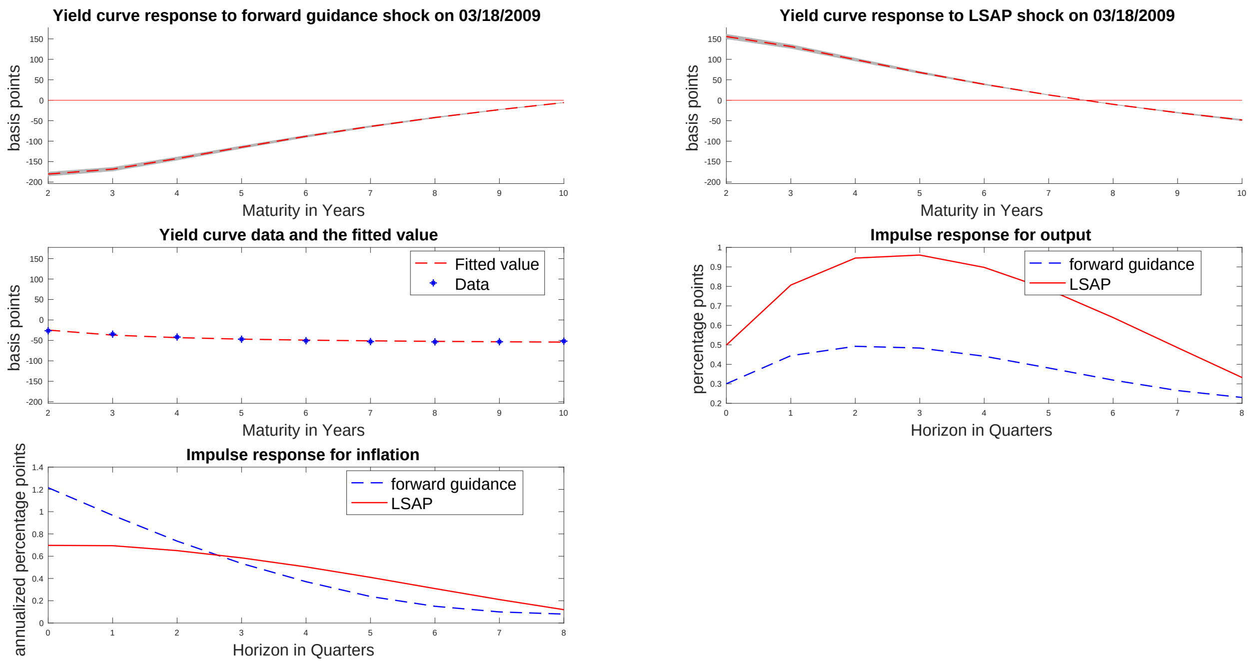
NOTES: Estimated effects on Treasury yield curve on Dec. 16, 2008. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value.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

Figure 15: Estimated Effects on 01/28/2009



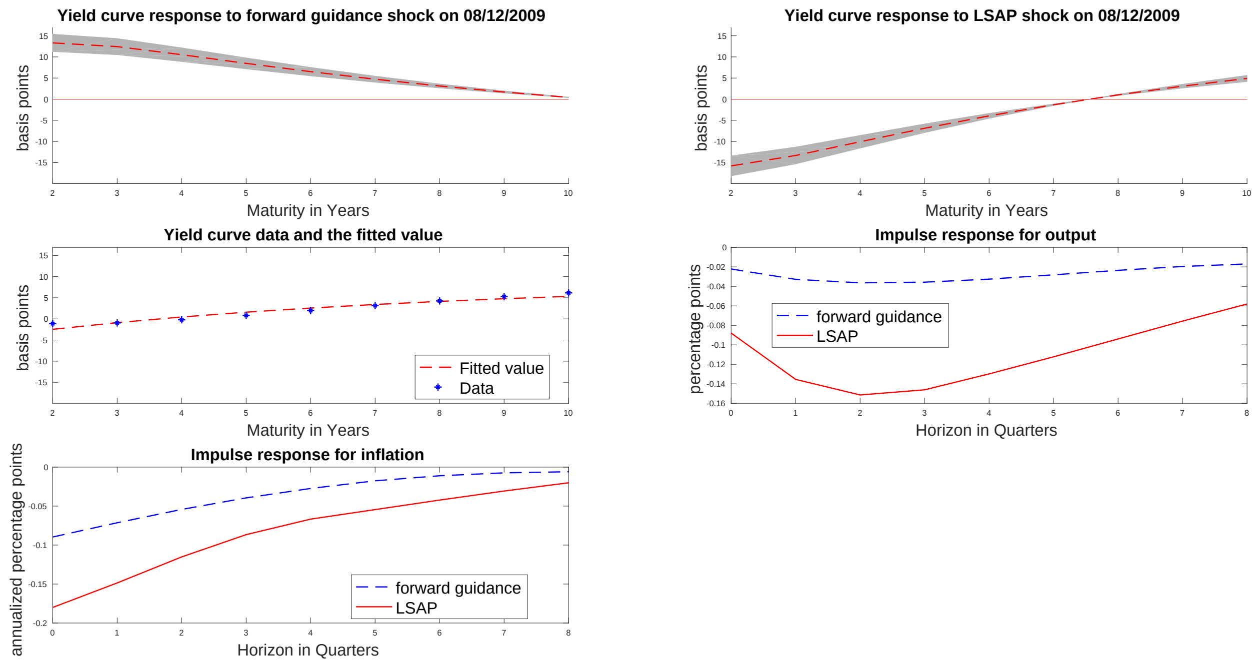
NOTES: Estimated effects on Treasury yield curve on Jan. 28, 2009. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value.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

Figure 16: Estimated Effects on 03/18/2009



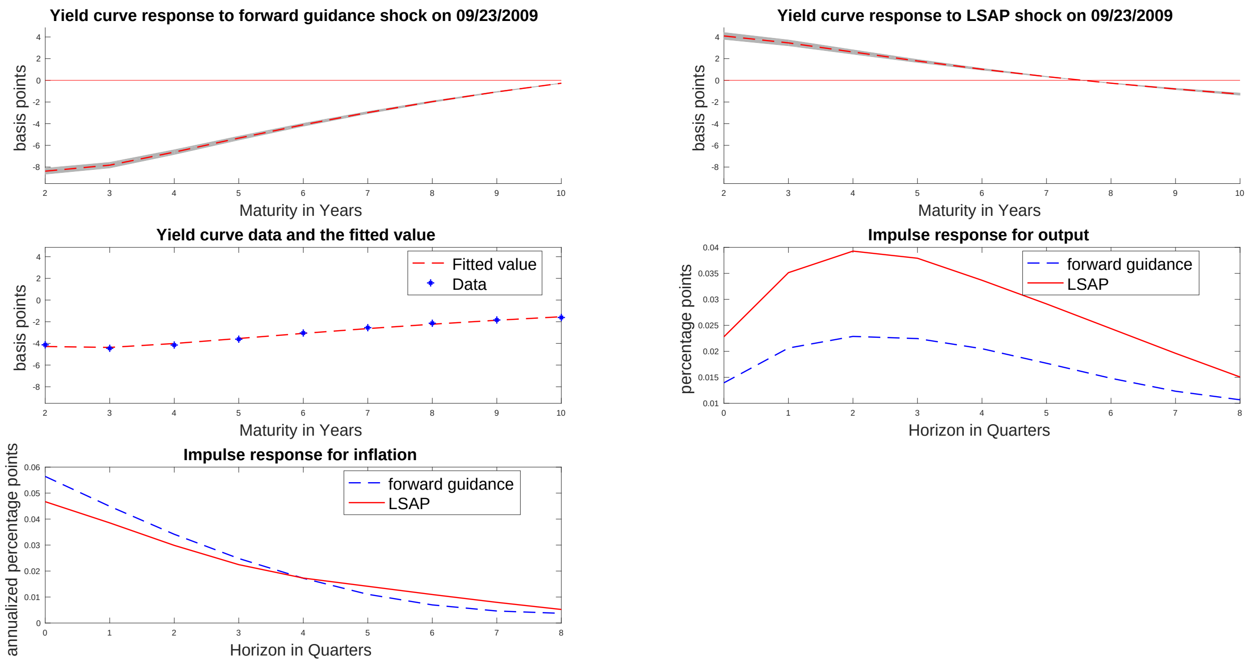
NOTES: Estimated effects on Treasury yield curve on March 18, 2009. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 17: Estimated Effects on 08/12/2009



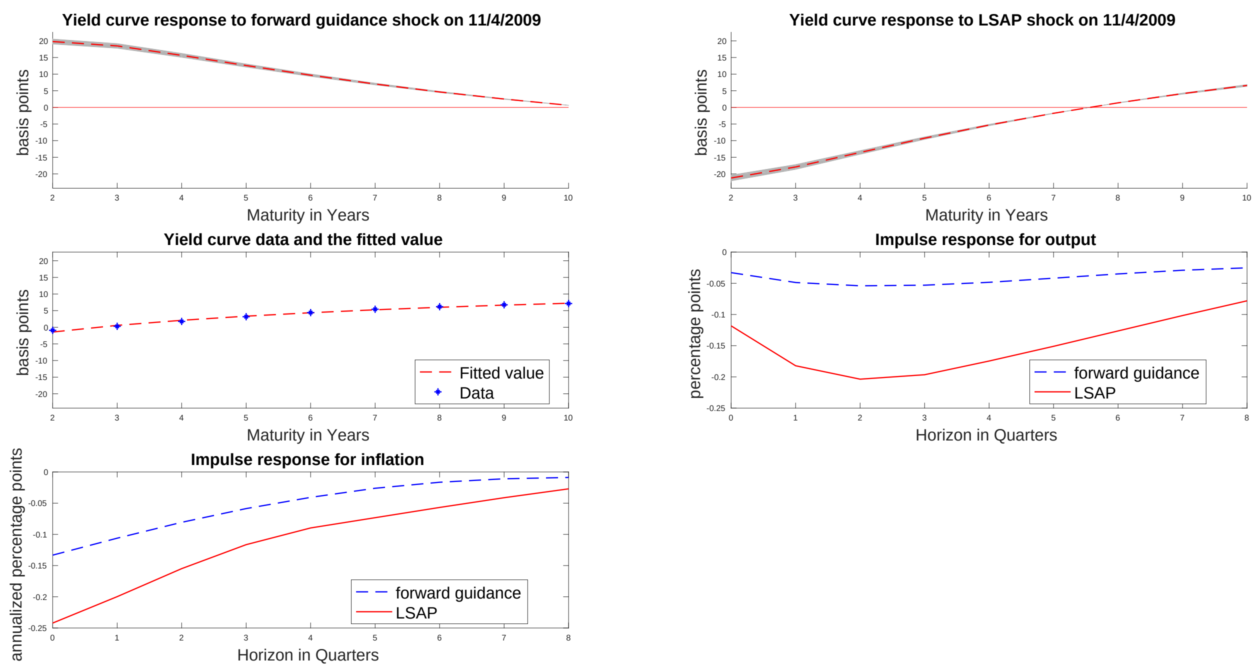
NOTES: Estimated effects on Treasury yield curve on Aug. 12, 2009. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 18: Estimated Effects on 09/23/2009



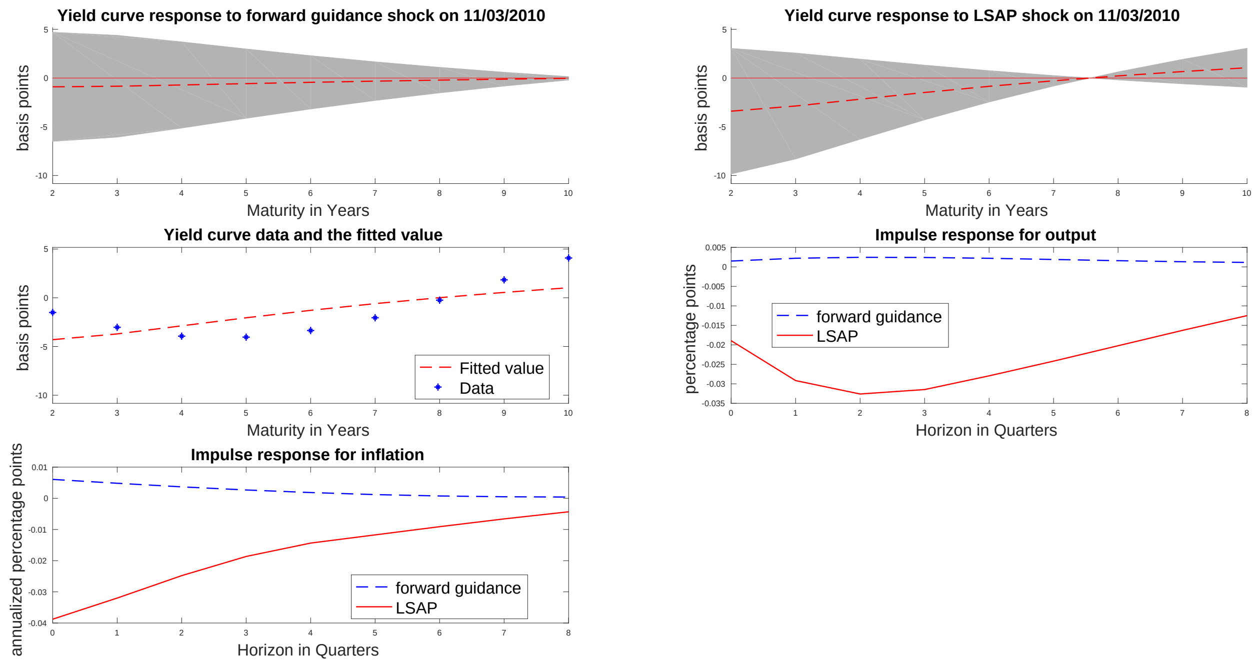
NOTES: Estimated effects on Treasury yield curve on Sept. 23, 2009. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 19: Estimated Effects on 11/04/2009



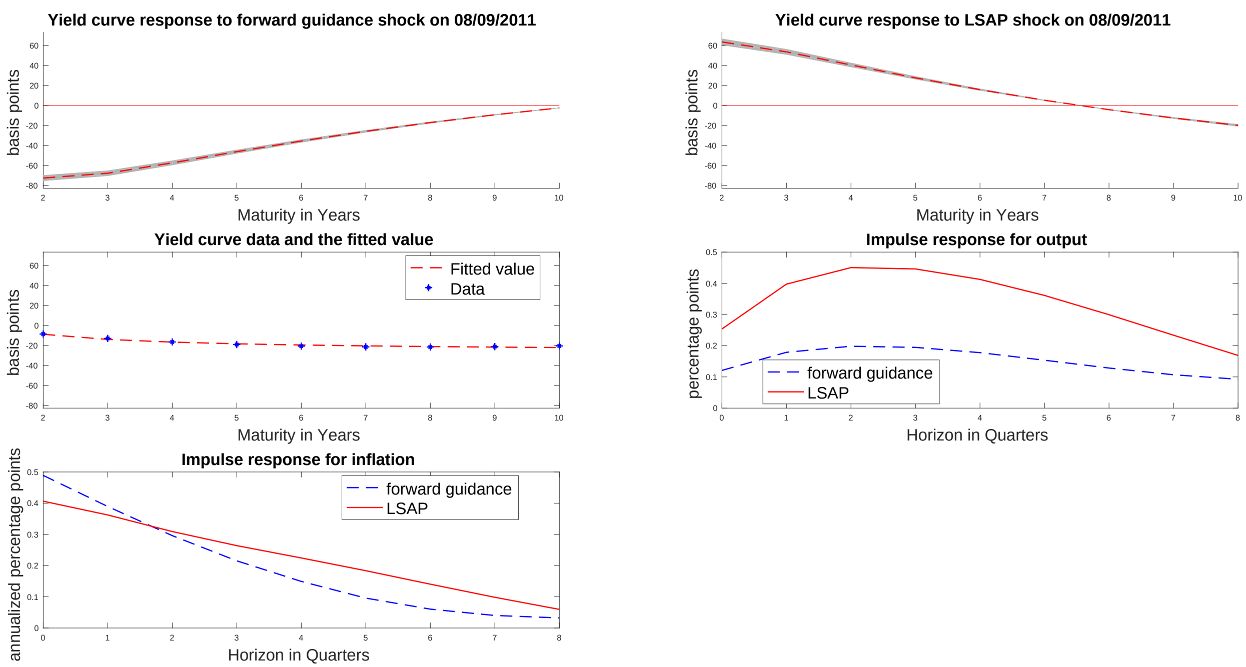
NOTES: Estimated effects on Treasury yield curve on Nov. 4, 2009. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 20: Estimated Effects on 11/03/2010



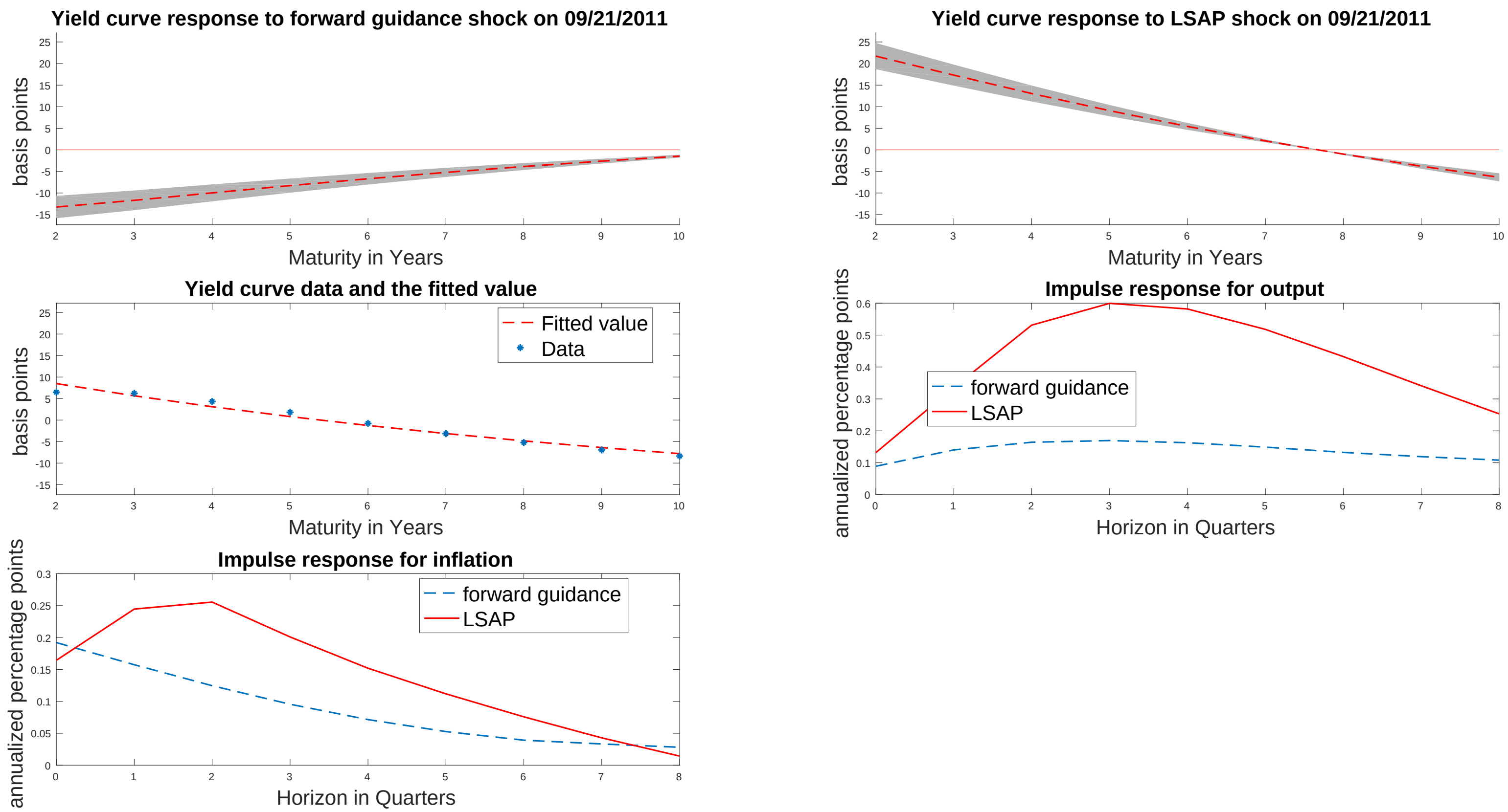
NOTES: Estimated effects on Treasury yield curve on Nov. 3, 2010. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 21: Estimated Effects on 08/09/2011



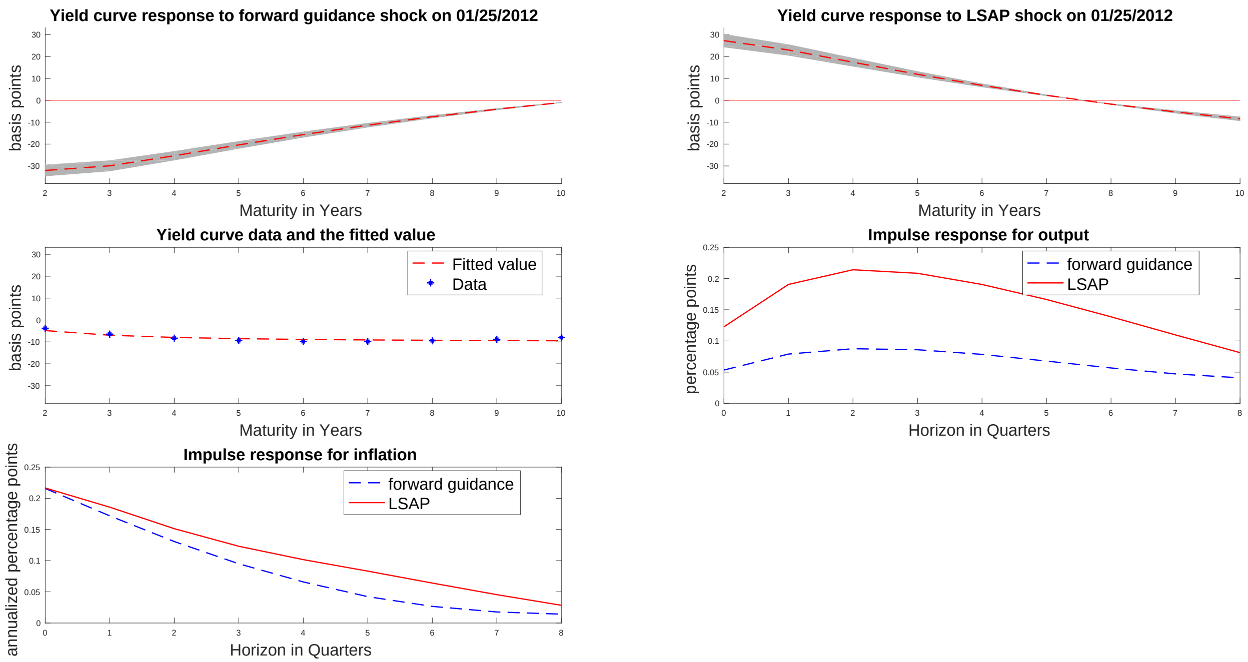
NOTES: Estimated effects on Treasury yield curve on Aug. 9, 2011. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value.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

Figure 22: Estimated Effects on 09/21/2011



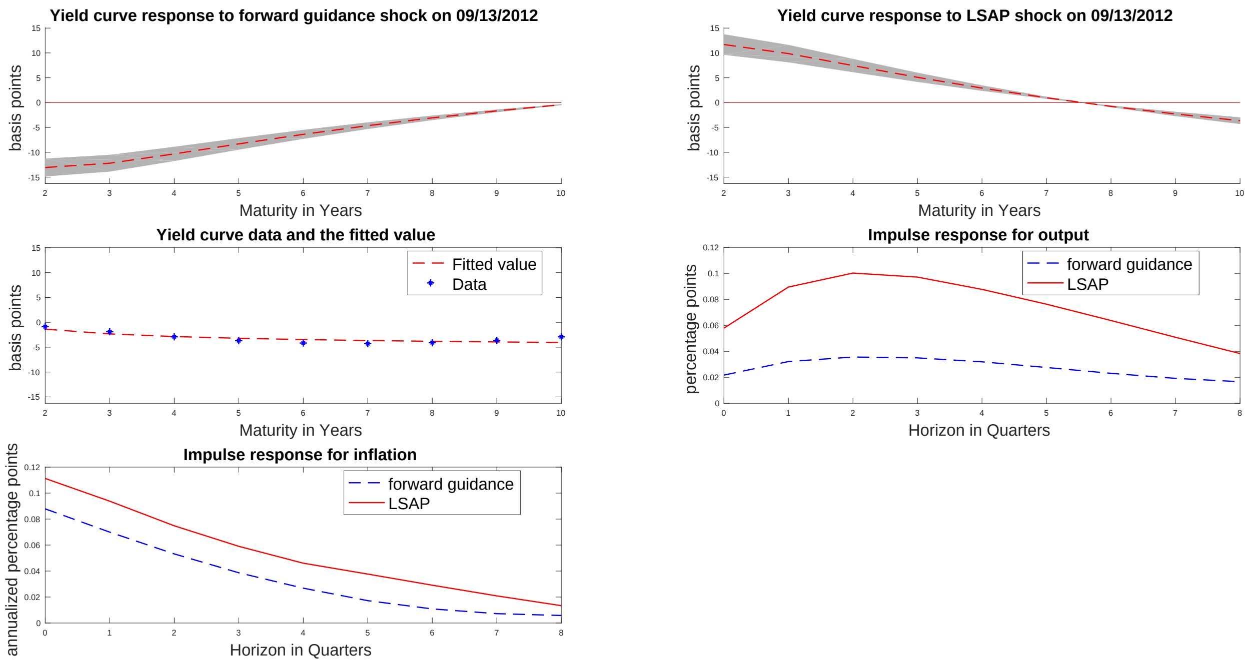
NOTES: Estimated effects on Treasury yield curve on Sept. 21, 2011. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value.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

Figure 23: Estimated Effects on 01/25/2012



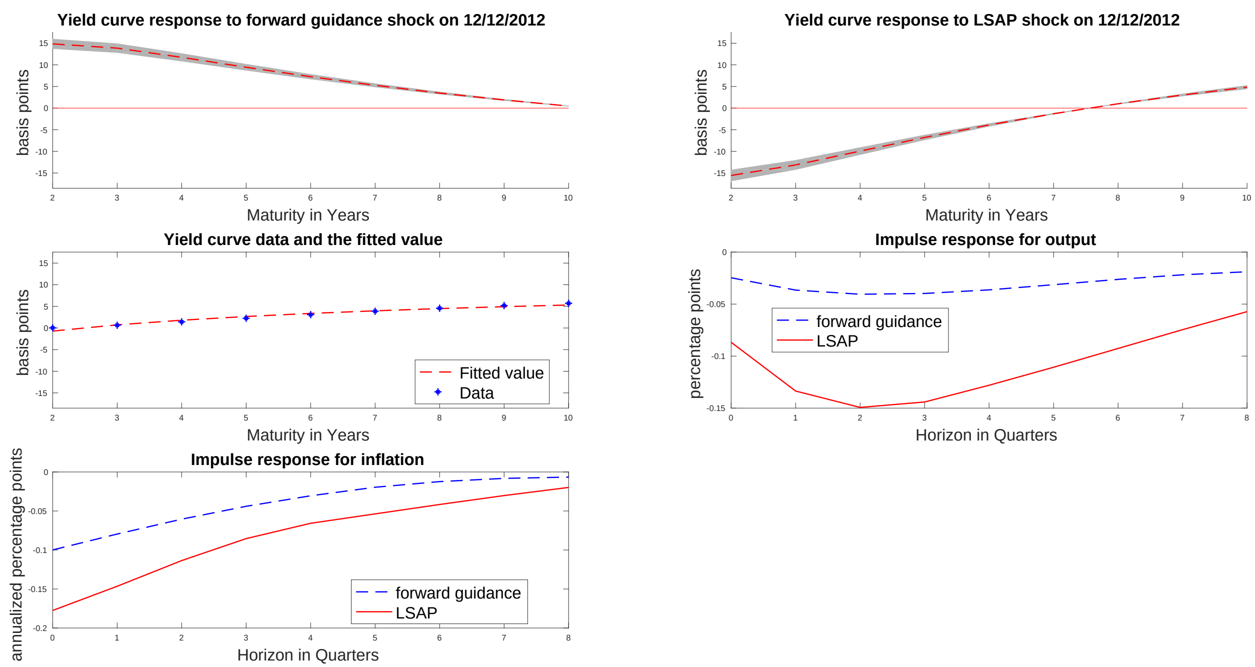
NOTES: Estimated effects on Treasury yield curve on Jan. 25, 2012. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 24: Estimated Effects on 09/13/2012



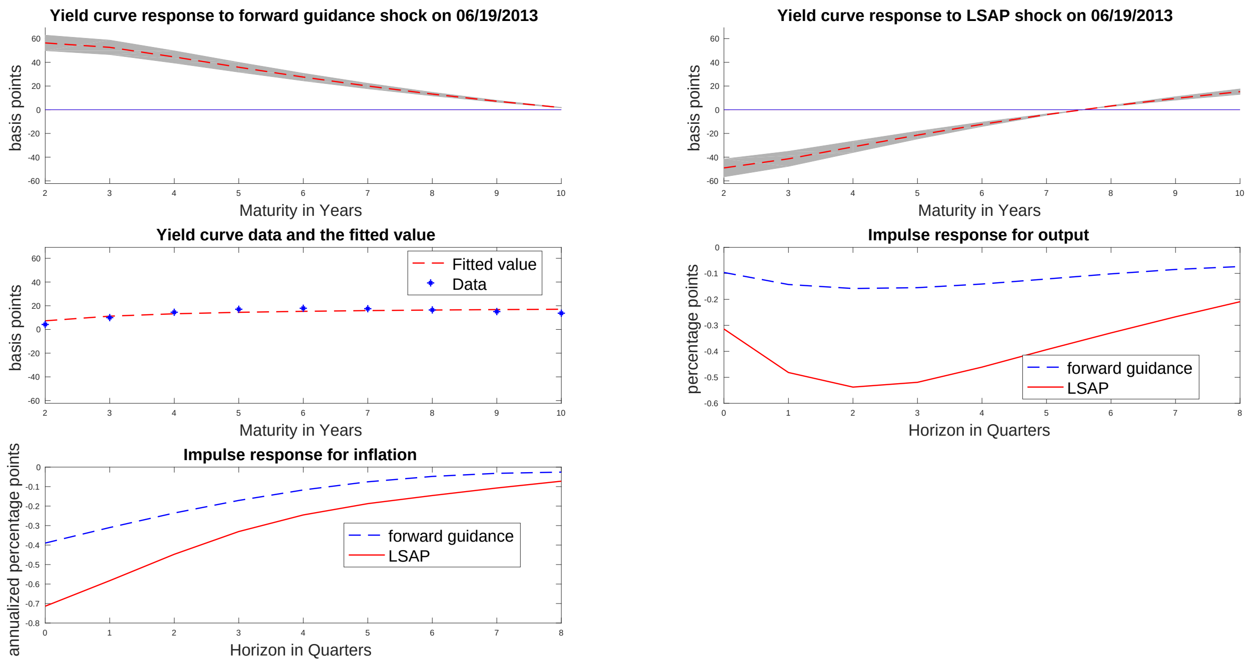
NOTES: Estimated effects on Treasury yield curve on Sept. 13, 2012. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 25: Estimated Effects on 12/12/2012



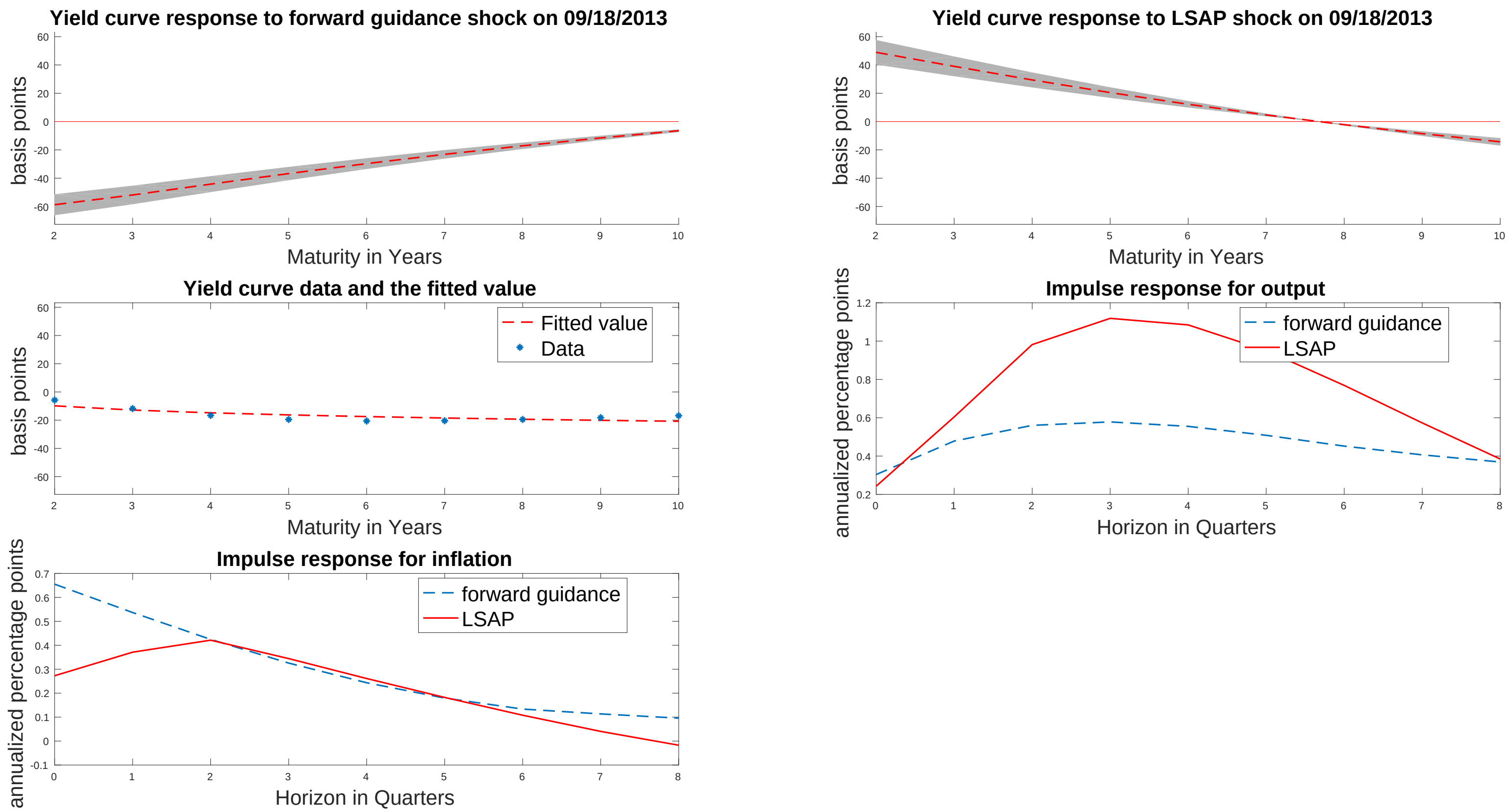
NOTES: Estimated effects on Treasury yield curve on Dec. 12, 2012. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 26: Estimated Effects on 06/19/2013



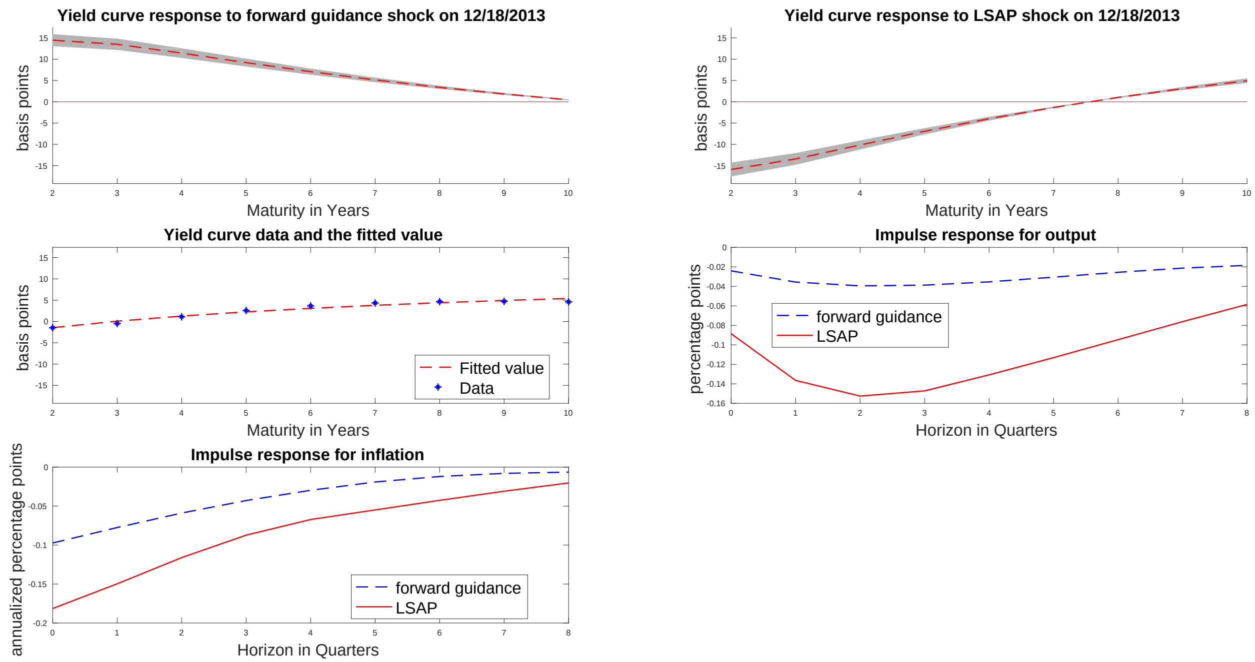
NOTES: Estimated effects on Treasury yield curve on June 19, 2013. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value.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

Figure 27: Estimated Effects on 09/18/2013



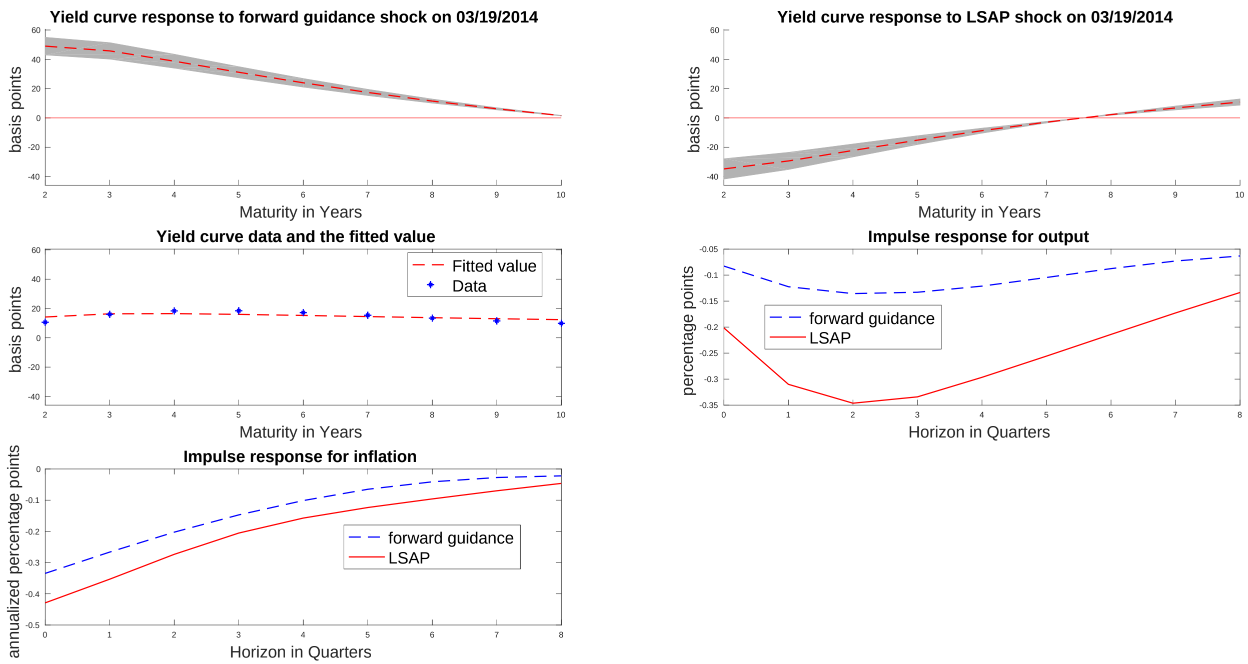
NOTES: Estimated effects on Treasury yield curve on Sept. 18, 2013. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 28: Estimated Effects on 12/18/2013



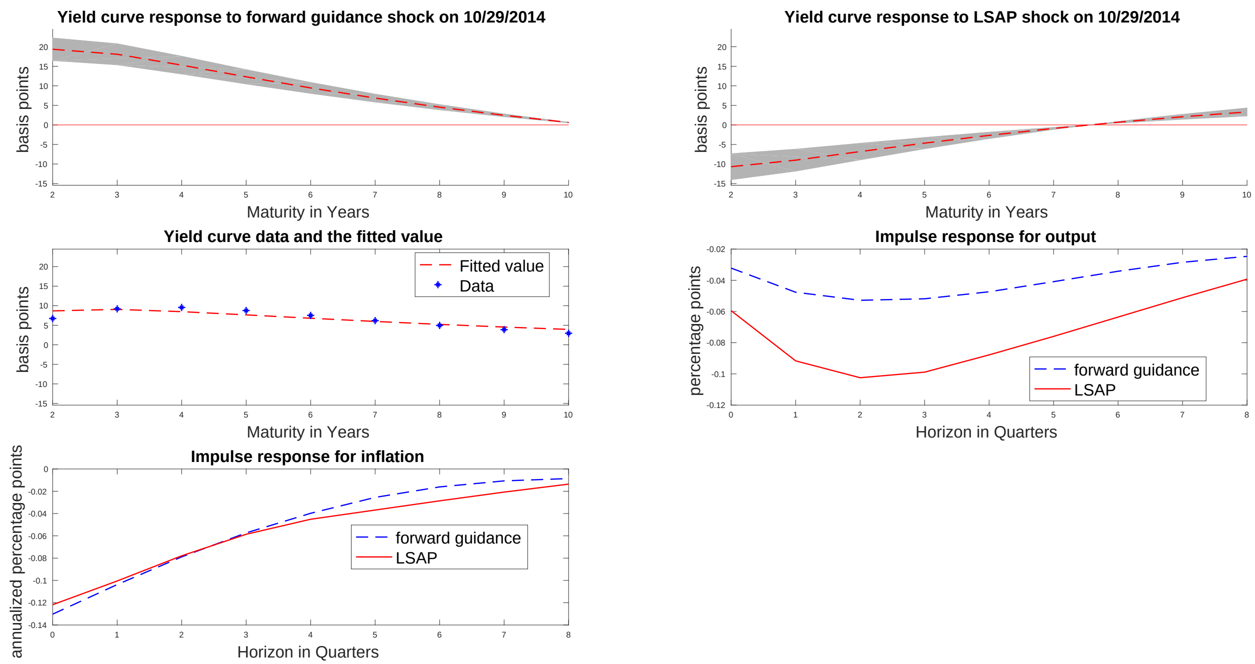
NOTES: Estimated effects on Treasury yield curve on Dec. 18, 2013. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 29: Estimated Effects on 03/19/2014



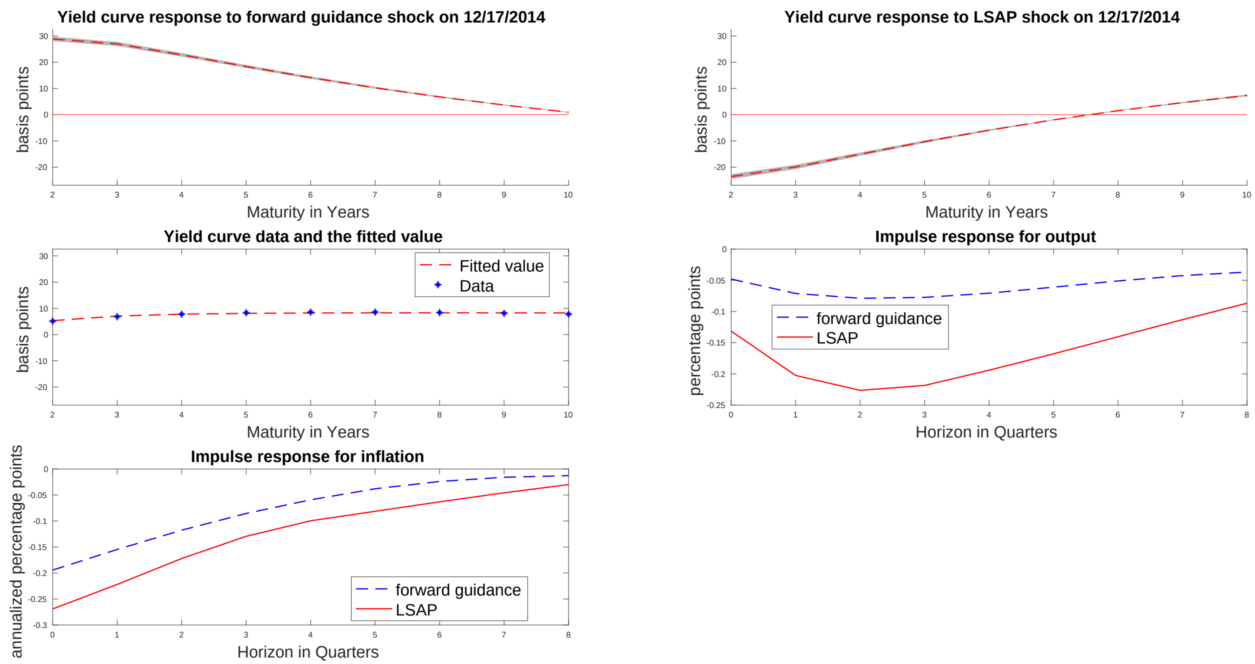
NOTES: Estimated effects on Treasury yield curve on March 19, 2014. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 30: Estimated Effects on 10/29/2014



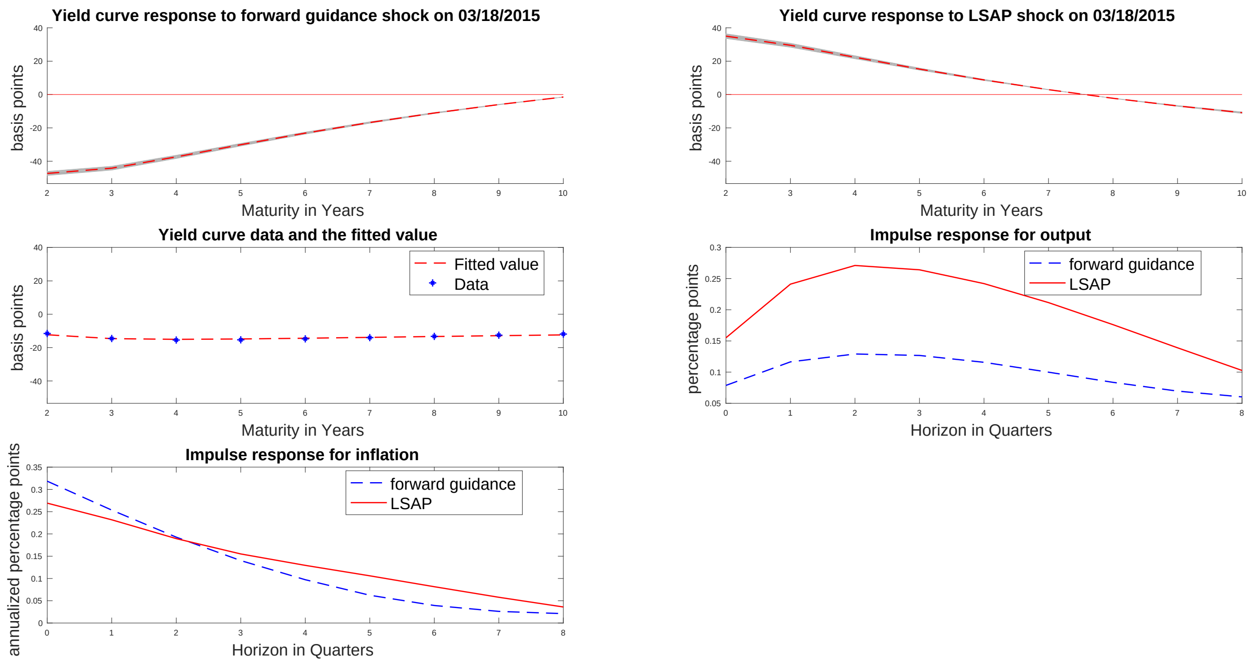
NOTES: Estimated effects on Treasury yield curve on Oct. 29, 2014. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 31: Estimated Effects on 12/17/2014



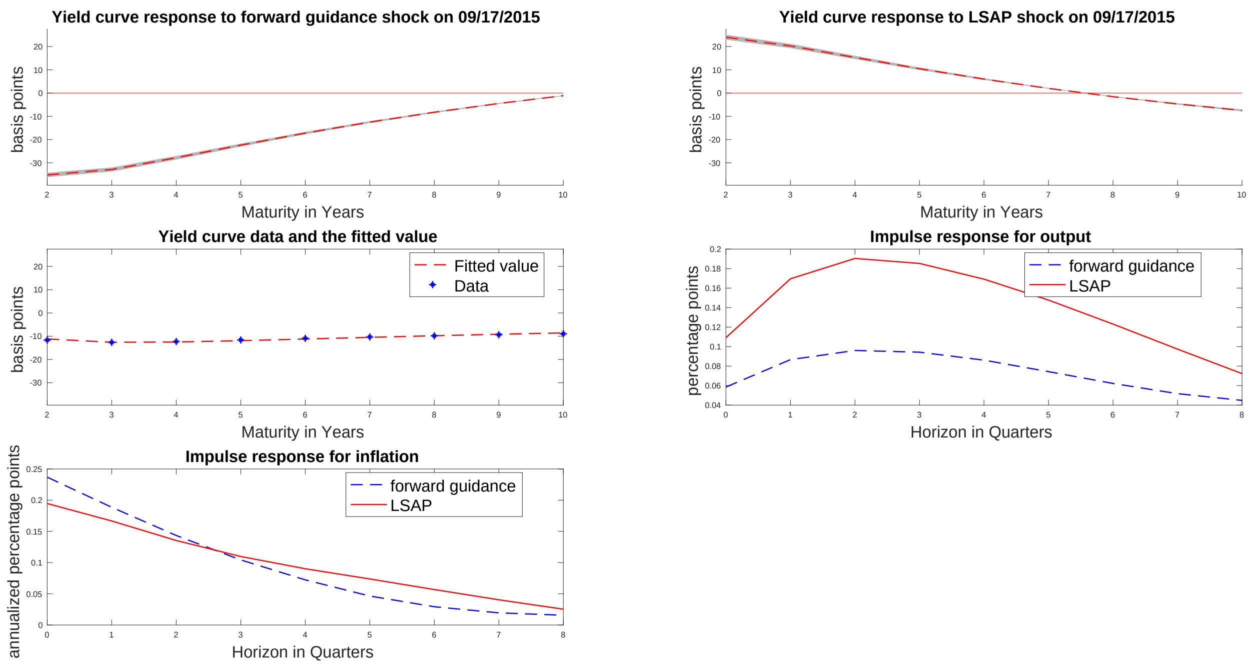
NOTES: Estimated effects on Treasury yield curve on Dec. 17, 2014. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 32: Estimated Effects on 03/18/2015



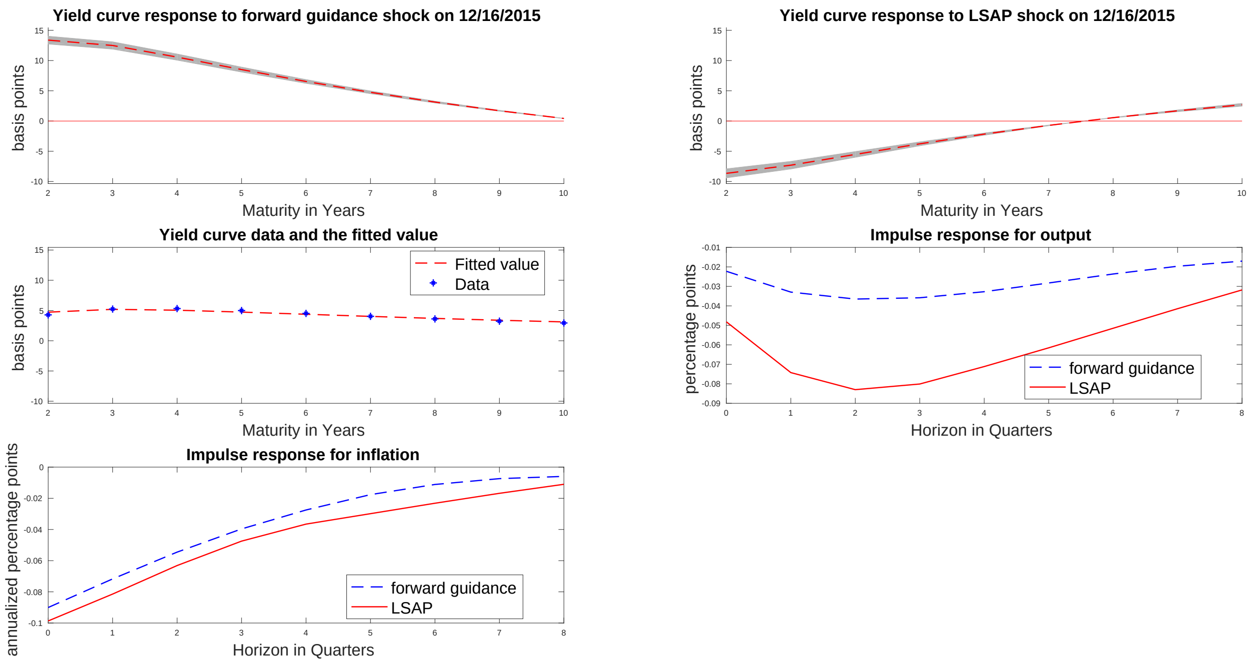
NOTES: Estimated effects on Treasury yield curve on March 18, 2015. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value.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

Figure 33: Estimated Effects on 09/17/2015



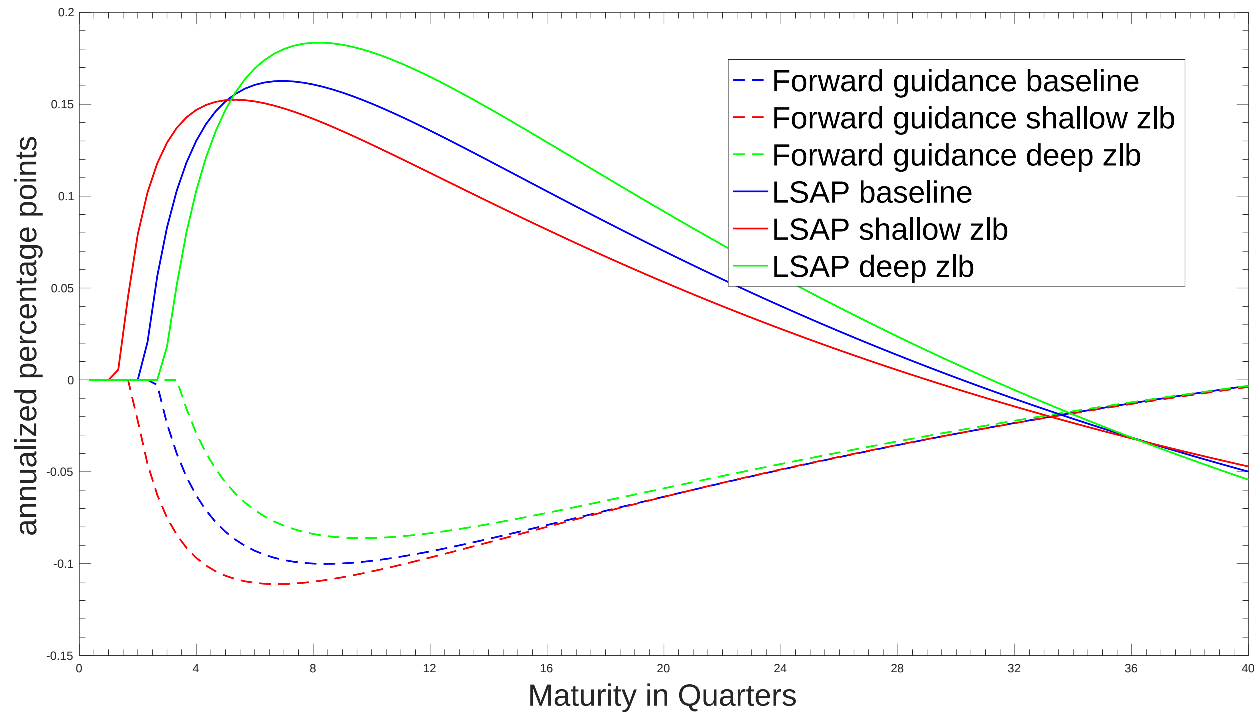
NOTES: Estimated effects on Treasury yield curve on Sept. 17, 2015. The upper left panel shows the effects to forward guidance shock, and the upper right panel to the LSAP shock. 90% confidence intervals are shown in both cases. The middle left panel compares the yield curve data with the fitted value. The middle right panel and the lower left panel show the impulse responses of output and inflation for the next 8 quarters.

Figure 34: Estimated Effects on 12/16/2015



NOTES: Estimated effects on Treasury yield curve on Dec. 16, 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.

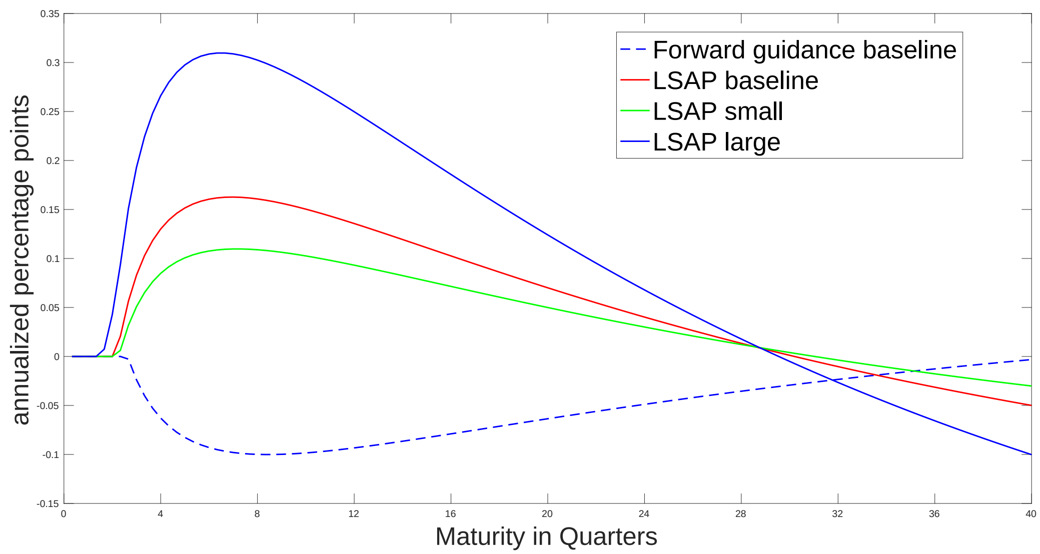
Figure 35: Difference Between Fitted Yield Curves When Initial Condition Varies



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

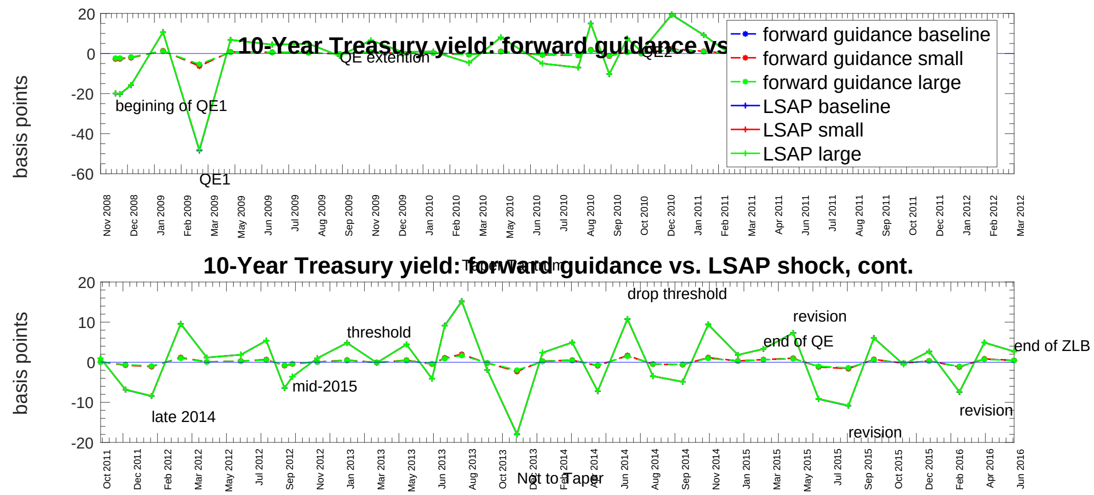
8 Appendix

Figure 36: Difference Between Fitted Yield Curves When Normalization Varies



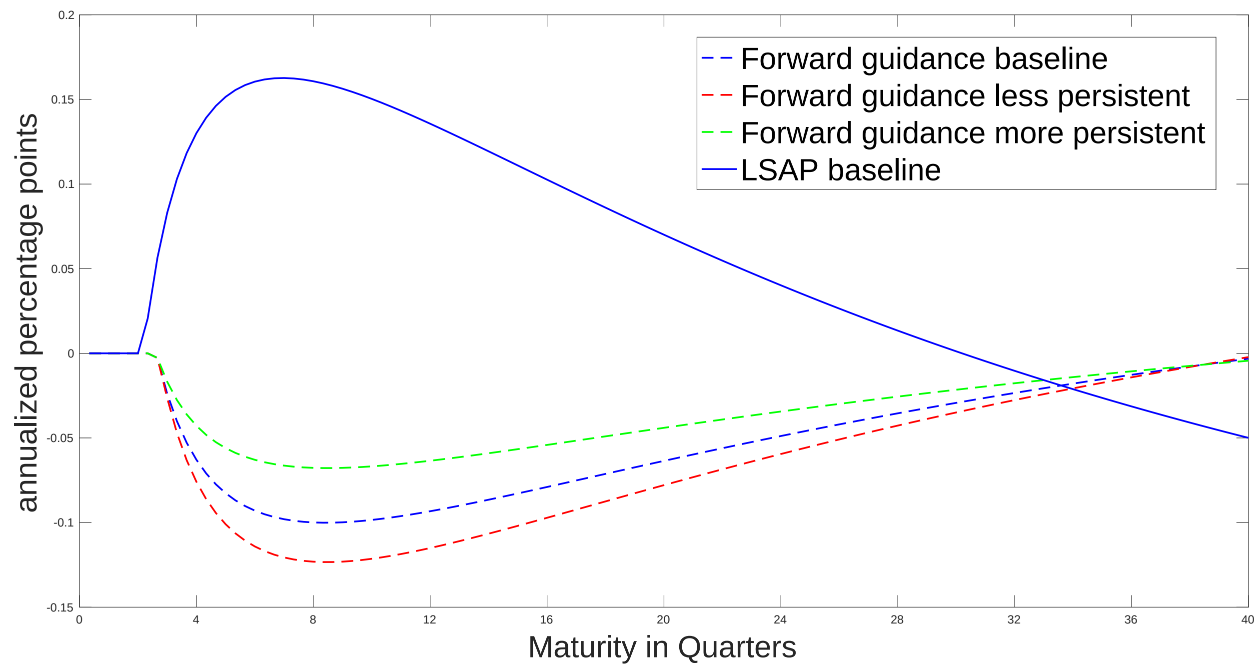
NOTES: Plot of the difference between fitted yield curves from a no-policy-response case.

Figure 37: Estimated Effects on 10-year Treasury Yield When Normalization Varies



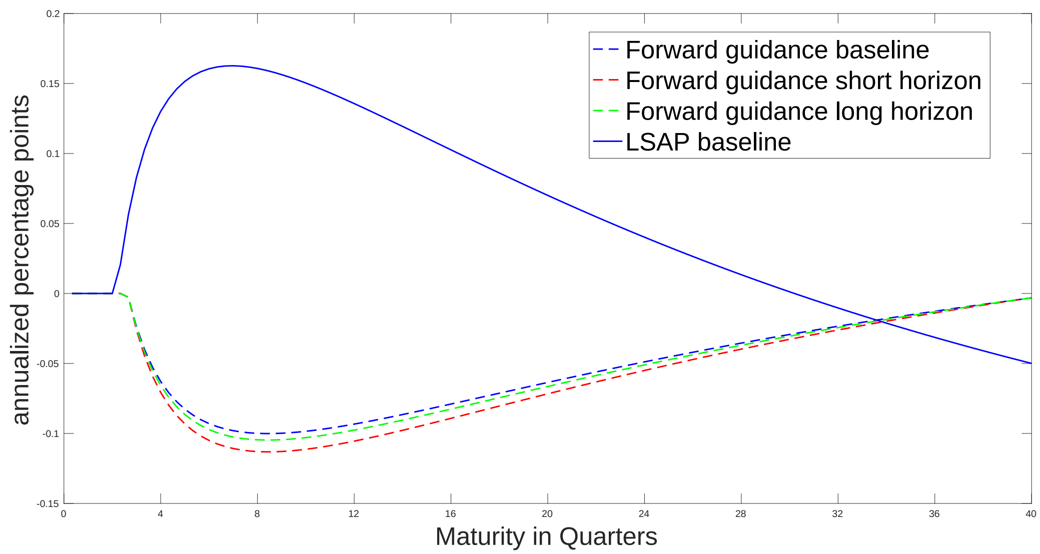
NOTES: Plot of estimated forward guidance (dashed line) and LSAP (solid line) factors for 10-year Treasury yield for all the event dates for different normalization. Notable announcements are labeled in the figure for reference. See text for details.

Figure 38: 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 39: 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.

Table 12: 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.
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		

Date	Forward Guidance Announcement	LSAP Announcement
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		
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.	

Date	Forward Guidance Announcement	LSAP Announcement
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.	