IDENTIFYING UNCONVENTIONAL MONETARY POLICY SHOCKS*

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Abstract

This paper proposes a novel method for identifying unconventional monetary policy shocks. The method incorporates the movement of two unconventional monetary policy indicators, namely, the size and composition of the central bank's balance sheet, after the bank makes policy decisions. Under some restrictions imposed in the vector autoregressive model, we identify two unconventional policy shocks, quantitative and qualitative shocks, as anticipated shocks that best portend the current and future paths of the unconventional policy indicators in response to the policy shocks. The qualitative easing shocks have expansionary effects on the real economy, while the quantitative easing shocks have contractionary effects.

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1 Introduction

Central banks have several monetary policy options, even under the interest rate lower bound (Bernanke and Reinhart (2004)). Since February 1999, for example, the Bank of Japan (BOJ) has newly developed its so-called unconventional monetary policy. By setting the targeted overnight call rate (OCR) to almost 0%, the BOJ adopted a quantitative easing policy in March 2001. Under this policy framework, the monetary base (MB), or size of the BOJ's balance sheet, expanded at an OCR of 0% through the growth of excess reserves in the BOJ's current account bases (see Figure 1). The quantitative easing policy ended in March 2006. The targeted rate, however, has remained well below 0.5% since then. In its quantitative and qualitative easing policy introduced in April 2013, the BOJ further deepened its unconventional policy framework not simply by enlarging its balance sheet, but by increasing the ratio of unconventional assets on the balance sheet.[1] Central banks in industrialized countries such as the U.K., the U.S., and the Euro area have followed with their own unconventional policy frameworks similarly characterized by increases in the sizes of central bank balance sheets and changes in the balance sheet compositions at extremely low policy-targeted interest rates.

Although the actual implementation of the unconventional monetary policy in many countries has stimulated empirical research on unconventional policy effects using the structural vector autoregressive (VAR) model, the policy effects on the real economy are still disputable. The difficulty in identifying exogenous unconventional policy shocks is particularly confounding in this respect.[2] One of the biggest challenges in assessing unconventional policy effects by VAR analysis is the choice of variables to use as monetary policy indicators precisely reflecting the central bank's policy decisions in the unconventional monetary policy. More simply, how should we associate the monetary policy indicators with the exogenous components of the unconventional monetary policy? A number of previous studies have assumed that

[1]See Shiratsuka (2010) and Ueda (2012) for a detailed explanation of unconventional assets in Japan.

[2]See Ugai (2007) and Joyce et al. (2012) for a survey of the empirical research on unconventional policy effects.

monetary aggregates such as the MB and excess reserves represent the central bank's policy stance, thus utilizing their reduced-form VAR innovations as exogenous components of the unconventional monetary policy (Iwata and Wu (2006), Inoue and Okimoto (2008), Honda et al. (2013), Kimura and Nakajima (2016), and Hayashi and Koeda (2017)).[3] This empirical strategy is essentially an extension of the standard recursive VAR approach to estimate the effects of the conventional monetary policy in which central banks control short-term nominal interest rates (Bernanke and Blinder (1992) and Christiano et al. (1996)). The other strand of empirical research for unconventional policy effects has employed a strategy requiring no extraction of exogenous policy components from the central bank's policy indicators. By assuming that unconventional monetary policy shocks can be represented collectively as a single unobservable policy shock, they impose sign restrictions on the impulse responses of the macroeconomic variables to the single monetary policy shock (Kapetanios et al. (2012), Baumeister and Benati (2013), Schenkelberg and Watzka (2013), Gambacorta et al. (2014), and Weale and Wieladek (2016)) and heterogeneous variance restrictions on the intensity of structural shocks including a single policy shock (Wright (2012), Rogers et al. (2014), and Shibamoto and Tachibana (2017)).

We also know, however, that central banks control for policy variables in tandem in a low interest rate environment. As long as they do so, the two aforesaid empirical strategies are insufficient to assess the different effects of unconventional policy tools. In the case of Japan, the BOJ has purchased a vast range of different financial assets such as exchange trade funds, commercial papers, and long-term government bonds. To investigate whether different policy instruments have different effects on the real economy, we assume that the monetary policy implemented by the BOJ in a low interest rate environment has been arranged in three dimensions: a *quantitative* easing setting, *qualitative* easing setting, and *conventional* policy rate setting.

[3]Previous studies applying the recursive VAR approach to the U.K. and the U.S. unconventional monetary policy do not necessarily use the MB or excess reserves as an unconventional monetary policy indicator; e.g., Wu and Xia (2016) used shadow policy rates for the analysis of the U.S., and Weale and Wieladek (2016) used asset purchase announcements for the analysis of the U.K. and the U.S.

In this paper we introduce a novel identification approach to disentangle the causal effects of the BOJ's three policy shocks on macroeconomic variables. To this end, we first show how the monetary policy indicators respond to the BOJ's policy decisions on a number of specific monetary policy meeting (MPM) days. Then we propose a new strategy for coping with the issues entailed in identifying unconventional monetary policy shocks by focusing on three issues: the variation of policy tools, the endogeneity of the monetary policy indicators, and unconventional policy shocks as anticipated shocks.

Following the previous literature, we employ a straightforward approach to pin down the timing when monetary policy shocks arise in the economy (Kuttner (2001), Cochrane and Piazzesi (2002), Gürkaynak et al. (2005a,b), Honda and Kuroki (2006), Gürkaynak et al. (2007) and Campbell et al. (2012)). The BOJ decides its policy scheme at MPMs (previously, the meetings were held once or twice a month) and publicly states its policy decision just after each meeting. As the public statement after the MPM is the BOJ's main communication tool, we exploit the idea that monetary policy shocks are reflected in the changes of asset prices just after the statement. In other words, we take up the market responses to the BOJ's policy decision statements, that is, the monetary policy surprises in financial markets or the revised expectations of market participants embedded in financial asset valuations, as monetary policy shocks. As long as we correctly characterize the monetary policy surprises, we can use them as the instrumental variables of the reduced-form VAR innovations to identify the causal effects of the BOJ's monetary policy shocks on macroeconomic variables.[4]

Another identifying issue is how monetary policy indicators respond to policy changes. As discussed above, previous studies on unconventional policy effects based on VAR analysis have taken either of two approaches. Some have assumed the reduced-form VAR innovations of monetary aggregates such as the MB to be unconventional policy shocks. Others have imposed restrictions on the impulse responses of some of the variables to a single unobserved

[4]See Ramey (2016) and Stock and Watson (2012, 2017) for a detailed survey of this empirical strategy for identifying U.S. monetary policy shocks using monetary policy surprises, namely, changes in asset market prices on Federal Fund Open Market Committee dates.

unconventional policy shock. Irrespective of the difference in methodology, both of these approaches make the common assumption that all monetary policy shocks to monetary aggregates are unanticipated, and that unconventional policy shocks yield favorable effects on the macroeconomy. Their identification, however, is not suitable in terms of the actual dynamics of the unconventional and conventional policy indicators. More specifically, the size and composition of a central bank's balance sheet do not reflect the policy changes of the central bank immediately after an announcement, whereas the bank's policy rate does. As the BOJ clarifies in its statement, the target levels of unconventional policy instruments are basically achieved after several months or a year has passed from the BOJ's policy change announcement. Hence, agents in the economy can anticipate large changes in monetary policy indicators, including the monetary base, even in the long-run future. But if we impose an existing identification scheme in a VAR model such as a recursive restriction and a sign restriction and ignore the difference between those unconventional policy indicators and the OCR, we may misspecify those anticipated changes as unanticipated shocks.

Premising that anticipated unconventional monetary policy shocks are mainly attributable to the actual movements of observable unconventional policy indicators, we identify two *unconventional* monetary policy shocks relating to the size and composition of the BOJ's balance sheet as anticipated shocks, or news shocks, that best presage their current and future paths.[5] To identify the unconventional shocks, we employ the maximum forecast error variance (MFEV) approach from Francis et al. (2014), which builds on the work of Faust (1998). The MFEV approach identifies a shock such that its contribution to the forecast error variance of a time series process is maximized over all horizons up to a finite truncation horizon.[6] Thus, this approach isolates the primary driver of a time series process as an anticipated shock, and it can be applied to any case in which such dominant driving

[5]Milani and Treadwell (2012) tried to theoretically disentangle the anticipated and unanticipated components of policy shocks by constructing a New Keynesian model that incorporates news about future policy rates.

[6]Unlike the MFEV approach, the Faust's approach maximizes the contribution at a predetermined finite horizon.

process exists (Francis et al. (2014)). Given that the BOJ implements the unconventional monetary policy by altering the expected future course of monetary policy actions in its statement (Okina and Shiratsuka (2004)), the MFEV approach is suitable for identifying the two unconventional monetary policy shocks, since those shocks are identified by processes that most explain agents' expectation revisions about the future course of the two unconventional policy indicators.[7] Along with the MFEV approach, we also impose that the two anticipated policy shocks do not affect the contemporaneous changes in the OCRs. Thus, we also identify one *conventional* monetary policy shock as a shock that has an instantaneous impact on the BOJ's policy rate. These identifying restrictions reveal that central banks seek to gradually achieve their target levels for the unconventional policy measures after policy decisions and implement unconventional monetary policy when they cannot pursue the conventional policy option of lowering short-term nominal interest rates (Bernanke and Reinhart (2004)).

By identifying *quantitative*, *qualitative*, and *conventional* policy shocks, we provide evidence that the *quantitative* easing shock, the shock that increases the size of the BOJ's balance sheet, significantly decreases the long-term nominal interest rate without conferring any favorable effects on real economic activity. On the contrary, the *qualitative* easing and *conventional* policy shocks, the shocks that respectively increase the BOJ's unconventional asset ratio to its total assets and immediately decrease the policy rate, bring about expansionary effects.

The remainder of this paper is organized as follows. Section 2 analyzes the movement in each policy indicator in response to the BOJ's actual policy changes and our monetary policy surprise measures. Section 3 proposes an identification method considering different effects of the aforesaid three policy shocks on the economy. Section 4 reports the estimation

[7] In addition to the recursive restriction and the sing restriction approach, Weale and Wieladek (2016) also employed the Faust's approach, so that their asset purchase announcement shock is identified as a process that most explains the forecast error variance of asset purchases with a three month delay in their analysis of the U.K. and the U.S. unconventional monetary policy. However, as we will discuss in Subsection 4.2, our unconventional monetary policy shocks, identified using the MFEV approach, cause the size and the composition of the BOJ's balance sheet to reach a peak much later than the asset purchase announcement shock does.

results for the monetary policy shocks. Section 5 explores several implications given our empirical findings of unconventional monetary policy effects. Section 6 closes the paper with concluding comments. The Appendix provides a detailed description of the procedure we used to construct the monetary policy surprises.

2 Monetary Policy Changes and Monetary Policy Indicators

In this section we examine the movements of monetary policy indicators in response to policy changes. By doing so, we show the need for our method of using the structural VAR approach to identify monetary policy shocks relating to each of three policy indicators, one conventional and two unconventional. The conventional policy indicator is the OCR. The unconventional policy indicators are the MB and the composition ratio of the BOJ's unconventional assets to its total assets (termed "COMP" hereafter). Within the framework of the BOJ's unconventional monetary policy, the MB, or the size of the BOJ's balance sheet, is a quantitative policy indicator, and the composition ratio is a qualitative policy indicator (Shiratsuka (2010) and Ueda (2012)).

2.1 Event Study Illustration

In this subsection we conduct an event study analysis of the response of the policy indicators to the introduction of the new monetary policy schemes. The aim here is to illustrate more concretely the degree of variation in the response of the monetary policy indicators to actual policy changes and the importance of introducing a structural analysis. Figures 2 to 5 show the time path of the MB, COMP, and OCR during the following four periods: 1) the introduction of the zero interest rate policy in February 1999, 2) the end of the zero interest rate policy in August 2000 and introduction of quantitative easing in March 2001, 3) the end of quantitative easing in March 2006 and return of the conventional monetary policy through short-term interest rate control in July 2006, and 4) the introduction of the quantitative and qualitative easing policy in April 2013.

A common pattern can be observed in all of the figures: the short-term interest rate (OCR) responded to the BOJ's monetary policy immediately upon the entry of the new schemes, while the MB and COMP, the quantitative and qualitative indicators, responded more continuously and gradually. If we look at the period following the introduction of the zero interest rate policy in 1999 (Figure 2), for example, we see that the OCR decreased immediately in response to the policy change, whereas the MB and COMP showed only small immediate responses but then continuously rose thereafter.[8] This event study shows how the unconventional indicators move slowly and later in time in response to policy changes, while the policy rate moves immediately.

The ending of the zero interest rate policy in 2000 and the introduction of quantitative easing in 2001 (Figure 3) quickly raised and lowered the policy rate, respectively. Among the unconventional policy indicators, the COMP responded to the end of the zero interest rate policy and introduction of quantitative easing by immediately and continuously decreasing and increasing. On the contrary, the MB showed no immediate change following these policy changes. These responses of the unconventional policy indicators following the introduction of quantitative easing in March 2001 show that the BOJ began purchasing long-term government bonds as an unconventional asset, as the MB had already met its target level. From August to December 2001, however, the BOJ expanded quantitative easing by continuously increasing the MB and consistently lowering the OCR. In this period, the BOJ thus implemented the unconventional monetary policy through quantitative easing.

Note also that, as shown in Figures 2 and 3, the introduction and end of the zero interest rate policy in 1999 and 2000 yielded different associations between the responses of the three

[8]Under the conventional monetary policy framework, the COMP decreases because central banks purchase conventional assets to lower short-term nominal interest rates. From the estimated increase in the COMP following the decrease in the OCR, we can infer that the BOJ purchased unconventional assets with sufficient aggressiveness to induce the COMP to rise in the unconventional monetary policy framework after the introduction of the zero interest rate policy.

policy indicators. This finding suggests that the policy rate changes were associated with the different unconventional policy operations of the MB and COMP. Here, therefore, we go on to separately identify each policy shock involving the OCR, MB, and COMP.

As reported in Figure 4, the end of quantitative easing in March 2006 led to a continuous decrease in the MB and increase in the COMP, thereby serving as a quantitative tightening and qualitative easing policy. By contrast, the OCR remained unchanged in response to the policy change, as the BOJ maintained the zero interest rate policy in spite of its decision to end quantitative easing. These results tell us that even as the BOJ lifted the quantitative easing, leaving the policy rate in the zero lower bound, it conducted the unconventional monetary policy by controlling the MB and COMP (i.e., the targeted variables). We should also note that the OCR immediately rose following the recurrence of short-term interest rate controls in July 2006. The MB decreased slightly in this month, whereas the COMP decreased drastically. When the BOJ raised the target rate for the OCR in February 2007, the OCR and the COMP both rose while the MB remained unchanged. Hence, the periods of June 2006 and February 2007 were characterized by policy tightening in terms of the conventional monetary policy framework, and policy tightening and easing in terms of the unconventional qualitative policy framework.

While we see, from Figure 5, that the quantitative and qualitative easing policy introduced in 2013 was followed by continuous and gradual increases of the MB and COMP, it had almost no effect on the OCR. This was a consequence of the short-term interest rate, which had remained substantially in the zero lower bound since December 2008, when the BOJ lowered its target rate for the OCR from 0.3% to 0.1%.

Given the above event study analysis, we provide two insights to identify the monetary policy shocks delivered in the unconventional monetary policy regime. First, the responses of the three policy indicators have no particular relationship; that is, we find no simple associations among their responses to similar types of policy changes such as changes in the policy rate or the size of the central bank's balance sheet. In the absence of such a relationship, we have no way of integrating monetary policy shocks in the unconventional monetary policy regime into a single policy shock. Put differently, we must separately identify the three monetary policy shocks corresponding to the monetary policy indicators.

Second, the unconventional policy indicators (MB and COMP) show no responses immediately following the monetary policy changes, whereas the short-term nominal interest rate (OCR) responds quickly and substantially. This difference in the responses of the policy indicators to the policy changes stems from differences in the indicators themselves. The unconventional policy indicators are essentially quantitative financial variables that reach their target levels later, after central banks state their policy changes for the sizes and compositions of their balance sheets. In this sense, unconventional policy shocks relating to the MB and COMP must be characterized as "anticipated shocks" or "news shocks" that portend the future paths of these two indicators. By contrast, the policy rate is essentially the market price of reserve deposits, a variable that reaches its target level quickly through an immediate reaction of the reserves market.

2.2 Monetary Policy Surprises and Monetary Policy Indicators

As we discussed earlier in the Introduction, the fundamental issue to consider in identifying monetary policy shocks in relation to policy indicators is the timing of the central bank's policy decision announcement. In this subsection we discuss the source from which monetary policy shocks originate.

The BOJ decides its policy scheme in an MPM held about twice per month and publicly states its policy decision just after the meeting closes. As such, we can assume that the BOJ's monetary policy shocks originate from revisions in the expectations of agents in the asset markets. This empirical strategy helps us overcome identification problems that arise with regard to endogenous responses of monetary policy when we simply treat innovations of monetary policy indicators as policy shocks in a monthly or quarterly VAR model. If we were to apply the innovations in such VAR models, the models would be contaminated by their endogenous responses to the underlying financial variables and other macroeconomic variables left out of the VAR system (Romer and Romer (2004), Faust et al. (2004), Gertler and Karadi (2015), and Shibamoto (2016)).[9] Hence, as we go on to discuss in detail in the next section, we use monetary policy surprises in asset markets, or revisions in the expectations of agents in asset markets, as external instruments to control for the endogenous responses of the three monetary policy indicators to the variables remaining in and out of the VAR.

Previous studies constructed monetary policy surprises by focusing on changes in short-term interest rate futures and using their high-frequency daily trading data. Kuttner (2001), Cochrane and Piazzesi (2002), Gürkaynak et al. (2005a,b), Gürkaynak et al. (2007), and Campbell et al. (2012) constructed monetary policy surprises in federal funds or Eurodollar futures occurring on Federal Open Market Committee dates. Honda and Kuroki (2006) constructed monetary policy surprises in euro-yen futures occurring on the BOJ's MPM dates from 1989 to 2001. Although these studies examined financial market responses to exogenous monetary policy shocks under the conventional policy regime, this empirical strategy is still useful for identifying the BOJ's monetary policy shocks under the unconventional policy regime.[10] We cannot, however, follow the strategy simply because short-term interest rate futures have hardly changed since the BOJ's introduction of its unconventional monetary policy. Here, therefore, we depart from previous studies by looking beyond changes in a particular asset market and exploiting all information on changes in the major financial markets just before and just after the BOJ's public statements. More concretely, we employ the principal component approach of Bernanke et al. (2004) and Gürkaynak et al. (2005b) and prepare for the monetary policy surprises as common factors of unanticipated changes in the major financial market variables following the public statements.[11]

[9]Romer and Romer (2004), Faust et al. (2004), Gertler and Karadi (2015), and Shibamoto (2016) pointed out that the reduced-form VAR innovations of policy rates would have a substantial bias in identifying the monetary policy effect.

[10]Gagnon et al. (2011) and Swanson (2011) used an event study analysis to investigate monetary policy effects on an asset's market price in the U.S. Joyce et al. (2011) and Ueda (2012) used an event study analysis to estimate financial market responses to monetary policy in the U.K. and Japan.

[11]Unlike this paper, Bernanke et al. (2004) and Gürkaynak et al. (2005b) aggregated information on short-term futures with different maturities. We do not use the same type of information because, as discussed

We use twelve financial market variables to extract the monetary policy surprises as common factors: one futures rate (the three-month euro-yen TIBOR futures rate), five yen interest swap rates (the one-year, two-year, five-year, ten-year, and thirty-year yen interest swap rates), one short-term spot rate (the three-month euro-yen TIBOR rate), two spot exchange rates (the Yen-U.S. dollar spot exchange rate and the Yen-AUS dollar spot exchange rate in the Tokyo market), two stock price indexes (TOPIX and Nikkei Jasdaq index), and bank reserve deposits. Next, we compute the three common factors as monetary policy surprises on the twelve financial markets. The Appendix gives further details on the procedure we used to construct the three common factors.

Below we examine the statistical relevance among the monetary policy surprises and monetary policy indicators by running the following distributed lag regression of the policy indicators on the current and lagged monetary policy surprises:[12]

$$y_t^{MPI} = r_{\iota,MPI,MPS} + \sum_{pc=1}^{3}\sum_{h=0}^{H} r_{MPI,pc}^{MP,h} MPS_{t-h}^{pc} + e_t^{MPI,MPS}, \tag{1}$$

where y_t^{MPI} denotes each of the monetary policy indicators: OCR, MB, and COMP. For the MB, we examine not only its logarithmic value, but also its monthly growth rates of log-differenced values. MPS_{t-h}^{pc} indicates the h lagged values for the three monetary policy surprises generated using the factor analysis. $r_{\iota,MPI,MPS}$ and $e_t^{MPI,MPS}$ are constant terms and stochastic disturbances, respectively.

Table 1 reports the estimation results for the distributed lag regression. As the table shows, the monetary policy surprises are statistically correlated with the monetary policy indicators. Specifically, we find that they are significantly associated with the OCR at the horizon of $h = 0$, though most of our sample includes periods of 0% interest rates. This association tells us that monetary policy surprises have information on the movement in the

above, the nominal interest rates in short-term futures in Japan have stayed in the zero lower bound since the BOJ introduced the unconventional monetary policy.

[12]This regression corresponds to the first component ($\sum_{\tau=0}^{h} \Phi_\tau R^{MP} \xi_{t+h-\tau}^{MP}$) of regression (9) introduced in Subsection 3.3.

BOJ's policy rate. By contrast, monetary policy surprises show no significant association with the MB or COMP at the horizon $h = 0$, but are significantly associated with the MB $h \geq 12$ and with the COMP at $h \geq 2$. These estimation results imply that the MB and COMP respond to the BOJ's policy changes slowly and later in time.

Our finding on the responses of the unconventional monetary policy indicators clearly indicates that monetary policy surprises have substantial information on their future movements, but not on their contemporaneous ones. In other words, the public statements about changes in the two unconventional policy indicators released just after the MPM have the feature of a news shock that portends future changes in the indicators. In the next section we incorporate these medium- and long-term findings among the monetary policy surprises and two unconventional policy indicators into an identifying restriction on the intertemporal relations among the unconventional monetary policy shocks and indicators.

Note, also, that each of the monetary policy indicators has a differential association with the monetary policy surprises. These differential associations compel us to separately identify the three monetary policy shocks relating to the three policy indicators: one conventional monetary policy shock that aims to exogenously change short-term nominal interest rates and two unconventional monetary policy shocks that aim to exogenously change the size and composition of the central bank's balance sheet.

3 Identifying Monetary Policy Shocks under the Unconventional Policy Regime

This section describes the empirical strategy we use to identify the effects of the conventional and unconventional monetary policy shocks in the structural VAR analysis. First, we assume that monetary policy shocks originate from the public statements released just after the MPM. Second, we account for the identifying restrictions that incorporate the features of the monetary policy indicators discussed in Section 2. Specifically, we impose restrictions on the unconventional monetary policy shocks that turn out to capture current and future changes in the size and composition of the BOJ's balance sheet, while we define the conventional monetary policy shock as a shock that has an immediate impact on the central bank's policy rate, or the overnight call rate (OCR). In parallel, we assume that unconventional monetary policy shocks have no contemporaneous effects on the level of the OCR. This assumption reflects that the central bank tendency implements the unconventional monetary policy when conventional policy options (e.g., controlling the short-term interest rate) are no longer viable, as Bernanke et al. (2004) and others discussed.

Also note that in the setting of the VAR model, we assume the entry of a new policy scheme in the unconventional monetary policy regime discussed in Subsection 2.2, not as reflects a change in the central bank's deep parameter in its policy decision announcement, but as reflects the anticipated unconventional policy shocks that portends future changes in the MB and COMP, and the unanticipated conventional policy shock that leads to an immediate change in the OCR. Below, therefore, we do not employ the regime-switching and time-varying parameter VAR models, as in Kapetanios et al. (2012), Baumeister and Benati (2013), Kimura and Nakajima (2016), and Hayashi and Koeda (2017).

Our procedure for VAR identification is based on the following two-step approach. In the first step, we use the monetary policy surprises as the instrumental variables of the reduced-form VAR innovations of the three policy indicators and other macroeconomic variables. Specifically, we construct an impact matrix for the instantaneous responses of the VAR variables by disentangling the causal relationships among the monetary policy shocks and VAR variables. The impact matrix in this stage disregards the movement in the unconventional policy indicators following policy changes. We therefore impose restrictions, in the second step, to identify the unconventional monetary policy shocks (i.e., the quantitative and qualitative shocks), which we define as shocks that best explain the revisions of an agent's expectations about the current and future paths of the size and composition of the central bank's balance sheet, but that have no contemporaneous effects on the OCR. To this end, as discussed in Introduction, we employ the maximum forecast error variance (MFEV) approach from Francis et al. (2014).

3.1 Structural VAR Model

Letting y_t denote a $K \times 1$ vector of time-varying observables, this stochastic structure can be expressed in terms of the vector moving average representation:

$$y_t = \Phi(L)\epsilon_t, \tag{2}$$

where $\Phi(L) = I + \Phi_1 L + \Phi_2 L^2 + \cdots$ is a matrix polynomial in the lag operator, L, and ϵ_t denotes the $K \times 1$ vector of the reduced-form VAR innovations. The MB, COMP, and OCR are given by the first, second, and third elements of y_t, respectively. The structural vector moving average representation can thus be written as follows:

$$y_t = \Psi(L)\xi_t, \tag{3}$$

where $\Psi(L) = \Psi_0 + \Psi_1 L + \Psi_2 L^2 + \cdots$, and ξ_t denotes the $K \times 1$ vector of the structural shocks.

Let ξ_t^{MP} be the 3×1 policy shock vector $\xi_t^{MP} = [\xi_t^{UQN}, \xi_t^{UQL}, \xi_t^{CSR}]'$, where ξ_t^{UQN}, ξ_t^{UQL}, and ξ_t^{CSR} denote unconventional quantitative, qualitative, and conventional short-term monetary policy shocks, respectively. The space spanned by the policy shock vector ξ_t^{MP} is disentangled from the space spanned by other possible shocks of the $(K-3) \times 1$ vector ξ_t^X in the following linear relation between the reduced-form VAR innovations ϵ_t and structural shocks ξ_t:

$$\epsilon_t = R\xi_t = R^{MP}\xi_t^{MP} + R^X \xi_t^X, \quad \underset{(K \times K)}{R} = [\underset{(K \times 3)}{R^{MP}}, \underset{(K \times (K-3))}{R^X}], \quad \underset{(K \times 1)}{\xi_t} = [\underset{(3 \times 1)}{\xi_t^{MP}}, \underset{((K-3) \times 1)}{\xi_t^X}]', \tag{4}$$

where R^{MP} represents the impact matrix for the responses of the VAR variables y_t to the monetary policy shocks.

The variance-covariance matrix of the space spanned by the monetary policy shocks can be expressed as,

$$\Sigma^{MP} = R^{MP} E(\xi_t^{MP} \xi_t^{MP'}) R^{MP'} = R^{MP} R^{MP'}, \tag{5}$$

where the variance of monetary policy shocks is normalized to one. To distinguish a conventional policy shock from an unconventional one, we impose a restriction in which unconventional policy shocks have no contemporaneous effects on the level of the policy rate. More specifically, we can express this restriction as follows:

$$R^{MP} = \begin{pmatrix} R^{MP}_{1:3,1:3} \\ R^{MP}_{4:K,1:3} \end{pmatrix} = \begin{pmatrix} r^{UQN}_{MB} & r^{UQL}_{MB} & r^{CSR}_{MB} \\ r^{UQN}_{COMP} & r^{UQL}_{COMP} & r^{CSR}_{COMP} \\ 0 & 0 & r^{CSR}_{CR} \\ r^{UQN}_{XK-4} & r^{UQL}_{XK-4} & r^{CSR}_{XK-4} \\ \vdots & \vdots & \vdots \\ r^{UQN}_{XK} & r^{UQL}_{XK} & r^{CSR}_{XK} \end{pmatrix}. \tag{6}$$

3.2 Controlling the Endogeneity of the Monetary Policy Indicators

We use the monetary policy surprises extracted from the changes in the twelve major financial markets on MPM days as the instrumental variables of the reduced-form VAR innovations, ϵ_t. Thus, we aim to control for the endogeneity of the monetary policy indicators and disentangle the causal effects of the policy shocks on the VAR variables at the shock arrival time. More concretely, we conduct the following system regression:

$$\epsilon_t = \underset{(K \times 3)}{R^{MPS}} \underset{(3 \times 1)}{MPS_t} + e_t \ , \tag{7}$$

where MPS_t denotes the 3×1 vector of the three monetary policy surprises at a monthly frequency. The system regression yields the instantaneous responses of the VAR variables to the monetary policy shocks in the form of fitted values $\hat{R}^{MPS} MPS_t$. We then obtain the following variance-covariance matrix involving the contemporaneous impacts of the monetary policy shocks to the VAR variables:

$$\hat{\Sigma}^{MP} = \hat{R}^{MPS} MPS_t MPS_t' \hat{R}^{MPS'}. \tag{8}$$

3.3 Identifying Unconventional Policy Shocks

Here, we describe the second-step procedure to identify the conventional and unconventional monetary policy shocks. Specifically, we consider restrictions to extract the three types of structural shocks associated with the conventional and unconventional policy indicators from variance-covariance matrix (8), in which the endogeneity of the policy indicators is controlled for by the monetary policy surprises.

We identify the unconventional monetary policy shocks with help from MB and COMP, policy indicators that move gradually and meet their target levels soon after the BOJ's public statements on MPM days. To incorporate this feature into our identification of the unconventional monetary policy shocks, we define them as the surprise components of monetary policy that best explain the current and future paths of the MB and COMP.

This identification strategy requires that we model the revisions in the expectations of agents regarding the current and future paths of the unconventional policy indicators. We do so by employing the MFEV approach proposed by Francis et al. (2014).[13] This approach allows us to specify the revisions in the agents' expectations as maximization problems for the contributions of the unconventional policy shocks to the forecast error variances of the unconventional policy indicators.

To explain the MFEV approach, we begin by expressing the h-step-ahead forecast error

[13]Barsky and Sims (2011) employed the MFEV approach to identify news shocks, or anticipated shocks, about future technology. Zeev et al. (2015) used this approach to identify anticipated monetary policy shocks in the U.S. conventional monetary policy regime.

conditioning on the structural shocks ξ_t:

$$y_{t+h} - E_{t-1}y_{t+h} = \sum_{\tau=0}^{h} \Phi_\tau R \xi_{t+h-\tau} = \sum_{\tau=0}^{h} \Phi_\tau R^{MP} \xi_{t+h-\tau}^{MP} + \sum_{\tau=0}^{h} \Phi_\tau R^{X} \xi_{t+h-\tau}^{X}, \tag{9}$$

where the first and second equalities use equations (2) and (4). Therefore, the h-step-ahead forecast error due to monetary policy shocks $\xi_{t+\tau}^{MP}$ can be expressed as:

$$\sum_{\tau=0}^{h} \Phi_\tau R^{MP} \xi_{t+h-\tau}^{MP} = \sum_{\tau=0}^{h} \Phi_\tau \tilde{R}^{MP} D^{MP} \xi_{t+h-\tau}^{MP}, \tag{10}$$

where $\tilde{R}^{MP}$ represents the following $K \times 3$ orthogonalization matrix:

$$\tilde{R}^{MP} = \begin{pmatrix} \tilde{r}_{11} & 0 & 0 \\ \tilde{r}_{21} & \tilde{r}_{22} & 0 \\ \tilde{r}_{31} & \tilde{r}_{32} & \tilde{r}_{33} \\ \vdots & \vdots & \vdots \\ \tilde{r}_{K1} & \tilde{r}_{K2} & \tilde{r}_{K3} \end{pmatrix},$$

and D^{MP} denotes the 3×3 orthonormal matrix ($D^{MP}D^{MP'} = I$).[14] Thus, the share of the h-step-ahead forecast error variance of monetary policy indicator i attributable to monetary policy shock $\xi_t^{MP,j}$ is expressed as a variance decomposition of the following form:

$$\Omega_{i,j}^{MP}(h) = \frac{e_{1i}^{'} \left(\sum_{\tau=0}^{h} \Phi_\tau \tilde{R}^{MP} D^{MP} e_{2j} e_{2j}^{'} D^{MP'} \tilde{R}^{MP'} \Phi_\tau^{'} \right) e_{1i}}{e_{1i}^{'} \left(\sum_{\tau=0}^{h} \Phi_\tau \Sigma^{MP} \Phi_\tau^{'} \right) e_{1i}} = \frac{\sum_{\tau=0}^{h} \Phi_{i,\tau} \tilde{R}^{MP} d_j d_j^{'} \tilde{R}^{MP'} \Phi_{i,\tau}^{'}}{\sum_{\tau=0}^{h} \Phi_{i,\tau} \Sigma^{MP} \Phi_{i,\tau}^{'}}, \tag{11}$$

where e_{1i} and e_{2j} are the $K \times 1$ and 3×1 selection vectors, with one in the ith place and jth place and zeros elsewhere, and d_j is the 3×1 vector indicating the jth column of the

[14] In practice, we obtain an orthogonalization matrix $\tilde{R}^{MP}$ as follows. First, we perform a Cholesky decomposition of the 3×3 upper left submatrix $\hat{\Sigma}_{1:3,1:3}^{MP}$ of variance-covariance matrix (8), such that $\hat{\Sigma}_{1:3,1:3}^{MP} = \tilde{R}_{1:3,1:3}^{MP} \tilde{R}_{1:3,1:3}^{MP'}$. Then we calculate an orthogonalization matrix $\tilde{R}^{MP} = \hat{R}^{MPS} (\hat{R}_{1:3,1:3}^{MPS})^{-1} \tilde{R}_{1:3,1:3}^{MP}$ using the 3×3 upper left submatrix $\hat{R}_{1:3,1:3}^{MPS}$ of the impact matrix $\hat{R}^{MPS}$ for the responses of the VAR variables y_t to the monetary policy surprises.

orthonormal matrix D^{MP}. This variance decomposition models the revisions in an agent's expectations about the current and future path of policy indicator i at the time policy shock j emerges, where i ($i = 1, 2, 3$) indicates the place of the monetary policy indicators (MB, COMP, OCR) in vector variable y_t, and j ($j = 1, 2, 3$) indicates the place of monetary policy shocks ξ_t^{UQN}, ξ_t^{UQL}, and ξ_t^{CSR} in policy shock vector ξ_t^{MP}.

Note that $\tilde{R}^{MP} d_j$ is the $K \times 1$ vector corresponding to the jth column of a possible orthogonalization in equation (11), and thus interprets the contemporaneous impact of the jth monetary policy shock on the VAR variables. If we have estimate $\hat{d}_j$, we can therefore generate the impulse responses of the VAR variables to the jth monetary policy shock by using the estimated impact vector $\tilde{R}^{MP} \hat{d}_j$.

We employ the MFEV approach to identify the quantitative, qualitative, and conventional monetary policy shocks. More concretely, we begin by identifying the quantitative monetary policy shock, ξ_t^{UQN}, satisfying the following conditions:

$$\hat{d}_{UQN} = \arg\max \Omega_{MB,UQN}(h) = \frac{\sum_{\tau=0}^{h} \Phi_{MB,\tau} \tilde{R}^{MP} d_{UQN} d_{UQN}' \tilde{R}^{MP\prime} \Phi_{MB,\tau}'}{\sum_{\tau=0}^{h} \Phi_{MB,\tau} \Sigma^{MP} \Phi_{MB,\tau}'}, \tag{12}$$

s.t.

$$\tilde{r}_{31} d_{1,UQN} + \tilde{r}_{32} d_{2,UQN} + \tilde{r}_{33} d_{3,UQN} = 0, \tag{13}$$

$$d_{UQN}' d_{UQN} = 1, \tag{14}$$

Under constraint (13), the quantitative shock, ξ_t^{UQN}, has no contemporaneous effect on the OCR. This constraint reflects the central bank's practice of implementing the unconventional monetary policy when the conventional policy option of controlling the short-term interest rate is unavailable. Constraint (14) (d_{UQN} have unit length) ensures that d_{UQN} is the first column vector belonging to orthonormal matrix D^{MP}. After obtaining $\hat{d}_{UQN}$ by solving the above maximization problem, we calculate the impulse responses of the VAR variables to the quantitative monetary policy shocks using estimated impact vector $\tilde{R}^{MP} \hat{d}_{UQN}$.

Next, we identify the qualitative and conventional monetary policy shocks. Specifically, we identify the qualitative monetary shocks ξ_t^{UQL} by solving the following maximization problem:

$$\hat{d}_{UQL} = \arg\max \Omega_{COMP,UQL}(h) = \frac{\sum_{\tau=0}^{h} \Phi_{COMP,\tau} \tilde{R}^{MP} d_{UQL} d_{UQL}^{'} \tilde{R}^{MP'} \Phi_{COMP,\tau}^{'}}{\sum_{\tau=0}^{h} \Phi_{COMP,\tau} \Sigma^{MP} \Phi_{COMP,\tau}^{'}}, \qquad (15)$$

s.t.

$$\tilde{r}_{31} d_{1,UQL} + \tilde{r}_{32} d_{2,UQL} + \tilde{r}_{33} d_{3,UQL} = 0, \qquad (16)$$

$$d_{UQN} = \hat{d}_{UQN}, \qquad (17)$$

$$d_{UQL}^{'} d_{UQL} = 1, \qquad (18)$$

Under constraint (16), as under constraint (13) before, the qualitative policy shock has no contemporaneous impact on the OCR. Constraints (17) and (18) ensure that the qualitative shock is orthogonal to the quantitative shock identified in advance. In the identification of the qualitative shock, the second column in $R^{MP} \xi_t^{MP}$ is orthogonal to the first column obtained in maximization problems (12) through (14). This implies that, in the qualitative shock with a predetermined target level for the MB given, the central bank aims to change the composition of its assets through, for example, an operation twist.[15] We can compute the impulse responses to the qualitative monetary policy shocks using estimated impact vector $\tilde{R}^{MP} \hat{d}_{UQL}$. In the identification of the conventional monetary policy shock ξ_t^{CSR}, the third column in $R^{MP} \xi_t^{MP}$ is orthogonal to the first and second columns obtained through the above maximization problems and the surprise component of monetary policy has a contemporaneous impact on the OCR.

[15] In the quantitative and qualitative monetary easing from March 2013, the BOJ targets an annual increase of 60 to 70 trillion yen (80 trillion yen from October 2014) for a yearly expansion of the monetary base. To meet this target level for the monetary base, the BOJ purchases exchange trade funds, commercial papers, and long-term government bonds. Given the predetermination of the target level for the monetary base, the recursive restriction for the quantitative and qualitative shocks is plausible.

4 Estimation Results for Unconventional Monetary Policy Shocks

In this section we discuss the empirical results obtained using the monetary policy shocks identified by the method presented in the previous section. We focus on unconventional monetary policy shocks in particular. In addition to the three monetary policy indicators (MB, COMP, OCR), we include six macroeconomic variables in constructing the VAR: two asset market prices, three real economic variables, and one price indicator. The two asset market prices are the stock price index, SP, and the 10-year government bond yield, 10YJGB. The three real economic variables are the one-year real interest rate, 1YREAL; the ratio of the commercial bank's safe assets (JGB holdings) versus risky assets (equity holdings and bank lending), SAFE/RISK; and the index of industrial production, IIP. The consumer price index, CPI, is included as the price indicator. As discussed below, we also include other candidates for the VAR variables to conduct robustness checks. Our sample period is from April 1998 to February 2014.[16] We set the lag length to one in the reduced-form VAR estimation based on the Bayesian information criteria.

4.1 Conventional and Unconventional Monetary Policy Shocks

Here we report the statistical relevance between the reduced-form VAR innovations and monetary policy surprises. Table 2 shows the estimation results for the system regression of the reduced-form VAR innovations on the three monetary policy surprises:

$$\hat{\epsilon}_t^k = \sum_{pc=1}^{3} r_{k,pc}^{MP} MPS_t^{pc} + \tilde{\epsilon}_t^{MP,k}. \tag{19}$$

The monetary policy surprises seem to explain substantial proportions of the reduced-

[16]The reason for our selecting this sample period is partially because the BOJ publishes detailed data on its asset composition from April 1998, and partially because we cannot obtain data on the one-year real interest rate after February 2004.

form VAR innovations. In particular, the asset prices (SP and 10YJGB) appear to quickly respond to the monetary policy surprises. On the contrary, the monetary policy surprises explain little of the monetary policy indicators (MB, COMP, OCR) when the shock arrives. The insignificance of the conventional policy indicator, or the policy rate, can be attributed to its inaction for most of our sample period from 1998 owing to the extremely low interest rate regime in Japan.

Table 3 presents the results for the variance decomposition of the three monetary policy indicators attributable to the monetary policy shocks for $h = 0, 12, 24, 36$, and 48 months ahead: $\Omega^{MP}_{MB,j}(h)$, $\Omega^{MP}_{COMP,j}(h)$ and $\Omega^{MP}_{OCR,j}(h)$, where j is the quantitative, qualitative, and conventional policy shock.

As the table clearly shows, the quantitative shock substantially accounts for the variations in the MB controlled by our external instruments, or the monetary policy surprises, while the conventional policy shock accounts for them to some degree, as well.[17] The quantitative and conventional monetary policy shocks appear to contribute greatly to the variation in the future COMP adjusted for the monetary policy shocks. The conventional policy shock explains all of the variation in the OCR for $h = 0$ according to our identification of this shock. After the first impact, however, the contribution of the quantitative shock to the variation in the OCR appears to increase at only a gradual rate.

4.2 Impulse Response Analysis

In this subsection we describe the estimated impulse responses to the exogenous monetary policy shocks. Figures 6 to 8 outline the estimated impulse responses to the quantitative, qualitative, and conventional monetary policy shocks of one standard deviation, respectively.

As Figure 6 shows, the quantitative easing shock leads to a gradual and continuous increase in the MB without affecting it immediately. The MB reaches a peak at around

[17]Note that most of the variance in the MB at $h = 0$ is attributable to qualitative easing shocks. However, the sum of the contribution of the three types of monetary policy shocks to the MB is economically negligible. Hence, this finding implies that the forecast variance in the MB at $h = 0$ cannot be explained by monetary policy shocks.

two years following the quantitative easing shock. As such, the quantitative shock can be identified as an anticipated shock linked to the expansion of the balance sheet (i.e., agents expect the MB to reach its target level soon after the BOJ announces its new target). The quantitative easing shock also leads to a slow increase in the COMP, clearly indicating that the BOJ tends to increase unconventional assets more than conventional assets in the process of raising the size of its balance sheet.[18]

For the estimated responses of nominal interest rates, the long-term nominal interest rate, 10YJGB, falls immediately, while the OCR decreases gradually and reaches its bottom one year later. A quantitative easing shock thus has a policy duration effect that decreases long-term interest rates immediately by working as a signal about the future path of policy rates.

The quantitative easing shock confers no favorable effects on the SP or SAFE/RISK, causing the former to decline and the latter to rise. We can infer, from the estimation results, that the quantitative easing shock was in no way instrumental in bringing about a portfolio rebalance where financial institutions with safer assets could be expected to lend more and increase the purchase of relatively risky assets, including stocks. Rather, the quantitative easing shock appeared to merely alter supply/demand relationships in the Japanese government bond market or change the market's expectations on the duration of the zero interest rate policy (Okina and Shiratsuka (2004) and Ugai (2007)).

Consistent with this inference, the quantitative easing shock brought about a less than favorable effect on the IIP and CPI, as well.[19] Given that this shock significantly decreases the long-term nominal interest rate, we can infer that the interest rate channel through the decrease in the long-term nominal interest rate due to quantitative easing fails to bring about the intended effects under Japan's unconventional monetary policy regime.

[18] In fact, the BOJ often faced an underbidding of securities purchases, where bids fell short of offers, in its open market operations to inject liquidity. This may have been a consequence of the lack of market demand for liquidity.

[19] Hayashi and Koeda (2017) found that exiting from the quantitative easing policy is expansionary if the actual-to-required reserve ratio is not unduly large.

As we see in Figure 7, the qualitative easing shock has a significant effect on the COMP without imparting a contemporaneous impact. More concretely, the COMP peaks almost six months later. On the contrary, the MB shows no significance response to the qualitative easing shock. In contrast to the quantitative easing shock, the qualitative easing shock leads to a substantive increase in SP, a decrease in the 10YJGB, and a decrease in SAFE/RISK. These findings imply that qualitative easing induces financial institutions to increase the purchase of risky assets and lend more. The BOJ's larger purchases of unconventional assets under qualitative easing resulted in a tight supply/demand balance in the long-term Japanese government bond market and a rise in the prices of long-term Japanese government bonds. We also observe a portfolio rebalance in response to the qualitative easing shocks.

For the estimated responses of the other real economic variables, 1YREAL decreases continuously in response to the qualitative easing shock, implying that qualitative easing raises inflation expectations while bringing about little change in the short-term nominal interest rate. The IIP and CPI both increase significantly.

Figure 8 shows that the conventional policy shock basically produces similar impulse responses to those demonstrated in the VAR literature (Bernanke and Blinder (1992), Christiano et al. (1996), and Bernanke and Mihov (1998) for U.S. monetary policy, and Miyao (2000, 2002), Fujiwara (2006), Nakashima (2006), and Shibamoto (2016) for Japanese monetary policy), although the initial responses of some the variables seem to differ. In the identification of the conventional policy shock, the OCR substantially falls after the shock arrives. This conventional policy shock leads to an increase in the MB and a decrease in the COMP.

The estimated impulse responses of the SP are not significant for about one year, but increase continuously from one year to three years following the conventional policy shock. The 10YJGB, the long-term nominal interest rate, appears not to significantly respond to the conventional policy shock.

The one-year real interest rate, 1YREAL, begins to fall after the OCR and returns to the pre-shock level about a year later, which shows that the inflation rate starts to increase from that period. From the negative responses of SAFE/RISK, we can infer that the conventional policy shock causes a portfolio rebalance even during this low interest rate period.

The conventional policy easing shock leads to increases in both the IIP and CPI, although the former shows a decrease in the first few periods.[20] The IIP peaks after the CPI begins to increase about two years following the conventional policy shock.

4.3 Exogeneity of Monetary Policy Shocks

In the previous sections we showed that qualitative easing shocks have favorable effects on the real economy while quantitative shocks do not. Our results, however, may arise from correlations between our monetary policy shocks and other determinants of the real economy.

To demonstrate the plausibility of our monetary policy shocks, we examine the associations among the nine variables in the VAR and the global economic variables out of the VAR. Although our identified policy shocks can be independently determined from global economic factors, the linkages between the Japanese economy and global economy allow us to determine the reduced-form VAR innovations of the policy indicators endogenously. From this analytical viewpoint, we conduct the following regression of the VAR forecast errors on the global economic factors:

$$\hat{\epsilon}_t^k = \sum_l r_{k,l}^x x_t^l + \tilde{\epsilon}_t^{x,k}, \tag{20}$$

where $\hat{\epsilon}_t^k$ denotes the VAR innovations estimated from the nine-variable VAR and x_t^l denotes the global economic variables expected to have substantive effects on the Japanese economy.

Table 4 shows that the oil price, OIL, is positively associated with the forecast errors of the short-term nominal interest rate (OCR), 1YREAL, and CPI. This finding tells us that the OCR rises as an endogenous response to increases in inflation rates and inflation expectations. The U.S. index of industrial production, USIP, is negatively associated with the

[20]The first decline in the IIP can be explained by the revisions of the expectations of market participants and firms regarding future economic conditions, revisions caused by conventional monetary policy shocks, as Romer and Romer (2000) pointed out.

VAR innovations of the long-term nominal interest rate (10YJGB). We can infer, from these estimates, that the decline in the U.S. economy is significantly associated with the increase in the demand for Japanese government bonds, indicating Japanese government bonds became a risk-off haven. Turning to the interrelation among stock market prices, the U.S. stock price index (USSP) is positively and substantively associated with the VAR innovations of the Japanese stock price index (SP).

When we look at the endogenous response of monetary policy to global financial fragility, the TED spread is positively associated with the forecast errors of the BOJ's COMP. Further, the federal funds rate is positively associated with the OCR. These findings imply that the financial fragility in the U.S. is associated with the BOJ's qualitative easing and a decrease in the policy rate.

In the next exercise we examine whether our identified monetary policy shocks can be determined from the above global economic variables using the following auxiliary regression:

$$\hat{\xi}_t^{MP,j} = \sum_l r_{j,l}^x x_t^l + \epsilon_{\xi,t}^{MP,j}, \tag{21}$$

where $\hat{\xi}_t^{MP,j}$ represents each of the qualitative, quantitative, and conventional monetary policy shocks. As Table 5 shows, none of the monetary policy shocks is significantly associated with the global economic variables at the 5% significance level. This estimation result ensures that our monetary policy shocks are exogenous to global economic shocks.[21]

The above analysis suggests that Japanese monetary policy endogenously responds to the global economic conditions. Hence, the simple use of the reduced-form VAR innovations of the monetary policy indicators can cause us to erroneously estimate the policy effects. Hence, we use our monetary policy shocks to disentangle the exogenous responses of the economy to monetary policy shocks from the endogenous responses.

[21] As an exception, the U.S. stock price index, USSP, is positively associated with the quantitative policy easing and the conventional policy easing at the 10% significance level. This finding implies that Japanese monetary policy shocks have an effect on U.S. stock prices under the unconventional monetary policy regime.

4.4 Robustness Check

Here we discuss the robustness of the impulse response analysis. In the previous subsection we demonstrated that our monetary policy surprises are useful as exogenous instruments to estimate monetary policy effects in terms of whether our monetary policy shocks are exogenous to global economic conditions. Yet as we discuss in the Appendix, we take no explicit steps, in constructing the monetary policy surprises, to control for macroeconomic news about Japan's real economic activity or inflation in the dynamic factor model (see equation (22) in the Appendix). Hence, our monetary policy surprises could include information on the macroeconomic news other than the monetary policy itself. We found, however, that even if we explicitly controlled for the macroeconomic news in the construction of the monetary policy surprises, the estimated impulse responses were no different from those reported in Subsection 4.2.[22]

We also conducted a robustness check on the impulse responses by including in the VAR model the all-industry activity index, unemployment rate, and index for the shipment of investment goods, instead of the IIP. While these alternative variables provided no favorable real effects for the quantitative easing shocks, they did provide favorable real effects for the qualitative easing shocks.

The above robustness checks for the impulse responses to our monetary policy shocks support the empirical results reported in Subsection 4.2.

5 Unconventional Monetary Policy Effects

In this section we explore several implications for the unconventional monetary policy effects on the macroeconomy in terms of two aspects in particular: comparison with existing VAR

[22]More precisely, we controlled for the macroeconomic news on MPM days in the factor model, $X_t = \Lambda F_t + \Gamma \cdot MNEWS_t + e_t$, where X_t represents the twelve financial market variables, F_t represents common factors as monetary policy surprises, and $MNEWS_t$ represents macroeconomic news dummies. We included five news dummies that take a value of one if news about the GDP, unemployment rate, IIP, CPI and Producer Price Index is published on the MPM days.

studies and hypotheses which should be further investigated about the unconventional policy effects.

5.1 Comparison with Unanticipated Policy Shocks

As discussed in Introduction, a number of previous studies have assumed that monetary aggregates such as the MB and excess reserves represent the central bank's policy stance, thus employing the standard recursive VAR approach or its extensions such as the regime-switching and time-varying parameter VAR models. In another VAR approach employed in previous studies, they assume that unconventional monetary policy shocks can be represented collectively as a single unobservable policy shock, thereby imposing sign restrictions on the instantaneous responses of macroeconomic variables to the single policy shock or heterogeneous variance restrictions on the intensity of structural shocks including a single policy shock.

Note that regardless of the difference in identification strategy, exogenous components of the unconventional monetary policy identified in the previous studies are characterized as an "unanticipated" unconventional monetary policy shock–unanticipated in the sense that unlike our "anticipated" policy shock, it does not portend the current and future paths of the MB and COMP. In addition, unlike this paper, those previous studies did not use the composition of the central bank's assets as an unconventional monetary policy indicator. In this subsection we compare the macroeconomic effects of our anticipated unconventional policy shocks, reported in Subsection 4.2, with those of unanticipated ones. For the comparison, we adopt the standard recursive VAR approach based on the Cholesky decomposition to extract an unanticipated unconventional policy shock. The reason that we employ the recursive approach is that the sign restrictions (Schenkelberg and Watzka (2013)) and the heterogeneous variance restrictions (Shibamoto and Tachibana (2017)) yield qualitatively the same impulse responses as the recursive ones using the data from Japan.[23] In doing so, we

[23]Schenkelberg and Watzka (2013) and Shibamoto and Tachibana (2017) focused on the BOJ's quantitative easing period from 2001 to 2006. However, we found that the three alternative approaches yield qualitatively

focus on four dimensions in particular; 1) effects on the MB, 2) effects on the interest rate on long-term government bonds, 3) effects on real economic activity, and 4) sample periods used for measuring unconventional policy effects.

Figures 9 and 10 show estimated impulse responses to the unanticipated MB and COMP shocks obtained using the Cholesky decomposition in the nine-variable VAR system, respectively.[24] We can observe that the evaluation of unconventional policy effects depends much on whether quantitative and qualitative easing shocks are identified as anticipated shocks (Figures 6 and 7) or unanticipated ones (Figures 9 and 10).

Effects on the Monetary Base

The difference in the dynamics of monetary aggregates conditioned on unconventional policy shocks is the most notable for comparison of the anticipated and unanticipated shocks. Existing VAR studies that have identified unconventional monetary policy shocks as unanticipated shocks have shown a contemporaneous impact on monetary aggregates.[25] Indeed, as shown in Figure 9, the unanticipated MB shock leads to an instantaneous increase in the MB, while the anticipated MB shock (i.e., our quantitative easing shock), leads to a gradual increase (Figure 6 and Subsection 4.2). Note that when identifying the anticipated MB shock by imposing restrictions (12) to (15), we do not impose any restrictions other than the intertemporal maximization of the forecast error of the current and future paths of the MB; hence our identification strategy for the anticipated MB shock lets the data speak more for unconventional policy effects on the MB, compared with the one for the unanticipated MB

the same impulse responses across sample periods.

[24]More specifically, in the nine-variable VAR system, we order the variables in the conventional manner: output and prices (IIP, CPI), policy indicators (OCR, MB, COMP) and the four financial variables including the stock price index (SP). For comparison with the anticipated MB and COMP shocks (i.e., the quantitative and qualitative shocks defined in Section 3), the nine-variable VAR system impose the same recursive restriction for the three monetary policy indicators: the OCR, MB, and COMP (see Subsection 3.3). We found that the conventional policy shock–related to the OCR–identified in this recursive VAR system yielded substantially the same impulse responses with those shown in Figure 8, and hence we do not reported here.

[25]Such a contemporaneous impact on monetary aggregates can be observed in Japanese VAR-based studies such as Honda et al. (2013), Schenkelberg and Watzka (2013), Kimura and Nakajima (2016), Hayashi and Koeda (2017), and Shibamoto and Tachibana (2017) for bank reserves, and Iwata and Wu (2006) for M1. As for the U.K. and U.S. VAR study Weale and Wieladek (2016) showed an contemporaneous impact on asset purchases. Gambacorta et al. (2014) showed a contemporaneous impact on total assets of a central bank in industrialized countries.

shock. Given this point, the non-contemporaneous response and the gradual increase of the MB are the most distinguished feature of the anticipated MB shock, and reflect more the actual dynamics of the MB: its target level is achieved gradually after a policy change announcement, but not abruptly in the announcement. We can observe the same tendency for the difference between the anticipated COMP shock (i.e., our qualitative easing shock) and the unanticipated COMP shock: the unanticipated COMP shock has an contemporaneous impact on the COMP (Figure 10), while the anticipated COMP shock does not (Figure 7).

Effects on the Interest Rate on Long-term Government Bonds

Some VAR-based studies of the unconventional monetary policy, particularly in the UK and the US, emphasized its causal effect on the long-term bond yields (Kapetanios et al. (2012), Wright (2012), Baumeister and Benati (2013), and Weale and Wieladek (2016)).[26] Their motivation stems from the assumption that the unconventional policy interventions in the Treasury market would lower the long-term bond yields, and then would spur real economic activity. Under this assumption, they identified an unanticipated policy shock, thereby demonstrating that a stimulative unconventional policy shock would lower the long-term bond yields and narrow the long-short spread of government bonds. However, such results for an unanticipated policy shock in the U.K. and the U.S. are not observed for the unanticipated MB and COMP shocks in Japan, as shown in impulse responses of 10YJGB in Figures 9 and 10, but observed for both the anticipated MB and COMP shocks, as shown in Figures 6 and 7.[27] Note that although the two anticipated shocks, our quantitative and qualitative easing shocks, cause an instantaneous decrease in the long-term government bond yield–an instantaneous contraction of the long-short spread of the 10YJGB and the OCR,– but the dynamics are quite different: the quantitative easing shock has a lasting effect on the

[26]To examine unconventional policy effects on the long-term bond yields, Wright (2012) employed the heterogeneous variance restriction approach, whereas Kapetanios et al. (2012) and Baumeister and Benati (2013) did the sign restriction approach. Weale and Wieladek (2016) employed four alternative approach including the recursive and sign restriction approaches.

[27]As discussed below, however, a significant decrease in 10YJGB is observed for the BOJ's quantitative easing period from 2001 to 2006.

long-term government bond yield, while the qualitative easing shock does not.[28] Irrespective of the difference in the dynamics, however, our two anticipated unconventional shocks lower the long-term government bond yields, as in the UK and the US VAR-based studies.

Effects on Real Economic Activity

Although both our quantitative and qualitative easing shocks lower the long-term government bond yield, the two anticipated shocks have each different effects on real economic activity: the quantitative easing shock has contractionary effects on output (IIP), prices (CPI), and bank's risk appetite (Safe/Risk), while the qualitative easing shock has expansionary ones (Figures 6 and 7). This implies that a decrease in the long-term government bond yield due to the unconventional monetary policy is not necessarily associated with a rise in real economic activity (Okina and Shiratsuka (2004) and Ugai (2007)), and unconventional policy effects on real economic activity would much depend on the policy tools.[29] With regard to the similarity in real effects of the anticipated and unanticipated policy shocks, both the anticipated and the unanticipated COMP shock have expansionary effects on output, prices, and bank's risk appetite (Figures 7 and 10), but neither the anticipated nor the unanticipated MB shock does not (Figures 6 and 9).

Quantitative Easing Period

We have shown that not only the anticipated MB shock, but also the unanticipated MB one, do not have expansionary effects on real economic activity. However, this result is not consistent with those of previous VAR-based studies emphasizing expansionary effects of the central bank's quantitative easing policy–in particular, the BOJ's quantitative easing from March 2001 to March 2006 (Honda et al. (2013), Schenkelberg and Watzka (2013), Hayashi

[28]The qualitative easing shock has a typical feature of the operation twist: while the MB hardly changes following the qualitative shock, the overnight call rate increases and the long-term interest rate (10YJGB) decreases. See Swanson (2011) for effects of the operation twist in the U.S.

[29]Okina and Shiratsuka (2004) empirically demonstrated that although the BOJ's quantitative easing was effective in stabilizing market expectations about the future path of short-term interest rates, thereby lowering longer-term interest rates, such effects failed to be transmitted to the whole economy in Japan. Ugai (2007) also pointed out that the BOJ's quantitative easing had only a limited effect on raising aggregate demand and prices, though succeeded in lowering the yield curve.

and Koeda (2017), and Shibamoto and Tachibana (2017)). With due consideration of their finding for the quantitative easing period in Japan, we also report estimated impulse responses to the anticipated and unanticipated MB shocks obtained using the sample period from March 2001 to March 2006. In Figure A1 of online Appendix A, we can observe that the anticipated MB shock still yields a gradual increase in the MB, and also has contractionary effects on real economic activity even in the BOJ's quantitative easing period. On the other hand, as shown in Figure 2A, the unanticipated MB shock, being accompanied with a contemporaneous increase in the MB and a significant decrease in the long-term government bond yield, has expansionary effects in the quantitative easing period, as in the previous studies. These results indicate that our quantitative easing shock identified as the anticipated MB shock generates robust results across sample results and policy schemes, but the unanticipated MB shock does not.[30] Why the unanticipated MB shock has the expansionary effects only in the quantitative easing period remains an open question.[31]

5.2 Hypotheses about Unconventional Monetary Policy Effects

We have thus far found that our quantitative easing shocks, or the anticipated MB shocks, have no favorable effects on the real economy, although they do precipitate decreases in the long-term nominal interest rate, as expected by the BOJ. On the contrary, our qualitative easing shocks, or the anticipated COMP shocks, cause favorable effects not only on the long-term interest rate, but also on real economic activity. In this subsection we draw from these findings to propose two hypotheses about the unconventional policy effects for future research.

One hypothesis holds that the ineffectiveness of quantitative easing shocks can be explained by their effect in raising concern about the future fragility of the real economy.

[30]We found that both the anticipated and unanticipated COMP shocks have expansionary effects in the qualitative easing period also.

[31]The authors explore this reason by examining the time series property of the unanticipated MB shock. We find that the unanticipated MB shock is substantially associated with both the Japanese and the U.S. stock price index, even if we control the stock prices in the VAR model; hence we infer that it may not be a "pure" monetary policy shock.

According to Romer and Romer (2000), Ellingsen and Söderstrom (2001), Claus and Dungey (2012), Campbell et al. (2012), and Nakamura and Steinsson (2017), monetary policy actions provide the public with signals of the central bank's information. If the quantitative easing by the BOJ worked as a signal presaging future decreases in output and inflation, this signal would suppress firm investment and wage growth.

Another hypothesis involves economic uncertainty and its effect in instilling a caution in real economic activity. Bekaert et al. (2013) used stock market option-based implied volatility data, or VIX data, to demonstrate that conventional policy easing by lowering the short-term interest rate decreases economic uncertainty, which in turn leads to favorable effects on the real economy (see also Aastveit et al. (2013) and Creal and Wu (2017)).[32] If the quantitative easing shock elevates economic uncertainty while the qualitative easing shock contributes to its reduction, the difference in the estimated responses of the real economic variables to the two unconventional policy shocks could be explained along this line.[33]

6 Conclusion

Previous research has found favorable effects of the unconventional monetary policy. Previous studies may take a flawed approach in the policy evaluation by assuming either that the MB is the central bank's only unconventional monetary policy measure or that the underlying unconventional monetary policy shocks can be captured by one variable alone. They neglect to distinguish between quantitative and qualitative monetary policy shocks in both cases, which prevents them from correctly disentangling the policy effects. We proposed a new method to separately identify the two unconventional policy shocks and conventional policy

[32]Creal and Wu (2017) In terms of the instability in investors' inflation expectations, Gürkaynak and Wright (2012) pointed out that the instability could come from a lack of central bank credibility, a problem that might drive a wedge between actual and perceived inflation targets.

[33]Using the volatility index Japan (VXJ), which is provided by The Center of the Study of Finance and Insurance and is in strict accordance with the Chicago Board Options Exchange approach underlying the VIX, we found that the quantitative easing shock would increase the VXJ, while the qualitative easing shock would decrease it. See Figure B in online Appendix B. As with our qualitative easing shock, the unexpected asset purchase identified by Weale and Wieladek (2016) decreases the VIX in both the U.K and the U.S.

shock, using the unconventional monetary policy in place in Japan since 1999.

Previous policy evaluations of unconventional policy effects have also been criticized for assuming that the unconventional monetary policy shock should be embodied as the reduced-form VAR innovations in the MB. This type of identification is the usual method for assessing the conventional monetary policy, in which the central banks aim to control the policy rates. Quantitative and qualitative policy measures, meanwhile, differ from the policy rate in an important respect: by their very nature, both show no immediate responses to the public statements of the central banks on adjustments in their target levels. Our identification method incorporates this feature by defining the two unconventional policy shocks as anticipated shocks that portend the current and future paths of the two policy measures.

We find that the quantitative easing shock, which involves a gradual increase in the size of the BOJ's balance sheet, has contractionary effects on the macroeconomy, while the qualitative easing shock, which involves a gradual increase in the ratio of the BOJ's unconventional asset to its total assets, yields expansionary effects. Both shocks, meanwhile, significantly decrease the long-term nominal interest rate. Our future research will aim to explore why these two unconventional policy shocks yield such different policy effects along the lines suggested in this paper.

Appendix: Procedure for Constructing the Monetary Policy Surprises

We construct the monetary policy surprises from high-frequency daily trading data on the major financial markets just before and just after the BOJ's public statements. More concretely, we employ the principal component analysis method of Bernanke et al. (2004) and Gürkaynak et al. (2005b) and then prepare the monetary policy surprises as common factors of unanticipated changes in the major financial market variables following the public statements.

The principal component analysis method is based on the following factor model:

$$X_t = \Lambda F_t + e_t, \tag{22}$$

where X_t is the vector of n financial times series where all series are transformed as stationary in the rate of changes just before and just after the BOJ's public statements; e_t is the vector of n idiosyncratic disturbance terms; F_t is the vector of r unobserved common factors, and Λ is an $n \times r$ matrix of coefficients called factor loadings. We aim to use the principal component analysis to extract common factors, F_t.

Twelve financial market variables are included in X_t : one futures rate (the three-month euro-yen TIBOR futures rate), five yen interest swap rates (the one-year, two-year, five-year, 10-year, and 30-year yen interest swap rates), one short-term spot rate (the three-month euro-yen TIBOR rate), two spot exchange rates (the Yen-U.S. dollar spot exchange rate and Yen-AUS dollar spot exchange rate in the Tokyo market), two stock price indexes (TOPIX and Nikkei Jasdaq index), and bank reserve deposits. For the seven rate variables, we include their rates of change before and after the public statements. For the exchange rates, stock price indexes, and bank reserve deposits, we include their log-differences as percentages of their rates of change.

The twelve markets close at 3:00 p.m. The BOJ usually holds a press conference at 3:30 p.m. after the MPM, and media such as Bloomberg then convey the news about the BOJ's policy decisions. To duly consider the timing of the news release and the time required for sufficient recognition of the news, we use the closing values from the day before the public statement to the day after the statement to calculate changes over a two-day period for the twelve financial variables.[34]

We preliminarily exclude the MPM dates when the BOJ decided to coordinate policy with the Federal Reserve Bank, the European Central Bank, and the Bank of England and

[34] An event study analysis by Ueda (2012) showed that asset prices, including TOPIX and Japanese government bond yields, significantly respond to monetary policy changes from two days after the BOJ's public statements onward.

when the BOJ determined the policy measures to be taken after the Tohoku earthquake on March 11, 2011, on the presumption that the policy coordination and disaster event would contaminate the BOJ's policy effects.[35]

To select the number of common factors, we employ the information criteria proposed by Bai and Ng (2002) and Ahn and Horenstein (2013). The two information criteria suggest that we should adopt three common factors as monetary policy surprises in the twelve financial markets. When constructing monthly data on the monetary policy surprises, we aggregate two datasets of the three common factors, each of which is generated on two MPM days per month.

[35]The BOJ held MPMs on September 18, 2008, September 29, 2008, and November 30, 2011 for the policy coordination, and on March 14, 2011 for the Tohoku earthquake. We excluded these four MPM days.

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Table 1: Results for the Distributed Lag Regression of Each Monetary Policy Indicator on Monetary Policy Surprises

Lags	Monetary Policy Indicator: y^{MPI}					
	MB	COMP	OCR	Δ MB	Δ COMP	Δ OCR
H =0	1.396	4.292	9.090	1.873	5.125	2.904
	[0.706]	[0.232]	[0.028]	[0.599]	[0.163]	[0.407]
H =1	2.699	10.095	25.236	4.767	6.883	14.080
	[0.846]	[0.121]	[0.000]	[0.574]	[0.332]	[0.029]
H =2	5.661	58.326	34.790	12.970	29.063	23.700
	[0.773]	[0.000]	[0.000]	[0.164]	[0.001]	[0.005]
H =6	8.919	95.340	62.230	20.631	48.051	47.333
	[0.990]	[0.000]	[0.000]	[0.482]	[0.001]	[0.001]
H =12	19.605	185.518	214.987	54.311	95.749	62.147
	[0.996]	[0.000]	[0.000]	[0.052]	[0.000]	[0.011]
H =18	75.483	777.437	248.421	122.122	232.586	141.381
	[0.051]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
H =24	315.375	1852.061	682.937	268.248	567.294	271.981
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

Notes: The distributed lag regression model is specified as equation (1). This table shows Chi-square statistics (their p-values in brackets) resulting from tests of the null hypothesis: $r^{MP,h}_{MPI,pc} = 0$ for all $pc = 1, 2, 3$ and $h = 0, \cdots, H$.

Table 2: Results for the Regression of Each VAR Innovation on Monetary Policy Surprises

	VAR Innovation: $\hat{\epsilon}^k$								
	MB	COMP	OCR	SP	10YJGB	1YREAL	SAFE/RISK	IIP	CPI
χ^2	4.170	2.301	2.998	32.436	15.132	5.429	6.799	2.719	1.064
	[0.244]	[0.512]	[0.392]	[0.000]	[0.002]	[0.143]	[0.079]	[0.437]	[0.786]

Notes: The regression model is specified as equation (19). This table shows Chi-square statistics (their p-values in brackets) resulting from tests of the null hypothesis: $r^{MP}_{k,pc} = 0$ for all $pc = 1, 2, 3$.

Table 3: Forecast Error Variance Decomposition of Monetary Policy Indicators

	Variance Decomposition of MB			Variance Decomposition of COMP			Variance Decomposition of OCR		
	Quantitative	Qualitative	Conventional	Quantitative	Qualitative	Conventional	Quantitative	Qualitative	Conventional
h =0	0.254	98.633	1.113	47.541	21.784	30.676	0	0	100
h =12	57.761	5.387	36.852	34.513	18.628	46.858	42.843	3.683	53.475
h =24	66.763	1.657	31.580	39.334	14.725	45.941	56.867	3.795	39.338
h =36	71.356	1.180	27.463	50.637	11.523	37.841	53.812	9.509	36.679
h =48	74.145	1.224	24.631	56.189	10.165	33.647	46.116	18.849	35.035

Notes: This table shows the estimated percentage share of the forecast error variance $\Omega_{i.j}^{MP}(h)$ of each monetary policy indicator i attributable to each monetary policy shock j for h months ahead.

Table 4: Results for the Regression of Each VAR innovation on Global Economic Factors

Regressors	VAR Innovation: $\hat{\epsilon}^k$								
	MB	COMP	OCR	SP	10YJGB	1YREAL	SAFE/RISK	IIP	CPI
Oil	-3.554	-3.264	0.121	2.121	-0.209	-0.226	0.002	-1.817	0.229
	(2.606)	(6.011)	(0.045)	(5.322)	(0.152)	(0.119)	(0.012)	(2.238)	(0.132)
USIP	8.637	58.560	-0.807	-93.932	-2.913	-2.719	0.311	14.906	0.359
	(26.118)	(50.972)	(0.610)	(63.223)	(1.122)	(1.875)	(0.130)	(34.884)	(1.272)
USSP	9.190	13.783	-0.017	72.483	0.521	0.225	0.036	7.311	0.014
	(4.918)	(9.193)	(0.085)	(8.787)	(0.256)	(0.207)	(0.023)	(4.239)	(0.235)
USTED	-0.366	6.880	0.064	12.375	0.300	0.127	0.015	1.853	-0.156
	(2.355)	(3.794)	(0.066)	(7.317)	(0.129)	(0.218)	(0.012)	(3.795)	(0.221)
FFR	-1.345	0.251	0.000	1.071	0.075	0.069	0.001	0.066	-0.007
	(1.279)	(2.234)	(0.022)	(2.204)	(0.045)	(0.042)	(0.006)	(0.765)	(0.054)
χ^2	4.231	6.828	10.399	85.956	17.170	10.095	12.334	3.256	4.675
	[0.517]	[0.234]	[0.065]	[0.000]	[0.004]	[0.073]	[0.030]	[0.661]	[0.457]

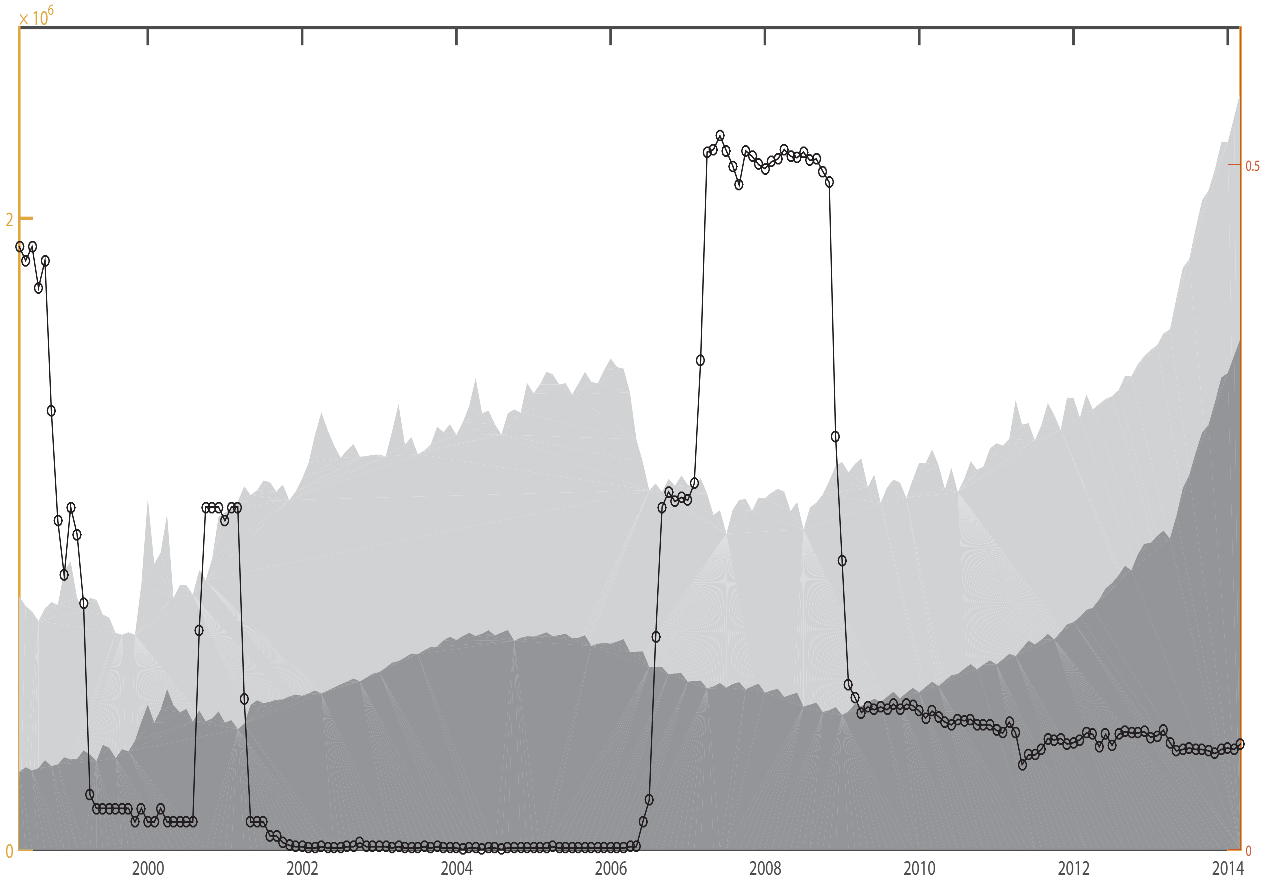
Notes: This table shows estimated coefficients in equation (20). Values in parentheses are standard errors. This table shows Chi-square statistics (their p-values in brackets) resulting from tests of the null hypothesis: $r_{k,l}^{x} = 0$ for all l =Oil,USIP,USSP,USTED,FFR.

Table 5: Results for the Regression of Each Monetary Policy Shock on Global Economic Factors

Regressors	Monetary Policy Shock: $\hat{\xi}^{MP*,j}$		
	Quantitative	Qualitative	Conventional
Oil	0.707	1.031	-0.408
	(1.153)	(1.216)	(1.067)
USIP	4.614	-5.285	-12.472
	(12.569)	(12.779)	(10.711)
USSP	-5.190	2.022	-2.677
	(2.853)	(2.999)	(1.533)
USTED	-0.371	-1.590	-1.383
	(2.137)	(1.606)	(1.420)
FFR	-0.459	-0.025	-0.388
	(0.483)	(0.411)	(0.378)
χ^2	3.852	2.512	6.507
	[0.571]	[0.775]	[0.260]

Notes: This table shows estimated coefficients in equation (21). Values in parentheses are standard errors. This table shows Chi-square statistics (their p-values in brackets) resulting from tests of the null hypothesis: $r^x_{j,l} = 0$ for all l=Oil,USIP,USSP,USTED,FFR.

Figure 1: Size, Unconventional Assets and Call Rate



Notes: The dark gray shadow and light gray shadow indicate the amounts of unconventional assets and conventional assets held by the Bank of Japan, respectively. The amounts are shown in units of 100 trillion Yen on the left-hand scale. The plotted line indicates the call rate in % on the right hand scale. Unconventional Assets include Exchange-Traded Funds (ETF), Real Estate Investment Trusts (RIET), corporate bonds, commercial paper, long-term government bonds, asset backed securities. Conventional assets include other assets such as short-term government bonds.

Figure 2: Monetary Policy Variables around the Introduction of ZIRP

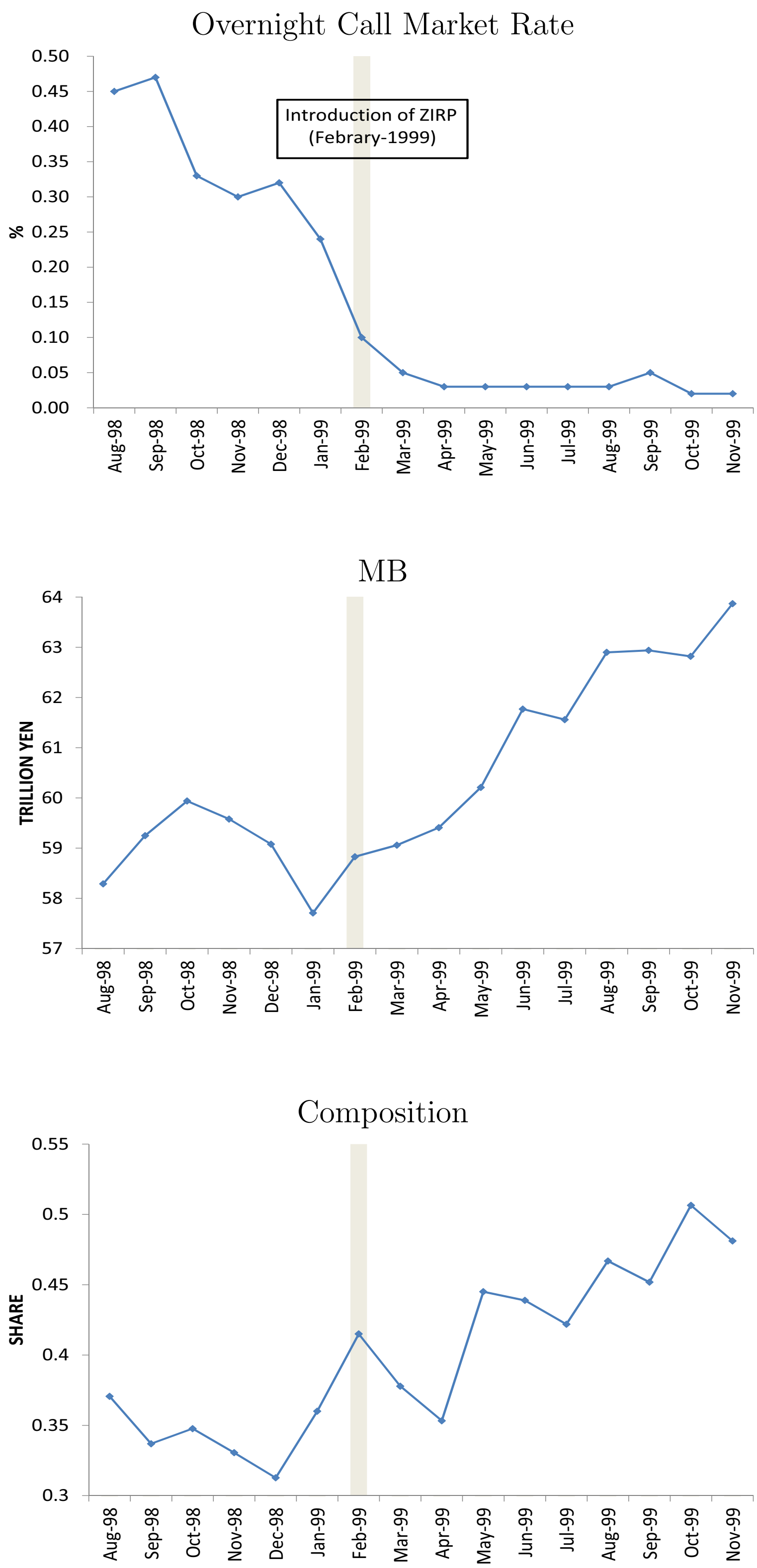


Figure 3: Monetary Policy Variables around the End of ZIRP and the Introduction of QEMP

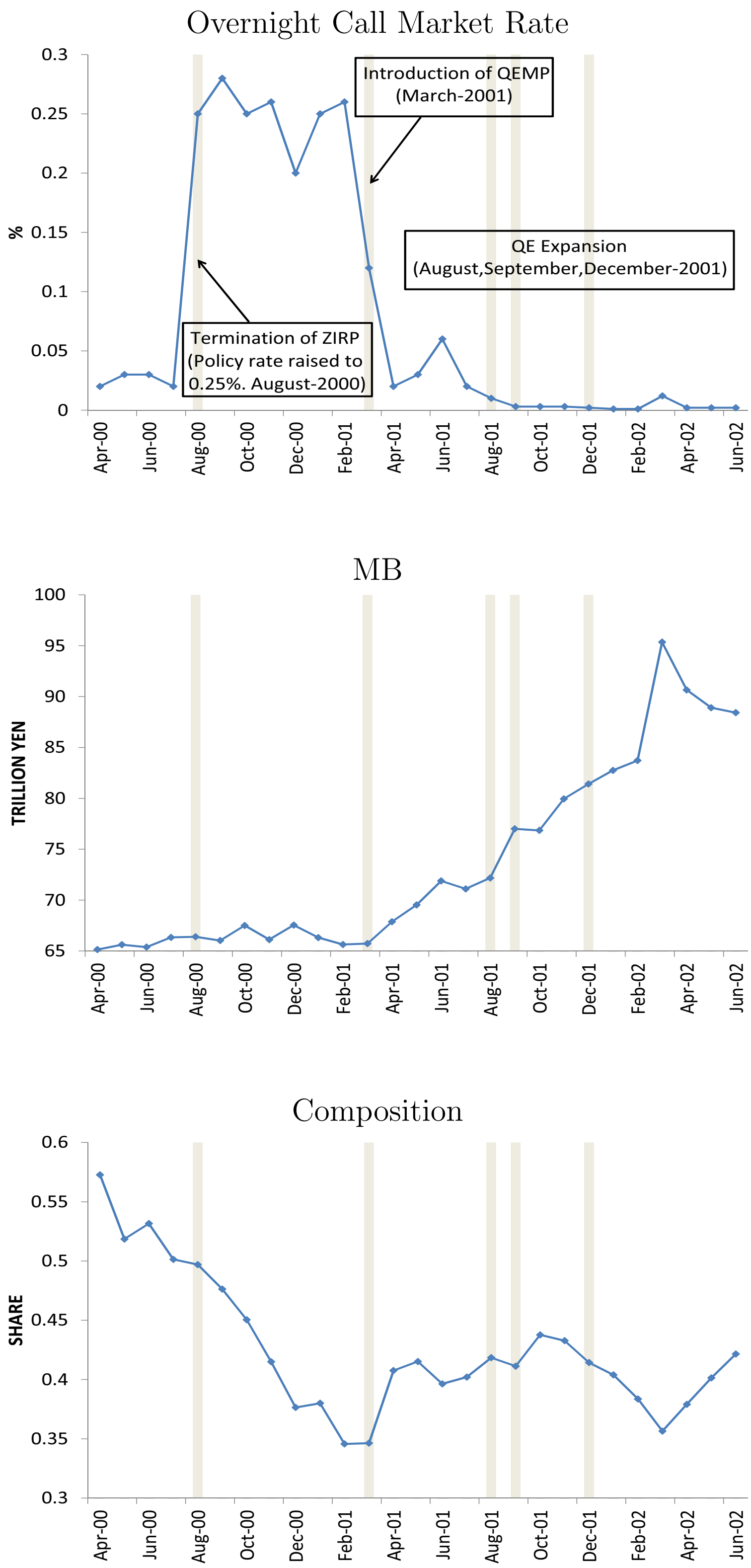


Figure 4: Monetary Policy Variables around the End of QEMP

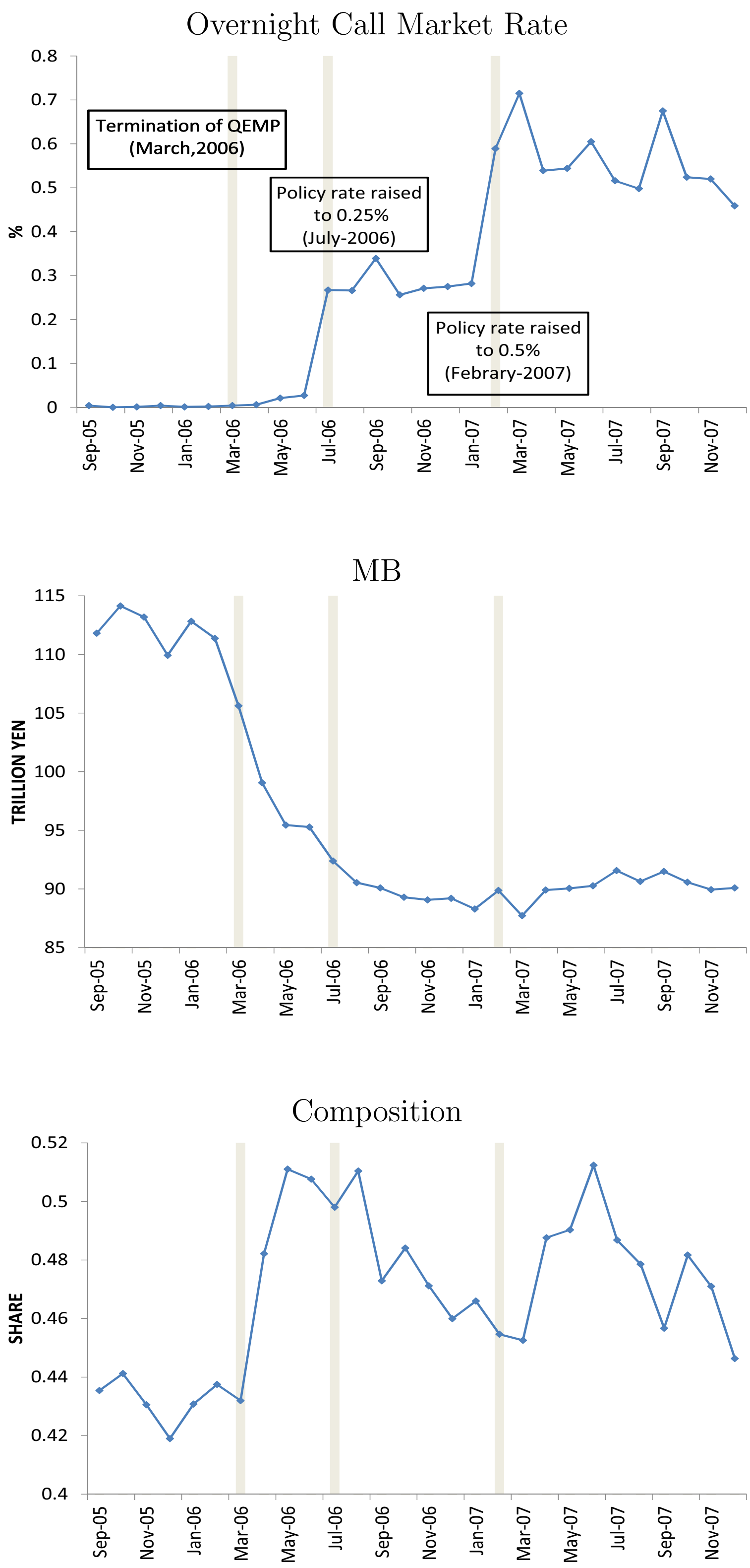


Figure 5: Monetary Policy Variables around the Introduction of QQE

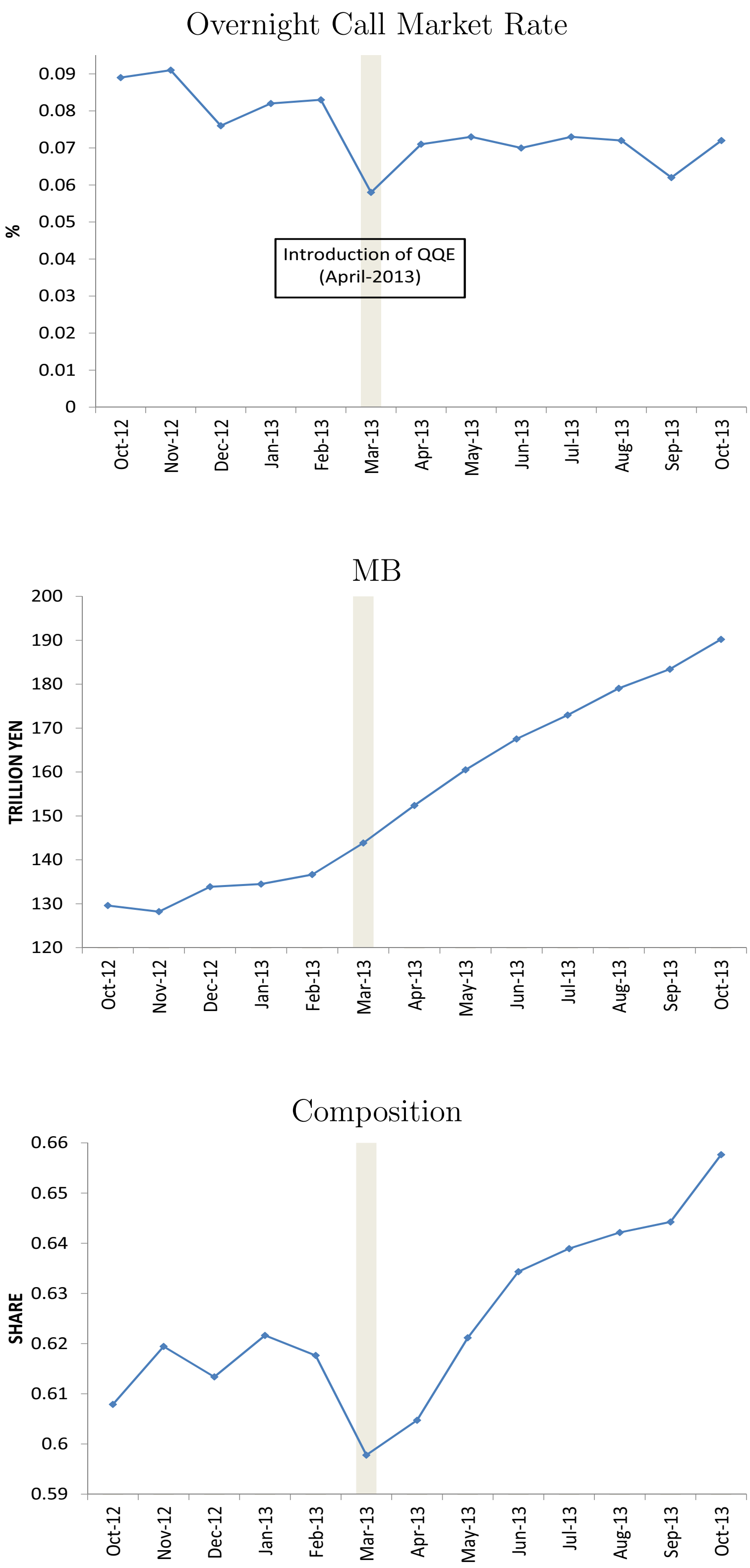
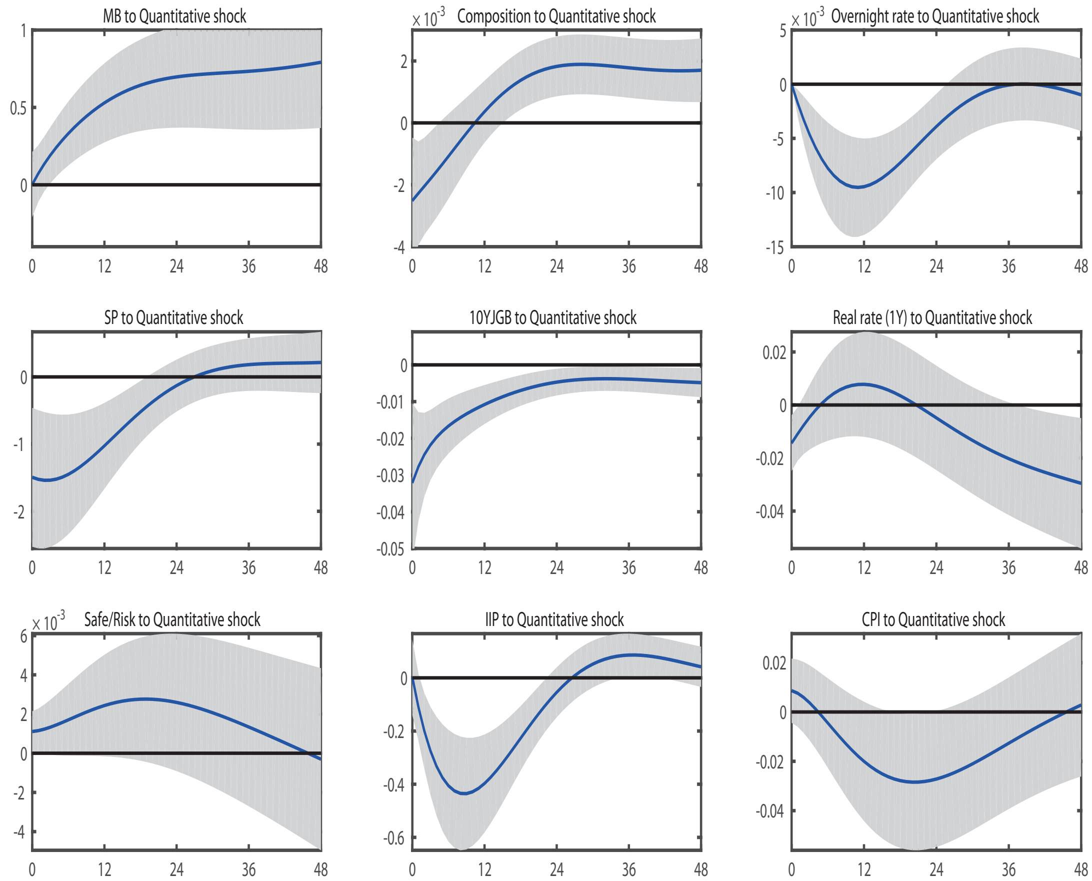
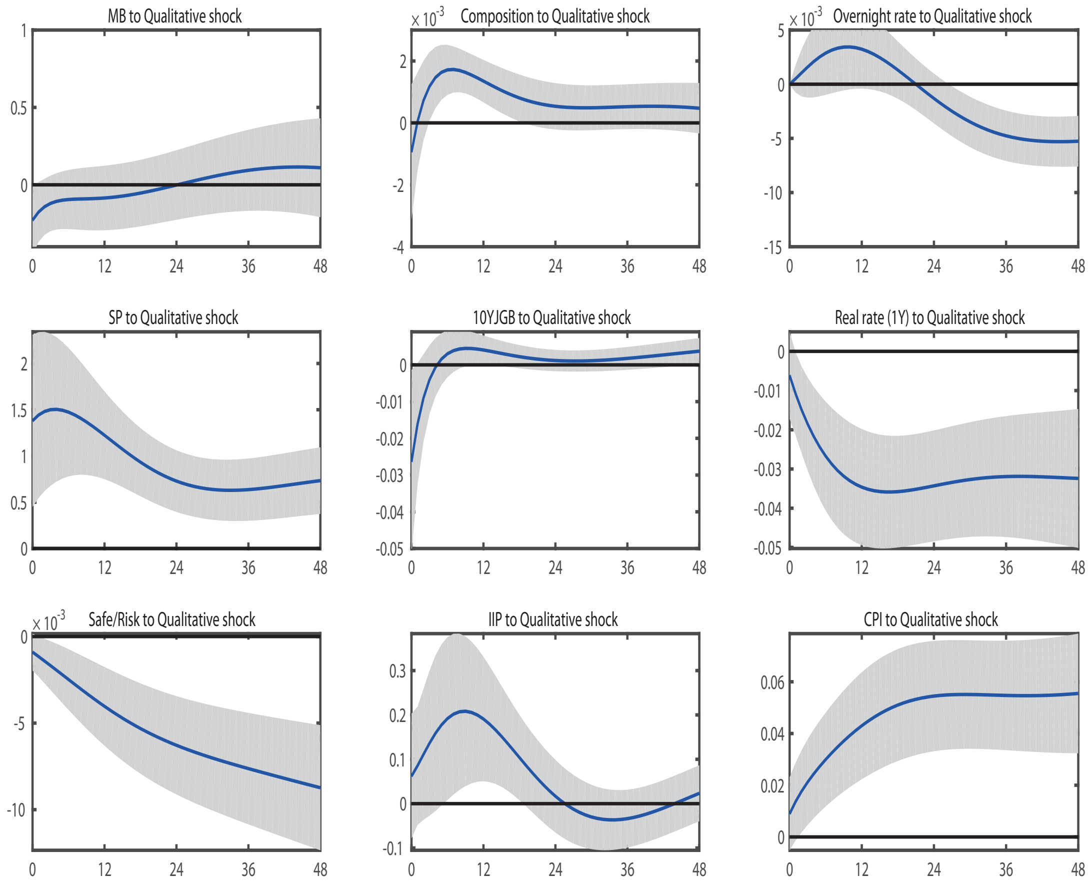


Figure 6: Impulse Responses to the Quantitative Easing Shock



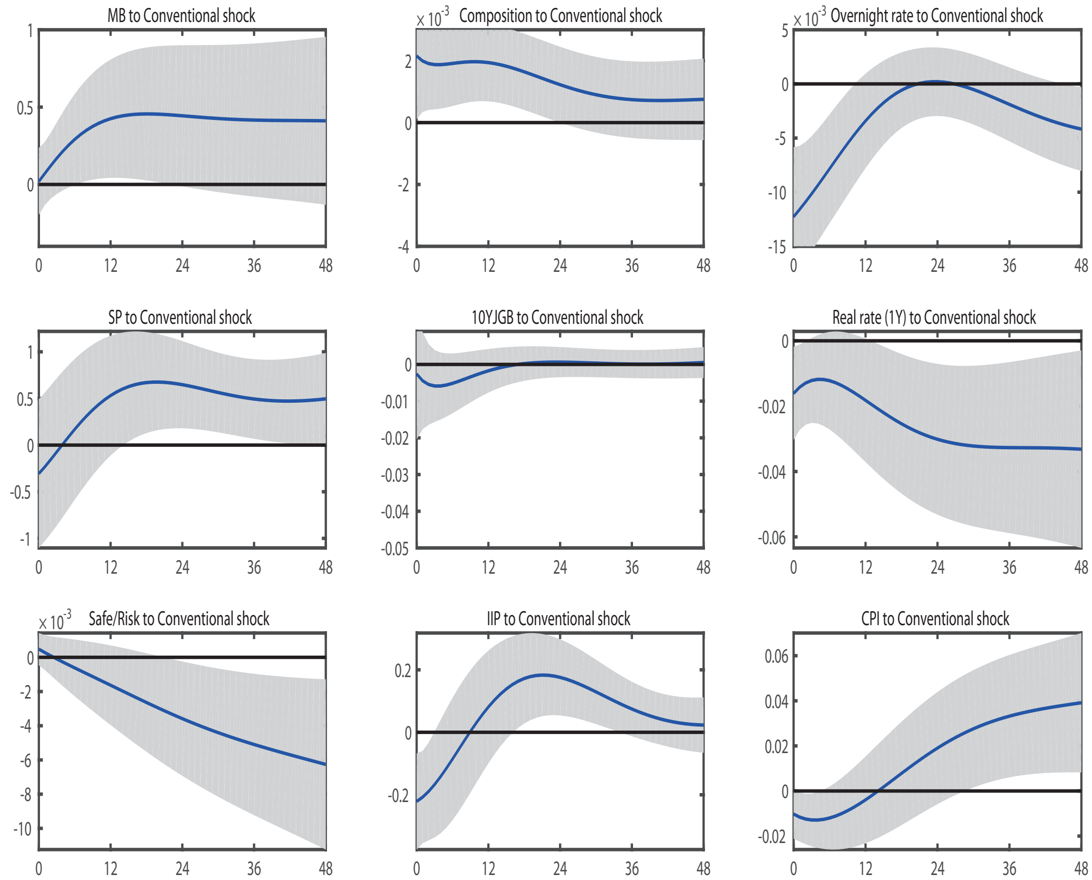
Notes: The solid lines represent the point estimates of the impulse responses to a quantitative monetary policy shock in the baseline VAR model. The shaded areas represent the ± one standard error confidence band calculated by the bias-adjusted bootstrap method with 1000 replications.

Figure 7: Impulse Responses to the Qualitative Easing Shock



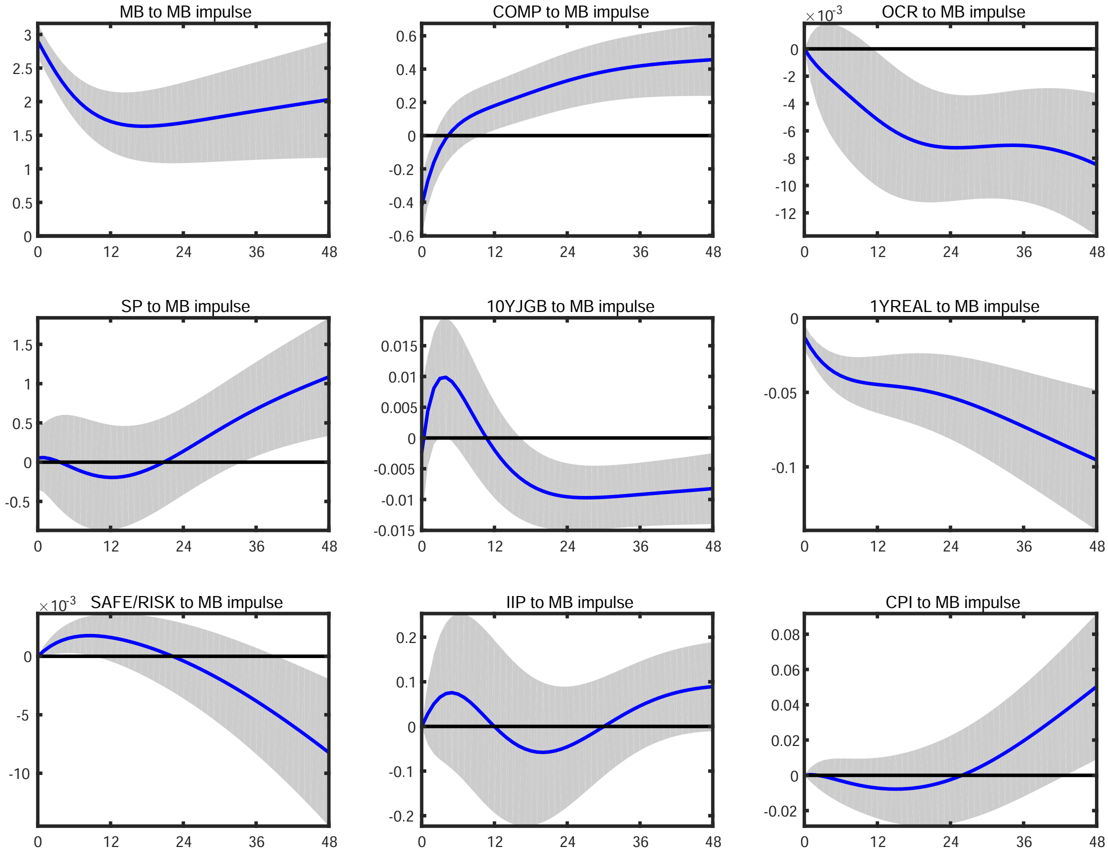
Notes: The solid lines represent the point estimates of the impulse responses to a qualitative monetary policy shock in the baseline VAR model. The shaded areas represent the ± one standard error confidence band calculated by the bias-adjusted bootstrap method with 1000 replications.

Figure 8: Impulse Responses to the Conventional Monetary Policy Easing Shock



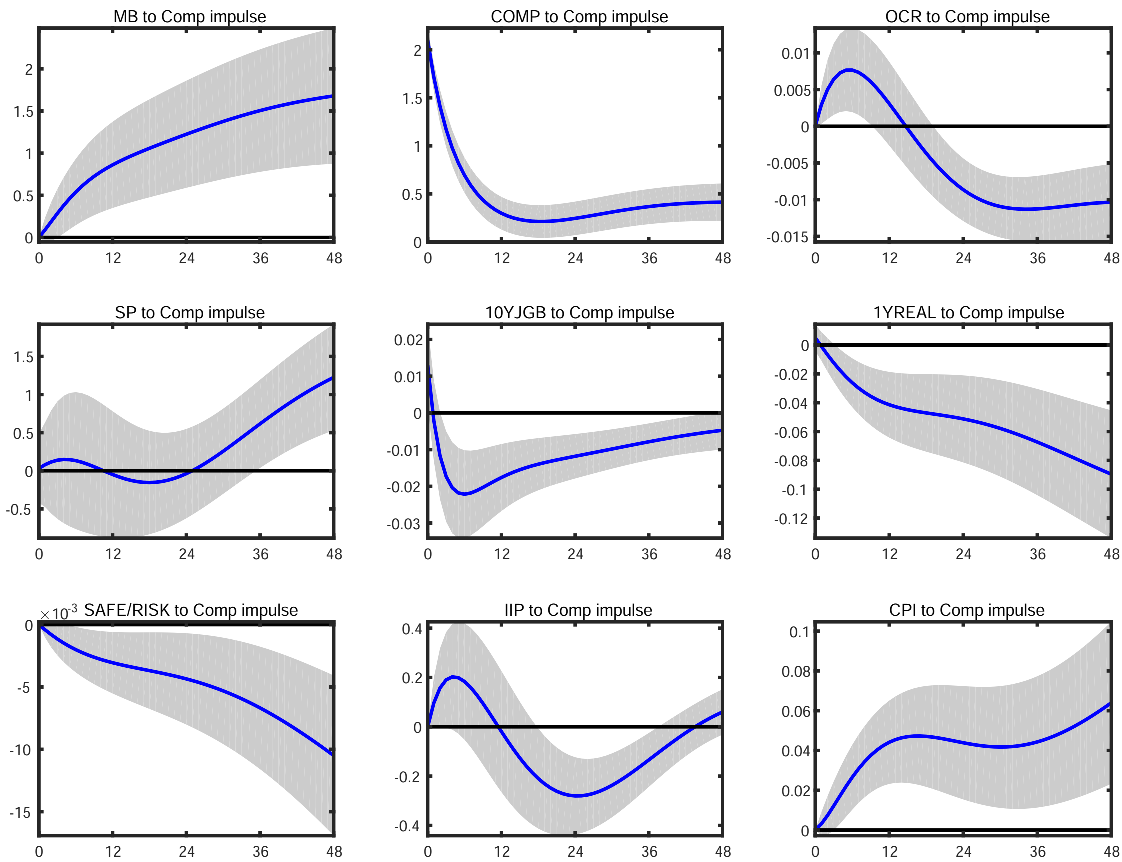
Notes: The solid lines represent the point estimates of the impulse responses to a conventional monetary policy shock in the baseline VAR model. The shaded areas represent the ± one standard error confidence band calculated by the bias-adjusted bootstrap method with 1000 replications.

Figure 9: Impulse Responses to the Unanticipated MB Shock



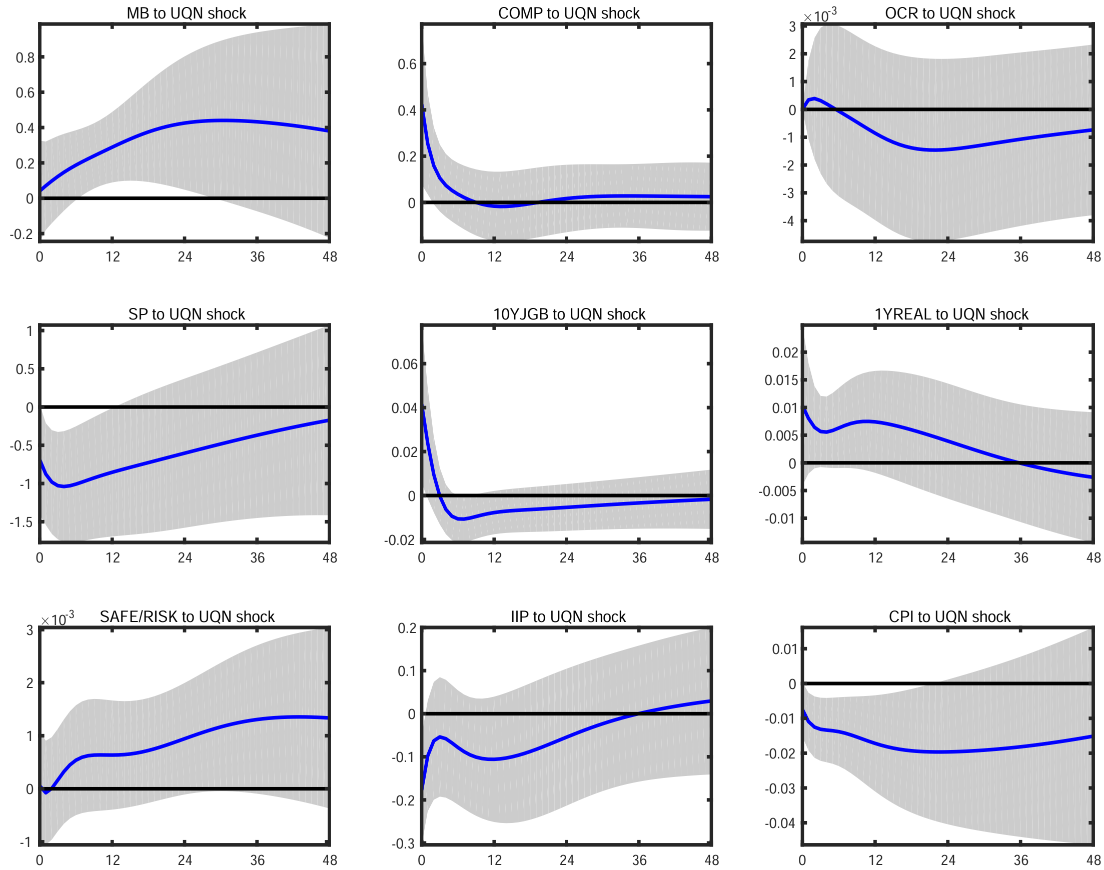
Notes: The solid lines represent the point estimates of the impulse responses to a MB shock obtained using the Cholesky decomposition in the nine-variable VAR system. The shaded areas represent the ± one standard error confidence band calculated by the bias-adjusted bootstrap method with 1000 replications.

Figure 10: Impulse Responses to the Unanticipated COMP Shock



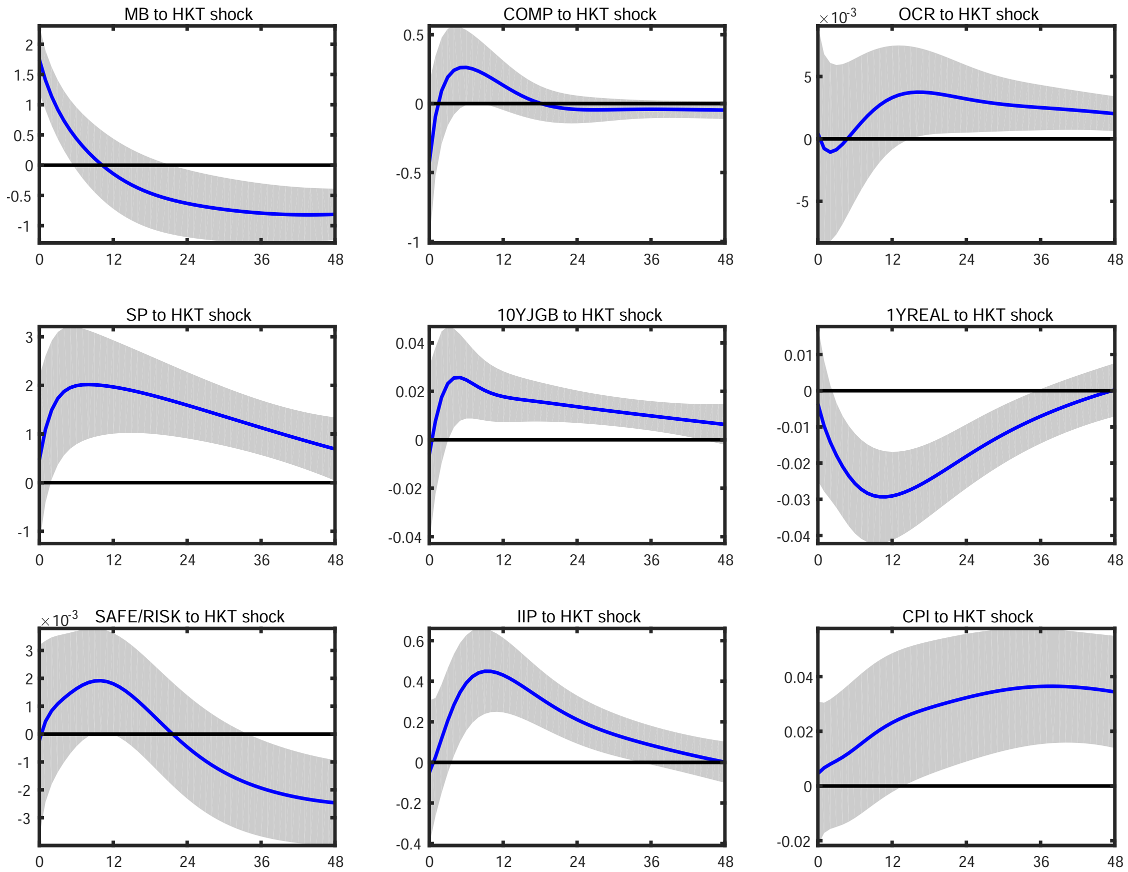
Notes: The solid lines represent the point estimates of the impulse responses to a COMP shock obtained using the Cholesky decomposition in the nine-variable VAR system. The shaded areas represent the ± one standard error confidence band calculated by the bias-adjusted bootstrap method with 1000 replications.

Figure A1: Impulse Responses to the Quantitative Easing Shock



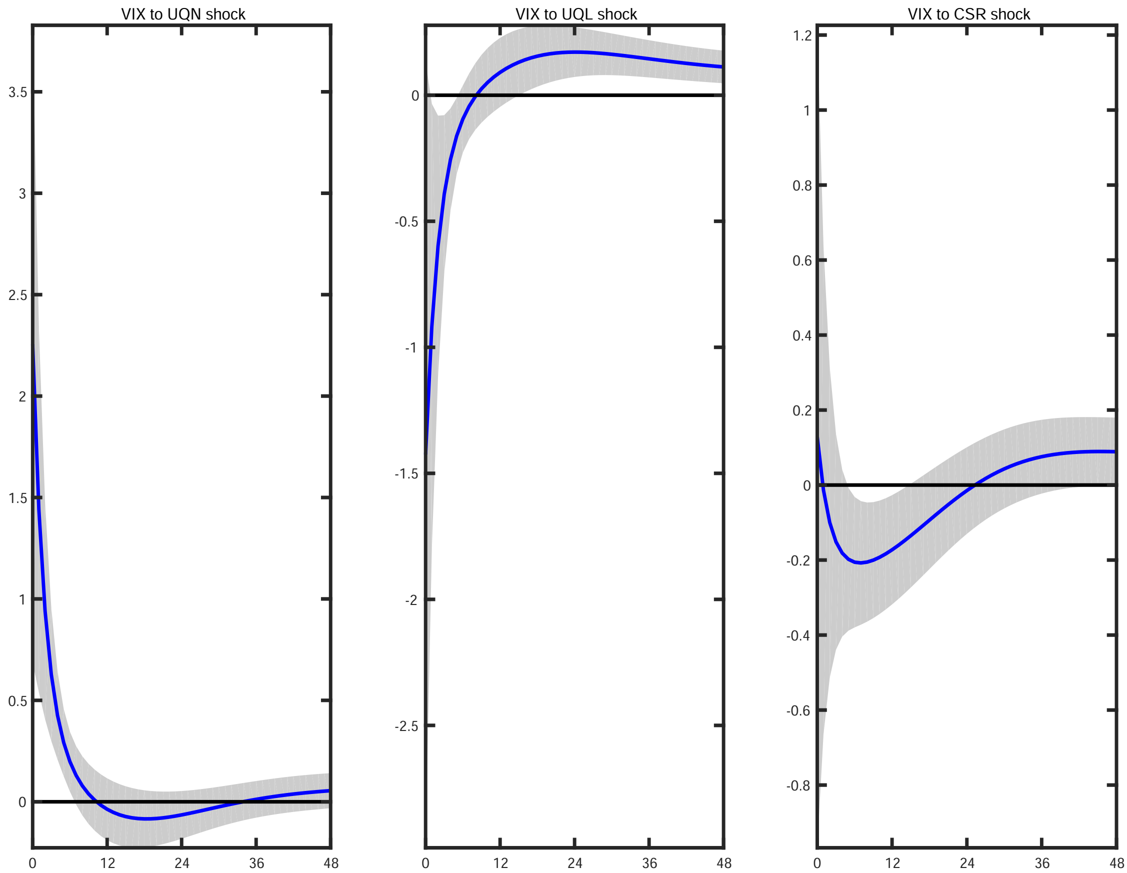
Notes: The solid lines represent the point estimates of the impulse responses to a quantitative monetary policy shock in the baseline VAR model using subsample from March 2001 to March 2006. The shaded areas represent the ± one standard error confidence band calculated by the bias-adjusted bootstrap method with 1000 replications.

Figure A2: Impulse Responses to the Unanticipated MB Shock



Notes: The solid lines represent the point estimates of the impulse responses to a MB shock obtained using the Cholesky decomposition in the nine-variable VAR system using subsample from March 2001 to March 2006. The shaded areas represent the ± one standard error confidence band calculated by the bias-adjusted bootstrap method with 1000 replications.

Figure B: Impulse Responses of VIX



Notes: The solid lines represent the point estimates of the impulse responses of VIX. The shaded areas represent the ± one standard error confidence band calculated by the bias-adjusted bootstrap method with 1000 replications.