Identifying Quantitative and Qualitative Monetary Policy Shocks*

Kiyotaka Nakashima † Masahiko Shibamoto ‡
Konan University Kobe University

Koji Takahashi §
Bank of Japan

February 2020

Abstract. This paper proposes a method for identifying quantitative and qualitative monetary policy shocks in the balance sheet operations of a central bank. The method is agnostic and flexible as it relies on no assumptions on how the size and composition of the central bank's balance sheet will respond after the bank makes a policy decision. We identify two types of policy shocks as "anticipated" shocks that best portend the current and future paths of these policy instruments in response to them. We obtain evidence that qualitative easing shocks have expansionary effects on the economy while quantitative easing shocks do not.

JEL Classification: E52, E58.

Keywords: quantitative easing; qualitative easing; conventional monetary policy; vector autoregressive model; anticipated shock

* This paper was previously circulated under the title "Identifying Unconventional Monetary Policy Shocks" but has since been substantially revised. We are grateful for the helpful comments and discussions by Kosuke Aoki, Natsuki Arai, Yoosoon Chang, Michael Dowell, Hiroshi Fujiki, James Hamilton, Naoko Hara, Philipp Hartmann, Yuzo Honda, Takeo Hoshi, Hibiki Ichiue, Keiichiro Inaba, Ryo Jinnai, Atushi Kataoka, Ryo Kato, Junko Koeda, Kenneth Kuttner, Ko Munakata, Michael Murach, Ryuzo Miyao, Yoji Morita, Yasutomo Murasawa, Tatsuyoshi Okimoto, Hugh Patrick, Mototsugu Shintani, Etsuro Shioji, Shigenori Shiratsuka, Koichiro Suzuki, Takeru Terao, Yoshiro Tsutsui; by seminar participants from the Bank of Japan, Columbia University, Hitotsubashi University, Kobe University, and Konan University; and by conference participants from the 2016 Japanese Economic Association Autumn Meeting, 2017 Western Economic Association Annual Meeting, 2018 China Meeting of the Econometric Society, 2018 Asian Meeting of the Econometric Society, 2018 International Association for Applied Econometrics Annual Conference, and 2019 CEBRA Annual Meeting. We would also like to thank Miho Kohsaka for providing excellent research assistance. This study received financial support in the form of Grants-in-Aid from the Japanese Ministry of Education and Science. The views expressed in this paper are mainly those of the third author and do not necessarily reflect the official views of the Bank of Japan.

† Kiyotaka Nakashima, Faculty of Economics, Konan University, Okamoto 8-9-1, Higashinada, Kobe, 658-8501, Japan, e-mail: kiyotaka@konan-u.ac.jp.

‡ Correspondence to: Masahiko Shibamoto, Research Institute for Economics and Business Administration, Kobe University, 2-1, Rokkodai, Nada, Kobe, 657-8501, Japan, e-mail: shibamoto@rieb.kobe-u.ac.jp.

§ Koji Takahashi, Financial System and Bank Examination Department, Bank of Japan, 2-1-1, Nihonbashi-Hongokucho, Chuo-ku, Tokyo, 103-8660, Japan, e-mail: kouji.takahashi-2@boj.or.jp

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 a so-called unconventional monetary policy. By setting the targeted overnight call rate to almost 0%, the BOJ adopted a quantitative easing policy in March 2001. Under this policy framework, the monetary base, or size of the BOJ's balance sheet, expanded at an overnight call rate of 0% through the growth of excess reserves in the BOJ's current account bases (see Figure 1). The BOJ discontinued its quantitative easing policy in March 2006 but has kept the targeted rate 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, such as long-term JGBs and risk assets (e.g., exchange-traded funds (ETF) and real estate investment trusts (REIT)), on its balance sheet.[1] Central banks in industrialized countries such as the U.K., U.S., and Euro area countries have followed with their own unconventional policy frameworks characterized by similar increases in the sizes of the central bank balance sheets and changes in the balance sheet compositions at extremely low policy-targeted interest rates.

While 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 that precisely reflect 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? Starting from the premise that monetary aggregates such as the monetary base and excess reserves represent a central bank's policy stance, several previous studies have used reduced-form VAR innovations

[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.

as exogenous components of the unconventional monetary policy (Iwata and Wu (2006), Inoue and Okimoto (2008), Honda et al. (2013), Kimura and Nakajima (2016), Miyao and Okimoto (2017), and Hayashi and Koeda(2018)).[3] This empirical strategy is essentially an extension of the standard recursive VAR approach to estimate the effects of the conventional monetary policy of controlling short-term nominal interest rates (Bernanke and Blinder (1992) and Christiano et al. (1996)).[4]

Other empirical studies on unconventional policy effects have 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 apply a VAR analysis that imposes sign restrictions on the impulse responses of the macroeconomic variables to single monetary policy shocks (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 single policy shocks (Wright (2012), Rogers et al. (2014), and Shibamoto and Tachibana (2017)).[5]

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 unconventional monetary policy implemented by the BOJ in its balance sheet operations has been arranged in two dimensions: a *quantitative* easing setting and *qualitative* easing

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

[4] Rudebusch (1998) and Nakamura and Steinsson (2018) discuss concerns underlying the use of the standard recursive VAR approach to identify monetary policy shocks.

[5] Non-VAR approaches that assume a single unobservable unconventional monetary policy shock also include the event study approach (Gagnon et al. (2011), Krishnamurthy and Vissing-Jorgensen (2011), Joyce et al. (2011), Swanson (2011), and Ueda (2012)) and the difference-in-difference approach (Foley-Fisher et al. (2016) and Rodnyansky and Darmouni (2017)).

setting.

In this paper we introduce a novel identification approach to disentangle the causal effects of the BOJ's quantitative and qualitative monetary policy shocks on macroeconomic variables. We first show how the unconventional policy indicators respond to the BOJ's policy decisions on a number of specific days when monetary policy meetings are held. Then we propose a new strategy for coping with the issues entailed in identifying the unconventional monetary policy shocks by focusing on two issues: the endogeneity of the monetary policy indicators, and quantitative and qualitative monetary policy shocks as "anticipated" shocks.

Following in the vein of 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; 2005b; 2007), Honda and Kuroki (2006), Campbell et al. (2012), and Nakamura and Steinsson (2018)). The BOJ decides its policy scheme at monetary policy meetings (previously, the meetings were held once or twice a month) and publicly states its policy decision just after each meeting. We exploit the idea that monetary policy shocks are reflected in the changes of asset prices just after the BOJ deploys its main communication tool, the public statement it issues on the latest monetary policy meeting. 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.[6]

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 regarded reduced-form VAR innovations of monetary aggregates such as the monetary base as unconventional policy shocks. Others have imposed restrictions on the impulse responses of some of the variables to a single

[6] See Ramey (2016) and Stock and Watson (2012; 2018) for detailed surveys 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.

unobserved unconventional policy shock. Regardless of the difference in methodology, both of these approaches assume that all monetary policy shocks to monetary aggregates are "unanticipated," and both approaches provide evidence that unconventional policy shocks yield favorable effects on the macroeconomy. The identification of shocks, however, is unsuitable 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 may 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. If, however, 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 short-term policy rate, we run the risk of misspecifying those anticipated changes as unanticipated shocks.

Premising that 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.[7] We identify the unconventional shocks using the maximum forecast error variance (MFEV) approach from Francis et al. (2014), a method that builds on the work of Faust (1998) in the framework of monetary policy analysis. 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.[8] Two features of the MFEV approach make it more agnostic

[7] 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. Tsuruga and Wake (2019) find that a time lag between the decision and implementation of money-financed fiscal stimulus may cause a recession by using New Keynesian DSGE model, indicating the importance of distinguishing between anticipated and unanticipated stimulus.

[8] Unlike the MFEV approach, Faust's approach maximizes the contribution at a predetermined finite horizon. In addition to the recursive restriction and the sign restriction approach, Weale and Wieladek (2016) also employed Faust's approach in an analysis of the U.K. and U.S. unconventional monetary policy. Their study identified the asset purchase announcement shock as the process that most robustly explained

and flexible than the existing approaches in identifying unconventional policy shock. First, the MFEV approach relies on no assumptions of the central bank's two balance sheet instruments. Second, the approach isolates the primary driver of a time series process as an anticipated shock and can be applied to any case in which the same dominant driving process exists (Francis et al. (2014)). The MFEV approach is suitable for identifying the two unconventional monetary policy shocks, given that the BOJ implements the unconventional monetary policy by altering the expected future course of monetary policy actions, including the balance sheet operations in its statement (Okina and Shiratsuka (2004)). Both types of shock are identified as the processes that most fully explain the revisions in the agent's expectations of the future course of the two unconventional policy indicators. To our knowledge, this paper is the first to identity unconventional monetary policy shocks as shocks on the expected paths of a central bank's quantitative and qualitative measures in its balance sheet operations.

By identifying quantitative and qualitative monetary policy shocks, we provide robust 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 shock, the shock that increases the BOJ's unconventional asset ratio to its total assets, brings about expansionary effects.

The remainder of this paper is organized as follows. Section 2 constructs our monetary policy surprise measures and examines the movement of each policy indicator in response to the BOJ's monetary policy shocks. Section 3 discusses a method to identify quantitative and qualitative monetary policy shocks as anticipated shocks. Section 4 reports the estimation results for the unconventional monetary policy shocks. Section 5 explores the robustness of our empirical findings on unconventional monetary policy effects, along with several implications of the findings. Section 6 closes the paper with concluding comments. The Appendix provides detailed definitions of the variables used in this paper.

the forecast error variance of asset purchases, with a three month delay. Compared with the asset purchase announcement shock, however, the unconventional monetary policy shocks we identified by the MFEV approach cause the size and composition of the BOJ's balance sheet to reach a peak much later (to be discussed later, in Subsection 4.2).

2. Monetary Policy Surprises and the Movements of Monetary Policy Indicators in Response 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. After beginning this section with a discussion of the source from which monetary policy shocks originate, we examine the movements of monetary policy indicators in response to monetary policy shocks. In doing so, we demonstrate why it becomes necessary to apply our method of using the structural VAR approach to identify monetary policy shocks in relation to each of three policy indicators, one conventional and two unconventional. The conventional policy indicator is the uncollateralized overnight call rate, that is, the BOJ's targeted short-term policy rate. The unconventional policy indicators are the monetary base and the composition ratio of the BOJ's unconventional assets to its total assets. The unconventional assets include long-term JGBs, ETFs, stock, REITs, commercial papers, and corporate bonds.[9] Within the framework of the BOJ's unconventional monetary policy, the unconventional assets ratio is regarded as a qualitative policy indicator (Shiratsuka (2010) and Ueda (2012)), while the monetary base, or the size of the BOJ's balance sheet, is regarded as a quantitative policy indicator.

Note that we use the sample period from April 1998 to January 2016 throughout this paper. We selected this sample period for two reasons: first, because the BOJ publishes detailed data on its asset composition from April 1998; second, because the transmission mechanism through control of the short-term rate may change when the policy rate turns negative after the BOJ introduces a negative interest policy in February 2016 (see e.g., Brunnermeier and Koby (2019) and Eggertsson et al. (2019)). The Appendix provides detailed definitions of the variables used in this paper.

2.1. **Monetary Policy Surprises** The BOJ decides its policy scheme in a monetary policy meeting (MPM) held about twice per month and publicly states its policy decisions just after the meeting closes. We can assume, therefore, that the BOJ's monetary policy shocks originate from revisions in the expectations of agents in the asset markets. This

[9] We obtain each component of the unconventional assets from Bank of Japan Accounts.

empirical strategy helps us overcome identification problems that would arise with regard to endogenous responses of monetary policy if we simply treated 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)).[10] As an alternative, therefore, 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. This approach will be discussed in the next section.

Previous studies constructed monetary policy surprises by focusing on changes in short-term interest rate futures and using high-frequency daily trading data. Kuttner (2001), Cochrane and Piazzesi (2002), Gürkaynak et al. (2005a; 2005b; 2007), Campbell et al. (2012) and Nakamura and Steinsson (2018) 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.

This strategy, however, is of limited use for our purposes, given that short-term interest rate futures have hardly changed since the BOJ introduced its unconventional monetary policy. Here, therefore, we depart from the 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), Gürkaynak et al. (2005b), and Swanson (2018) to prepare for monetary policy surprises as common factors of unan-

[10] 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.

ticipated changes in the major financial market variables following public statements. If we obtain l common factors for market participant surprises over a central bank's policy decisions, we can construct at most l types of monetary policy shocks.

The principal component analysis of monetary policy on meeting day t is based on the following equation:

$$\mathbf{X_t} = \mathbf{\Lambda F_t} + \eta_\mathbf{t}, \tag{1}$$

where $\mathbf{X_t} = (x_{1t}, .., x_{nt})'$ denotes the vector of n financial time series, $\eta_\mathbf{t}$ indicates the vector of n idiosyncratic disturbance terms, $\mathbf{F_t}$ is the vector of l unobserved common factors, and $\mathbf{\Lambda}$ is a matrix of the coefficients identified as factor loadings. We aim to extract common factors $\mathbf{F_t}$ by using the factor model. We include 12 financial market variables x_{it} $(i = 1, .., 12)$: one futures rate (three-month euro-yen TIBOR futures), five yen interest swap rates (1, 2, 5, 10, 30 years), one short-term spot rate (three-month euro-yen TIBOR), two spot exchange rates on the Tokyo market (yen-U.S. dollar and yen-AUS dollar), two stock indexes (TOPIX and Nikkei JASDAQ), and bank reserve deposits.[11]

We calculate the differences in the seven interest rate variables and the log differences of the two exchange rates, two stock indexes, and bank reserves as percentages of the rate of change before and after public statements. More concretely, we use the closing values at 3:00 p.m. from the day before the public statement to the day after the statement to calculate changes of the 12 financial variables over the two-day period in order to duly consider the timing of the public statement and the time required for the news to be sufficiently recognized (see Ueda (2012)).[12] That is, for stock prices, exchange rates, and

[11] Here we take no explicit steps, in constructing the monetary policy surprises, to control for macroeconomic news about real economic activity or inflation in the dynamic factor model. 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 results for quantitative and qualitative monetary policy effects were no different from those reported in Sections 4 and 5. More precisely, we controlled for the macroeconomic news on policy meeting days in the factor model, $\mathbf{X_t} = \mathbf{\Lambda F_t} + \mathbf{\Gamma M_t} + \eta_\mathbf{t}$, where $\mathbf{M_t}$ represents macroeconomic news dummies. We included five news dummies, assigning each a value of one if any news about the GDP, unemployment rate, Industrial Production Index, Consumer Price Index, or Producer Price Index was published on policy meeting days.

[12] An event study analysis by Ueda (2012) showed that asset prices, including TOPIX and Japanese

bank reserves, x_{it} is defined as follows:

$$x_{it} = \log(P_{it+1}/P_{it-1}) \times 100, \tag{2}$$

and for interest rates,

$$x_{it} = r_{it+1} - r_{it-1}, \tag{3}$$

where P_{it+1} and P_{it-1} indicate the closing values of exchange rates, stock indexes, and bank reserves on the day after a monetary policy meeting and the closing values of the same on the day before the monetary policy meeting, respectively, and r_{it+1} and r_{it-1} denote the closing interest rates.

We preliminarily exclude the dates of the meetings at which the BOJ coordinated policy with the Fed, the European Central Bank, or the Bank of England. We also exclude the date on which the BOJ agreed on its policy responses to the Tohoku earthquake of March 11, 2011, as policy coordination and disaster response would be likely to contaminate the BOJ's policy effects.[13]

We select the number of common factors using the information criteria proposed by Bai and Ng (2002) and Ahn and Horenstein (2013): the former and the latter respectively suggested that the preferred model is the one that minimizes and maximizes the information criteria. Table 1 reports the two information criteria applied. These criteria suggest that we should adopt three common factors as monetary policy surprises in the twelve financial markets. We can therefore construct at most three types of monetary policy shocks.

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.

government bond yields, significantly respond to monetary policy changes from two days after the BOJ's public statements onward. For a robustness check, however, we also used narrower time windows to extract the monetary policy surprises. We found that the results are qualitatively the same as those reported below.

[13] The BOJ held meetings on September 18, 2008, September 29, 2008, and November 30, 2011 to coordinate policy. In a meeting on March 14, 2011, the BOJ agreed on its policy response to the Tohoku earthquake.

2.2. **Monetary Policy Indicators' Response** In this subsection we examine the statistical relevance among the monetary policy surprises and monetary policy indicators based on how differently each of the monetary policy indicators responds to monetary policy shocks whose information is contained in monetary policy surprises. To this end, we run the following distributed lag regression of the policy indicators on the current and lagged monetary policy surprises:[14]

$$PI_t = \sum_{j=1}^{3} \sum_{h=0}^{H} r_h^j \; PS_{t-h}^j + \text{Controls} + e_t^{PI}, \tag{4}$$

where PI_t denotes the change or the level in each of the monetary policy indicators—the short-term policy interest rate (SR), monetary base (MB), and composition ratio of the BOJ's unconventional assets to total assets (COMP) —in month t. The change in the monetary base is expressed using the monthly growth rates (annual rate) of the log-differenced values. The level in the monetary base is expressed using logarithmic values $\times$ 1200. PS_{t-h}^j denotes the h lagged values for the three monetary policy surprises generated using the factor analysis. e_t^{PI} denotes stochastic disturbances. Controls include a constant term and the one-lagged value of PI_t.

Table 2 reports Chi-square statistics and P-values for testing the null hypothesis, $r_h^j = 0$ for all $j = 1, 2, 3$, in the distributed lag regression at the horizon of $h = H$. As the table shows, the monetary policy surprises are statistically correlated with the monetary policy indicators but associate with the indicators in different ways. Specifically, we find that the monetary policy surprises are significantly associated with the short-term policy rate (ΔSR_t and SR_t) at the horizon of $H = 0$, or the contemporaneous time of the policy shock arrival. This association tells us that the short-term policy rate immediately responds to the BOJ's policy changes. In contrast, monetary policy surprises show no significant associations with the monetary base (ΔMB_t and MB_t) or the unconventional assets ratio (ΔCOMP_t and COMP_t) at the horizon $H = 0$, but are significantly associated with the monetary base at $H \geq 12$ and with the unconventional assets ratio at $H \geq 2$. These estimation results

[14] This regression is essentially the same as the local projection method (see Jordà (2005) and Stock and Watson (2018)).

imply that the monetary base and unconventional assets ratio respond to the BOJ's policy changes slowly and later in time.

Our finding on the responses of the quantitative and qualitative 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 issued just after the MPM on the bank's decision to change the two unconventional policy indicators behave like anticipated shocks that portend future changes in the indicators. Therefore, if we were to 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 short-term policy rate, we would misspecify those anticipated changes as unanticipated shocks. 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 associates differently with the monetary policy surprises. The differences between the 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 Quantitative and Qualitative Monetary Policy Shocks This section describes the empirical strategy we use to identify the effects of the two unconventional monetary policy shocks (quantitative and qualitative monetary policy shocks) and the one short-term policy rate shock with the three principal components of the monetary policy surprises 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 unconventional monetary policy shocks as shocks that capture current and future changes in the size and composition of the BOJ's balance sheet, and we define the short-term policy rate shock as a shock that is realized after the unconventional monetary policy shocks. In Section 5 we show that estimated impulse responses to the quantitative and qualitative policy shocks based on this assumption are robust even under the alternative assumption that the policy rate shock is followed by the two unconventional policy shocks involving the central bank's balance sheet operations.

Also note that in setting the VAR model, we change our assumptions about the entry of a new policy scheme in an unconventional monetary policy regime. When, for example, the central bank introduces or halts a zero interest rate policy, quantitative easing policy, or quantitative and qualitative easing policy, we assume that the new scheme reflects not a change in the central bank's deep parameter in its policy decision announcement, but a policy shock that either portends future changes in the monetary base and unconventional assets ratio or leads to an immediate change in the short-term policy rate. Below, therefore, we make no use of regime-switching and time-varying parameter VAR models such as those of Kapetanios et al. (2012), Baumeister and Benati (2013), Kimura and Nakajima (2016), Miyao and Okimoto (2017), and Hayashi and Koeda (2018).

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 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. To this end, as discussed in the 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 in month t, this stochastic structure can be expressed in terms of the vector moving average representation:

$$y_t = \Phi(L)u_t, \tag{5}$$

where $\Phi(L) = I + \Phi_1 L + \Phi_2 L^2 + \cdots$ is a matrix polynomial in the lag operator, L, and u_t denotes the $K \times 1$ vector of the reduced-form VAR innovations. The monetary base (MB), unconventional assets ratio (COMP), and short-term policy rate (SR) 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:

$$y_t = \Psi(L)\epsilon_t, \tag{6}$$

where $\Psi(L) = \Psi_0 + \Psi_1 L + \Psi_2 L^2 + \cdots$, and ϵ_t denotes the $K \times 1$ vector of the structural shocks. Let ϵ_t^{MP} be the 3×1 policy shock vector $\epsilon_t^{MP} = [\epsilon_t^{QN}, \epsilon_t^{QL}, \epsilon_t^{SR}]'$, where ϵ_t^{QN}, ϵ_t^{QL}, and ϵ_t^{SR} denote unconventional quantitative, qualitative policy shocks, and conventional short-term interest rate shocks, respectively. The space spanned by the policy shock vector ϵ_t^{MP} is disentangled from the space spanned by other possible shocks of the $(K-3) \times 1$ vector ϵ_t^X in the following linear relation between the reduced-form VAR innovations u_t and structural shocks ϵ_t:

$$u_t = R\epsilon_t = R^{MP}\epsilon_t^{MP} + R^X \epsilon_t^X,$$

$$\underset{(K \times K)}{R} = [\underset{(K \times 3)}{R^{MP}}, \underset{(K \times (K-3))}{R^X}], \quad \underset{(K \times 1)}{\epsilon_t} = [\underset{(3 \times 1)}{\epsilon_t^{MP}}, \underset{((K-3) \times 1)}{\epsilon_t^X}]', \tag{7}$$

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,

$$\Sigma^{MP} = R^{MP} E(\epsilon_t^{MP} \epsilon_t^{MP'}) R^{MP'} = R^{MP} R^{MP'}, \tag{8}$$

where the variance of monetary policy shocks is normalized to one. The impact matrix

R^{MP} satisfies the variance-covariance matrix but it is not unique. For some arbitrary orthogonalization of this impact matrix, $\tilde{R}^{MP}$, the entire space of possible impact matrices can be written as:

$$R^{MP} = \tilde{R}^{MP} D, \tag{9}$$

where D denotes the 3×3 orthonormal matrix ($DD' = I$). Note that $\tilde{R}^{MP} d_j$ ($j = 1, 2, 3$) (where d_j is the 3×1 orthonormal vector indicating the jth column of the orthonormal matrix D) is the $K \times 1$ vector, and thus interprets the contemporaneous impact of the jth monetary policy shock on the VAR variables. In the following subsections we construct this impact matrix (9) to identify the three types of monetary policy shocks.

3.2. **Controlling the Endogeneity of the Monetary Policy Indicators** We use three principal components of the monetary policy surprises (PS_t) extracted from the changes in the twelve major financial markets on MPM days as instrumental variables for the reduced-form VAR innovations, u_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:

$$u_t = \underset{(K \times 3)}{R^{PS}} \underset{(3 \times 1)}{PS_t} + e_t \ , \tag{10}$$

where PS_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 BOJ's public statements in the form of fitted values $u_t^{ps} = \hat{R}^{PS} PS_t$. We then obtain the following variance-covariance matrix incorporating the instantaneous impacts of the public statements on the VAR variables:

$$\Sigma^{PS} = E(u_t^{ps} u_t^{ps'}). \tag{11}$$

A diagonal element of this variance-covariance matrix, $\Sigma_{i,i}^{PS}$ ($i = 1, \cdots, k$), includes the instantaneous forecast error variances of the VAR variables attributable to the BOJ's public statements on MPM days.

3.3. **Identifying Quantitative and Qualitative Monetary Policy Shocks** Here we describe the second-step procedure to identify the conventional and unconventional monetary policy shocks. We identify the unconventional monetary policy shocks with help from the monetary base and unconventional assets ratio, assuming that agents believe that the policy indicators will meet their target levels 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 anticipated shocks that best portend the current and future paths of the monetary base and unconventional assets ratio.

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).[15] In this approach, we specify the revisions in the agents' expectations as maximization problems for the contributions of the unconventional policy shocks to the h-step-ahead forecast error variances of the unconventional policy indicators.

To explain the MFEV approach, we begin by expressing the h-step-ahead forecast error conditioning on the structural shocks ϵ_t:

$$y_{t+h} - E_{t-1}y_{t+h} = \sum_{\tau=0}^{h} \Phi_\tau R \epsilon_{t+h-\tau} = \sum_{\tau=0}^{h} \Phi_\tau R^{MP} \epsilon_{t+h-\tau}^{MP} + \sum_{\tau=0}^{h} \Phi_\tau R^{X} \epsilon_{t+h-\tau}^{X}, \tag{12}$$

where the first and second equalities use equations (5) and (7). The h-step-ahead forecast error due to monetary policy shocks $\epsilon_{t+\tau}^{MP}$ can therefore be expressed as:

$$\sum_{\tau=0}^{h} \Phi_\tau R^{MP} \epsilon_{t+h-\tau}^{MP} = \sum_{\tau=0}^{h} \Phi_\tau \tilde{R}^{MP} D \epsilon_{t+h-\tau}^{MP}, \tag{13}$$

where the equality uses equation (9). If we have orthogonalization matrix $\tilde{R}^{MP}$ and or-

[15] Barsky and Sims (2011) employed the MFEV approach to identify anticipated shocks related to future technology. Zeev et al. (2017) used this approach to identify anticipated monetary policy shocks in the U.S. conventional monetary policy regime.

thonormal vector d_j ($j = 1,2,3$), we can therefore generate the impulse responses of the VAR variables to the jth monetary policy shock from the impact vector $\tilde{R}^{MP} d_j$.

We first prepare for an orthogonalization matrix $\tilde{R}^{MP}$ such that it satisfies the following condition:

$$\Sigma^{PS} = \tilde{R}^{MP} D D' \tilde{R}^{MP\prime}. \tag{14}$$

This equality ensures that the impact matrix $\tilde{R}^{MP} D$ is determined based on the estimated instantaneous responses $\hat{R}^{PS}$ of the reduced-form VAR innovations to the central bank's public statements in equations (10) and (11). Next, we employ the MFEV approach, thereby obtaining the orthonormal vector d_j ($j = 1,2,3$) with a given orthogonalization matrix $\tilde{R}^{MP}$ satisfying equation (14), as discussed below.

From the h-step-ahead forecast error (13), the share of the h-step-ahead forecast error variance (FEV) of the unconventional policy indicator i ($i = 1,2$) attributable to the associated unconventional monetary shock $\epsilon_{j,t}^{MP}$ ($j = i$) is expressed as a variance decomposition of the following form:

$$\Omega_j^i(h) = \frac{\iota_{1i}' \left(\sum_{\tau=0}^{h} \Phi_\tau \tilde{R}^{MP} D \iota_{2j} \iota_{2j}' D' \tilde{R}^{MP\prime} \Phi_\tau' \right) \iota_{1i}}{\iota_{1i}' \left(\sum_{\tau=0}^{h} \Phi_\tau \Sigma^{PS} \Phi_\tau' \right) \iota_{1i}} = \frac{\overbrace{\sum_{\tau=0}^{h} \Phi_{i,\tau} \tilde{R}^{MP} d_j d_j' \tilde{R}^{MP\prime} \Phi_{i,\tau}'}^{\text{FEV of policy indicator } i \text{ due to } \epsilon_{j,t}^{MP}}}{\underbrace{\sum_{\tau=0}^{h} \Phi_{i,\tau} \Sigma^{PS} \Phi_{i,\tau}'}_{\text{FEV of indicator } i \text{ due to public statements}}}, \tag{15}$$

where i ($i = 1,2$) indicates the place of the unconventional monetary policy indicators (MB and COMP) in vector variable y_t, and j ($j = i$) indicates the place of the associated unconventional policy shocks ϵ_t^{QN}, ϵ_t^{QL}, and ϵ_t^{SR} in policy shock vector ϵ_t^{MP}. ι_{1i} and ι_{2j} are the $K \times 1$ and 3×1 selection vectors, with ones in the ith place and jth place and zeros elsewhere, and d_j is the 3×1 orthonormal vector indicating the jth column of the orthonormal matrix D. The selection vectors outside of the parentheses in both the numerator and denominator ι_{1i} pick out the ith row of the matrix of the moving average coefficients, which is denoted by $\Phi_{i,\tau}$.

Variance decomposition (15) models the extent to which the revisions in an agents' expectations about the h-step-ahead path of unconventional policy indicator i at the time of the BOJ's public statement (represented by the denominator) are attributed to the associated unconventional policy shock j, denoted by $\epsilon_{j,t}^{MP}$ (where the contributed component of j is represented by the numerator). The MFEV approach to identify unconventional monetary policy shocks (i.e., quantitative and qualitative policy shocks) maximizes the variance decomposition by mapping unconventional policy indicator i to the associated unconventional policy shock j. This identification is based on the legitimate assumption that when the central bank announces its plans of action on two unconventional policy instruments—the change in the size of its balance sheet (MB) and the purchase of more or less unconventional assets (COMP)—agents will hear the announcement and update their expectations about the paths of the policy instruments accordingly, as Figure 2 illustrates. In other words, as long as the central bank keeps the its promises (at least for operations on the size of its balance sheet and the composition of its assets) and secures the agents' trust in the central bank's announcement, the identification of the associated two unconventional policy shocks based on the MFEV approach allows us to reveal the actual movements in the two balance sheet instruments after the unconventional policy shocks arrive.

Also note that unlike an existing identification scheme such as a recursive restriction or a sign restriction, the MFEV approach makes no assumption on how the size and composition of the central bank's balance sheet will respond after the bank makes a policy decision. This approach only assumes that agents revise their expectations of the path of a policy indicator according to the scheduling actions that the central bank announces with regard to the indicator. In this sense, the MFEV approach is more agnostic and flexible than the existing identification approach in identifying a particular type of policy shock relating to monetary policy indicators. Given the specific movements of the quantitative and qualitative policy measures following policy changes (see Subsection 2.2), this approach allows us to prevent misspecification of the quantitative and qualitative monetary policy shocks.

To identify the quantitative, qualitative, and short-term policy rate shocks with the MFEV approach, we begin by identifying the quantitative monetary policy shock, ϵ_t^{QN}, satisfying the following conditions:

$$\hat{d}_1 = \arg\max_{d_1} \ \Omega_1^1(h), \tag{16}$$

s.t.

$$d_1^{'} d_1 = 1. \tag{17}$$

Constraint (17) (d_1 have unit length) ensures that d_1 is the first column vector belonging to orthonormal matrix D. After obtaining $\hat{d}_1$ by solving the above maximization problem, we calculate the impulse responses of the VAR variables to the quantitative monetary policy shocks using the estimated impact vector $\tilde{R}^{MP}\hat{d}_1$.

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

$$\hat{d}_2 = \arg\max_{d_2} \ \Omega_2^2(h), \tag{18}$$

s.t.

$$d_2^{'} d_2 = 1, \tag{19}$$

$$d_1 = \hat{d}_1. \tag{20}$$

Constraint (19) ensures that d_2 is the second column vector belonging to orthonormal matrix D. Constraint (20) ensures that the qualitative shock is realized after the quantitative shock. This implies that, in a qualitative shock with a target level for the monetary base given, the central bank aims to change the composition of its assets through, for example, an operation twist.[16] We can compute the impulse responses to the qualitative monetary policy shocks using the estimated impact vector $\tilde{R}^{MP}\hat{d}_2$.

Once two column vectors in the 3×3 orthonormal matrix D are given as its first and

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

second column vectors $\hat{d}_1$ and $\hat{d}_2$, the third column vector d_3 is automatically determined. In the identification of the conventional short-term policy rate shock ϵ_t^{SR}, the third column in the impact matrix R^{MP} representing the impulse responses to the conventional policy rate shock is obtained as $\tilde{R}^{MP}\hat{d}_3$. The column vector is orthogonal to the first and second columns obtained through the above maximization problems, hence the surprise component of the monetary policy explains the small variation in the monetary base and unconventional assets ratio in the middle- and long-term period. In this sense, our identification strategy assumes that the central bank controls the short-term policy rate after it determined a plan of balance sheet extension and unconventional asset purchases. Section 5 demonstrated that even when we employ the alternative identification strategy in which a policy rate setting is assumed to precede a balance sheet setting, the estimated quantitative and qualitative policy effects do not depend on those identification strategies.

4. Results for Quantitative and Qualitative 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 two unconventional monetary policy shocks, that is, quantitative and qualitative monetary policy shocks, in particular. In addition to the three monetary policy indicators, the monetary base (MB), unconventional assets ratio (COMP), and short-term policy rate (SR), we include five macroeconomic variables in constructing the VAR: two asset market prices, two 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 two real economic variables are the GDP gap (GGAP) and the difference between the risky assets and safe assets held by commercial banks (BRISK).[17] The risky asset holdings of commercial banks consist of equity holdings and bank lending, while the safe assets consist of JGBs. The consumer price index (CPI) is included as the price indicator. See the Appendix for more detailed information on those variables in the VAR. As discussed in Section 2, our sample period is from April 1998 to January 2016. The number of lags in the VAR is determined to be two based on the

[17] We also use the unemployment rate, shipment of investment goods, and industrial production index in place of the GDP gap, but the results provided by these alternatives do not differ from the results reported below.

Schwarz-Bayesian Information Criterion.

4.1. **VAR Innovations and Monetary Policy Surprises** Here we report the statistical relevance between the reduced-form VAR innovations and monetary policy surprises. Table 3 shows the estimation results for the system regression of the reduced-form VAR innovations on the three monetary policy surprises as expressed in (10).

The monetary policy surprises significantly explain only the reduced-form VAR innovations of the short-term policy rate (SR) and the asset prices (SP and 10YJGB), which tells us that the three asset price variables quickly respond to exogenous policy changes. On the contrary, the monetary policy surprises explain little of the unconventional policy indicators (MB and COMP), real economic variables (GGAP and BRISK), or price indicator (CPI) when the shock arrives. We know, therefore, that these latter variables show no immediate responses to the monetary policy shocks. In particular, the significant explanatory power of the short-term policy rate and the weaker explanatory power of the quantitative and qualitative policy indicators are consistent with the results of the distributed lag regression (4) (see Subsection 2.2).

4.2. **Monetary Policy Shocks and the Responses of Policy Indicators** Table 4 presents the variance decomposition of the three monetary policy indicators attributable to each of the monetary policy shocks for $h = 0, 12, 24, 36$, and 48 months ahead.

While most of the variance of the monetary base (MB) and unconventional assets ratio (COMP) at $h = 0$ is attributable to the conventional policy rate shock, the table clearly shows that most of the variance of the two unconventional policy indicators at $h \geq 12$ is explained by their corresponding monetary policy shocks. More concretely: at $h \geq 12$ the quantitative shock explains almost all of the variance of the monetary base and the qualitative explains almost all of the variance of the unconventional assets ratio, while at $h \geq 36$ the two types of shock explain the variance of the unconventional assets ratio equally. This implies that the extension of the BOJ's balance sheet is realized slowly and gradually and that its medium- and long-term purchasing of unconventional assets is determined in accordance with the balance sheet extension.

The quantitative and qualitative monetary policy shocks appear to explain most of the variance of the short-term policy rate (SR). The variance of the policy rate at $h = 0$ is almost fully attributable to the qualitative policy shock, but most of the variance at $h \geq 12$ is accounted for by the quantitative policy shock. Our finding that the short-term policy rate shock accounts for much rather than little of the variance is consistent with the identifying assumption that the central bank's planning balance sheet operations dictates its control of the short-term policy rate. In Subsection 5.1, we will discuss a case in which the central bank's policy rate control comes before the balance sheet size and composition are controlled.

4.3. **Impulse Response Analysis** In this subsection we describe the estimated impulse responses to the exogenous monetary policy shocks. Figure 3 outlines the estimated impulse responses to the quantitative policy shock, the qualitative policy shock, and the short-term policy rate shock.

Effects of Quantitative Shocks

As the left column of Figure 3 shows, the quantitative easing shock leads to a gradual and continuous increase in the monetary base (MB) without affecting it immediately. The monetary base reaches a peak at around one year following the quantitative easing shock. We can thus identify the quantitative shock as an anticipated shock linked to the expansion of the balance sheet (i.e., agents expect the monetary base 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 unconventional assets ratio (COMP), which clearly shows that the BOJ tends to increase its unconventional assets more than its conventional assets when expanding its balance sheet.

In estimating the responses of the nominal interest rates, we find that the short-term policy rate (SR) and long-term nominal interest rate (10YJGB) both fall immediately, but that the latter falls more. The immediate response of the long-term interest rate implies that a quantitative easing shock 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 stock price (SP) or the commercial bank holdings of risky assets (BRISK), so both of the variables decline.

We can infer, from the estimation results, that the quantitative easing shock was in no way effective 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 result in a tight supply/demand balance in the long-term Japanese government bond market or to 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 less than favorable effects on the GDP gap (GGAP) and price indicator (CPI), as well.[18] Given that this shock significantly decreases the long-term nominal interest rate and generates a flattening yield curve, we can infer that the interest rate channel through the decrease in the long-term nominal interest rate in response to quantitative easing fails to bring about the intended effects under Japan's unconventional monetary policy regime.

Effects of Qualitative Shocks

As we see in the middle column of Figure 3, the qualitative easing shock has a significant effect on the unconventional assets ratio (COMP) without imparting a contemporaneous impact. More concretely, the unconventional assets ratio peaks almost six months later. On the contrary, the monetary base (MB) shows no significant response to the qualitative easing shock.

In contrast to the quantitative easing shock, the qualitative easing shock leads to a substantive increase in the stock price (SP), an increase in the long-term nominal interest rate (10YJGB), and a persistent increase in the commercial bank holdings of risky assets (BRISK). Unlike the effects we find when the BOJ expands its balance sheet, the larger purchases of unconventional assets under the qualitative easing policy increase the stock price and generated a steepening yield curve. Qualitative easing also prompts financial institutions to increase the purchase of unconventional assets and lend more in portfolio rebalancing.

For the estimated responses of the other real economic variables, the GDP gap (GGAP)

[18] Hayashi and Koeda (2018) found that exiting from the quantitative easing policy is expansionary if the actual-to-required reserve ratio is not unduly large.

and price indicator (CPI) both increase significantly.

Policy Rate Shock Effects under Planning the Balance Sheet Structure

As the right column of Figure 3 shows, a short-term policy rate shock that significantly decreases the policy rate leads not to a change in the monetary base (MB), but to an immediate decrease in the unconventional assets ratio (COMP). This effect tells us, as discussed in Section 3, that our identification scheme assumes that the BOJ determines its evolution of balance sheet structure before an actual change in the short-term policy rate. Once the BOJ decides to decrease (increase) the policy rate, however, the central bank implements the policy rate control temporarily by purchasing (selling) conventional assets and selling (purchasing) unconventional assets and by increasing the prices of conventional (unconventional) assets, with the balance sheet size unchanged.

In such identification of the short-term policy rate shock, the long-term nominal interest rate (10YJGB) immediately and substantially falls and the yield curve temporarily flattens. By contrast, the stock price (SP), the commercial bank holdings of risky assets (BRISK), the GDP gap (GGAP), and the price indicator (CPI) do not significantly respond to the short-term policy rate shock when the balance sheet is of a given size. These neutral effects of the policy rate shock on the stock price and real economy differ from those demonstrated in the VAR literature for conventional monetary policy effects.[19] This difference suggests that if the central bank keeps the size of its balance sheet unchanged in controlling the short-term policy rate (as seen in the normalization of the U.S. monetary policy since December 2015), the stock price and real economy could be neutral to the policy rate change.

In Section 5, we extend our impulse response analysis by conducting a robustness check based on the alternative identification scheme in which the central bank sets its policy rate before it sets its balance sheet structure.

5. Unconventional Monetary Policy Effects and Robustness In this section we conduct a robustness check based on an alternative identification strategy in which the central bank is assumed to control the short-term policy rate before it plans its balance

[19] See e.g., Bernanke and Blinder (1992), Christiano et al. (1996), and Bernanke and Mihov (1998) for details on the U.S. conventional monetary policy. See e.g., Miyao (2000; 2002), Nakashima (2006), and Shibamoto (2016) for details on the Japanese conventional monetary policy.

sheet structure. We also explore several implications of the unconventional monetary policy effects on the macroeconomy by focusing on comparisons with the existing VAR studies and hypotheses to be further investigated on the topic of unconventional policy effects.

5.1. **Alternative Identification and Robustness** To conduct a robustness check based on the alternative identification strategy, we introduce two additional identifying constraints besides constraints (16) to (20):

$$\tilde{r}_{31}d_{1,1} + \tilde{r}_{32}d_{2,1} + \tilde{r}_{33}d_{3,1} = 0, \tag{21}$$

and

$$\tilde{r}_{31}d_{1,2} + \tilde{r}_{32}d_{2,2} + \tilde{r}_{33}d_{3,2} = 0, \tag{22}$$

where $\tilde{r}_{31}$, $\tilde{r}_{32}$, and $\tilde{r}_{33}$ indicate the element of the third row vector of $\tilde{R}^{MP}$ related to the policy rate response to monetary policy shocks. The two constraints ensure that the central bank controls its policy rate before it controls its evolution of balance sheet. Put differently, the quantitative and qualitative monetary policy shocks have no immediate impacts on the short-term policy rate.[20] Figure 4 reports estimated impulse responses to the quantitative, qualitative, and short-term policy rate shocks based on this alternative identifying scheme.

The left and middle columns of Figure 4 clearly show that although the quantitative and qualitative easing shocks reflect no instantaneous response of the short-term policy rate in accordance with the predetermined policy rate assumption, the unconventional policy easing shocks generate the same patterns of impulse responses as those based on the predetermined balance sheet assumption (see Subsection 4.3). In this sense, our unconventional policy effects are robust irrespective of those different identifying schemes.

Unlike the policy rate shock under planning balance sheet operations, under the as-

[20] More precisely, once the policy rate shock is determined before the quantitative and qualitative policy shocks under identifying restrictions (21) and (22) and the quantitative shock is determined before the qualitative shock by solving maximization problem (16) and obtaining $\hat{d}_1$, the qualitative shock is automatically determined without solving maximization problem (20). As far as this identification strategy in maintained, however, such automatic determination of the qualitative shock is formally equivalent to solving maximization problem (20).

sumption that the BOJ sets policy rate before determining the balance sheet size and composition, the policy rate shock basically produces impulse responses similar to those demonstrated in the VAR literature for conventional monetary policy effects (see the right column of Figure 4). In this sense, the policy rate control that comes before the balance sheet setting can be seen as the conventional monetary policy even in an extremely low-interest regime, while the policy rate control subject to the long-term balance sheet control can be seen as an unconventional policy option in the central bank's balance sheet operations.

This contrast between the two types of short-term policy rate shocks can also be observed in their different results for the variance decomposition of the three monetary policy indicators. Table 5 reports results for the variance decomposition attributable to the associated monetary policy shocks. Compared with the policy rate control subject to the balance sheet control (see Subsection 4.2), the assumption that the BOJ sets the policy rate prior to setting other policy tools generates the estimation result showing substantive increases in the contribution of the short-term policy rate shock to the variance of each of the policy indicators.

In this type of identification of the policy rate shock, Figure 4 shows that the policy easing that immediately decreases the short-term policy rate (SR) leads to an increase in both the monetary base (MB) and unconventional assets ratio (COMP). The estimated impulse responses of the stock price (SP) remain less than significant for about one year after the policy rate shock, then increase steadily from the end of the first year to the end of the third year. The long-term nominal interest rate (10YJGB) immediately decreases and the long-short spread narrows, responding to the policy rate shock. From the positive responses of the commercial bank holdings of risky assets (BRISK), we can infer that the policy easing shock causes a portfolio rebalance. The policy rate shock leads to increases in both the GDP gap (GGAP) and price indicator (CPI), though the former initially decreases in the first few periods. The GDP gap peaks after the price indicator begins to increase, at about the one year point after the policy rate shock.

5.2. **Comparison with Unanticipated Policy Shocks** As discussed in the Introduction, a number of previous studies have assumed that monetary aggregates such as the monetary base and excess reserves represent the central bank's policy stance. These studies have thus employed the standard recursive VAR approach or extensions of that approach, such as regime-switching or time-varying parameter VAR models. Another VAR approach employed in previous studies assumes that unconventional monetary policy shocks can be represented collectively as a single unobservable policy shock. This other VAR approach, therefore, imposes sign restrictions on the instantaneous responses of macroeconomic variables to a single policy shock or imposes heterogeneous variance restrictions on the intensity of structural shocks, including single policy shocks.

Regardless of the difference in identification strategy, the exogenous components of the unconventional monetary policy identified in the previous studies are characterized as "unanticipated" unconventional monetary policy shocks. We describe such a shock as "unanticipated" because, in contrast to an "anticipated" policy shock, it provides no prior insight into the current and future paths of the monetary base and unconventional assets ratio. In addition, none of those previous studies took our approach of using 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 4.3) with the effects of our unanticipated unconventional policy shocks. For the comparison, we adopt the standard recursive VAR approach based on the Cholesky decomposition to extract an unanticipated unconventional policy shock. We employ the recursive approach because 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 when using the data from Japan.[21]

In doing so, we focus on four dimensions in particular: 1) effects on the monetary base, 2) effects on the interest rate of long-term government bonds, 3) effects on real economic activity, and 4) the exogeneity of unconventional monetary policy shocks.

Figure 5 shows estimated impulse responses to the unanticipated monetary base shock (left column) and composition shocks (right column) obtained using the Cholesky decom-

[21] Schenkelberg and Watzka (2013) and Shibamoto and Tachibana (2017) focused on the BOJ's quantitative easing period from 2001 to 2006. We found, however, that the three alternative approaches yielded qualitatively the same impulse responses across sample periods.

position in the eight-variable VAR system, respectively.[22] We find that the evaluation of unconventional policy effects heavily depends on whether quantitative and qualitative easing shocks are identified as anticipated (Figure 3) or unanticipated shocks (Figure 5).

Effects on the Monetary Base

The difference in the dynamics of monetary aggregates conditioned on unconventional policy shocks is the most notable when comparing the anticipated and unanticipated shocks. Existing VAR studies identifying unconventional monetary policy shocks as unanticipated shocks have demonstrated a contemporaneous impact on monetary aggregates.[23] Indeed, as shown in the left column of Figure 5, the unanticipated monetary base shock leads to an immediate increase in the monetary base (MB), while the anticipated monetary base shock (i.e., our quantitative easing shock) leads to a gradual increase (see Figure 3).

Also note that, as emphasized in Subsection 3.3, we do not impose any restrictions other than the maximization of the forecast error of the current and future paths of the monetary base when identifying the anticipated monetary base shock by imposing restrictions (16) and (17). Hence, our strategy for identifying the anticipated monetary base shock lets the data speak more for unconventional policy effects on the monetary base, compared with our strategy for identifying the unanticipated monetary base shock. Given this point, the non-contemporaneous response and the gradual increase of the monetary base are the most distinguished features of the anticipated monetary base shock and reflect more of

[22] More specifically, in the eight-variable VAR system we order the variables in the conventional manner: output and prices (GGAP, CPI), policy indicators (MB, COMP, SR), and the four financial variables, including the stock price index (SP). For comparison with the anticipated monetary base and composition shocks (i.e., the quantitative and qualitative shocks defined in Section 3), the eight-variable VAR system imposes a recursive restriction for the three monetary policy indicators, in which three unanticipated monetary shocks are determined in the order of an unanticipated policy shock to the monetary base (MB), the unconventional assets ratio (COMP), and the short-term policy rate (SR) (see Section 3). We find that the impulse responses yielded by the short-term policy rate shock (related to the SR) identified in this recursive VAR system are substantially the same as the impulse responses shown in Figure 3. Hence, we do not report them here.

[23] Such a contemporaneous impact on monetary aggregates can be observed in Japanese VAR-based studies: e.g., Iwata and Wu (2006) for M1, and Honda et al. (2013), Schenkelberg and Watzka (2013), Kimura and Nakajima (2016), Shibamoto and Tachibana (2017), Miyao and Okimoto (2017), and Hayashi and Koeda (2018) for bank reserves. In one VAR-based study on the U.K. and U.S., Weale and Wieladek (2016) showed a contemporaneous impact on asset purchases. Gambacorta et al. (2014) showed a contemporaneous impact on the total assets of central banks in industrialized countries.

the actual dynamics of the monetary base: the targeted monetary base level is achieved gradually after a policy change announcement, but not abruptly in the announcement.

We can observe the same tendency in the difference between the anticipated composition shock (i.e., our qualitative easing shock) and the unanticipated composition shock: the unanticipated composition shock has an contemporaneous impact on the unconventional assets ratio (COMP), as shown in Figure 5, while the anticipated composition shock does not, as shown in Figure 3.

Effects on Long-term Government Bond Yields

Some VAR-based studies of the unconventional monetary policy, particularly in the UK and the US, have emphasized the policy's causal effect on long-term bond yields (e.g., Kapetanios et al. (2012), Wright (2012), Baumeister and Benati (2013), and Weale and Wieladek (2016)).[24] Their motivation stems from the assumption that unconventional policy interventions in the Treasury market would lower the long-term bond yields and then spur real economic activity. Under this assumption they identify 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. Such results for an unanticipated policy shock in the U.K. and U.S. are observed for the anticipated monetary base shock (i.e., our qualitative policy shock) and the two unanticipated shocks in Japan, as shown in the impulse responses of the 10-year government bond yield (10YJGB) (see Figures 3 and 5), but not for the anticipated composition shock (i.e., our qualitative policy shock).

Note that while the two anticipated shocks, our quantitative and qualitative easing shocks, both have substantial impacts on the long-term government bond yield (10YJGB) and long-short spread of the long-term yield and short-term policy rate (SR), the dynamics are quite different: the quantitative easing shock has an immediate and persistent effect on the long-term government bond yield and causes a contraction of the long-short spread, while the qualitative easing shock has a slow and less persistent effect and generates a

[24] 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) used the sign restriction approach. Weale and Wieladek (2016) employed four alternative approaches, including the recursive and sign restriction approaches.

steepening yield curve. The unconventional policy effects on the yield curve depend on the policy tools, as well as the anticipated and unanticipated policy shocks.

Effects on Real Economic Activity

Our quantitative easing and qualitative easing shocks exert opposing effects on not only the long-term government bond yield, but also real economic activity. While the quantitative easing shock has contractionary effects on output (GGAP), prices (CPI), and the risk appetite of banks (BRISK), the qualitative easing shock has expansionary effects (left and middle columns of Figure 3). These effects imply that a decrease in the long-term government bond yield stemming from the expansion of the monetary base cannot be presumed to be associated with a rise in real economic activity (Okina and Shiratsuka (2004) and Ugai (2007)), and that unconventional policy effects on real economic activity are likely to be heavily dependent on the policy tools.[25]

Both the anticipated and unanticipated composition shocks have expansionary effects on output, prices, and the risk appetite of banks, though the magnitude and persistency of the effects differ between the two composition shocks (right columns of Figures 3 and 5). Regarding the quantitative policy tools, the anticipated monetary base shock has no such expansionary effects (left column of Figure 3), whereas the unanticipated base shock has expansionary effects about one year after the shock arrival (left column of Figure 5).[26]

Exogeneity of Unconventional Monetary Policy Shocks

Why the unanticipated monetary base shock has expansionary effects remains an open

[25] 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, and thereby brought longer-term interest rates down, these effects were not transmitted to the whole economy in Japan. Ugai (2007) similarly pointed out that the BOJ's quantitative easing had only a limited effect on raising aggregate demand and prices, though it succeeded in lowering the yield curve.

[26] Previous VAR-based studies emphasizing the expansionary effects of the BOJ's quantitative easing policy focused on the quantitative easing from March 2001 to March 2006 (e.g., Honda et al. (2013), Schenkelberg and Watzka (2013), Shibamoto and Tachibana (2017), and Hayashi and Koeda (2018)). We also examined the impulse responses to the anticipated and unanticipated monetary base shocks obtained during the quantitative easing period from 2001 to 2006. While we found that the anticipated monetary base shock still yielded a gradual increase in the monetary base and exerted contractionary effects on real economic activity even in the quantitative easing period, the unanticipated monetary base shock and contemporaneous increase in the monetary base had expansionary effects, as demonstrated in the previous studies. We also found that both the anticipated and unanticipated composition shocks had expansionary effects in the qualitative easing period.

question. To explore this question, we examine the associations among the unanticipated monetary policy shocks and global economic variables out of the eight-variable VAR. The linkages between the Japanese economy and global economy may endogenously determine the unanticipated changes in the policy indicators, including the monetary base. From this analytical viewpoint, we conduct the following system regression of the unanticipated monetary policy shocks on global economic factors:

$$UP_t = R_u^{GF} GF_t + e_t^u, \tag{23}$$

where UP_t denotes the vector variable composed of the unanticipated monetary policy shocks in month t obtained from the eight-variable recursive VAR, and GF_t denotes a vector variable composed of five global economic variables expected to have substantive effects on the Japanese economy: the oil price (OIL), global index of industrial production (GIP), U.S. economic policy uncertainty index (USEPU), U.S. TED spread (USTED), and federal funds rate (FFR)) .

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

$$PS_t = R_p^{GF} GF_t + e_t^p, \tag{24}$$

where PS_t represents the three monetary policy surprises, that is, the basis of our qualitative, quantitative, and short-term policy rate shocks.

Table 6 reports the estimation results for the two system equations (23) and (24). As the left panel of Table 6 shows, the unanticipated policy rate shock (USR) is not associated with any of the global economic factors. The unanticipated monetary base shock (UMB), on the other hand, is negatively and positively associated with the global index of industrial production (GIP) and the U.S. economic policy uncertainty index (USEPU), respectively. This indicates that the unanticipated monetary base shock increases as an endogenous response to the deterioration in the global economic condition. The unanticipated composition shock (UCOMP) is also significantly associated with the U.S. economic policy uncertainty index, though in contrast to the unanticipated monetary base shock, its correlation with the index is negative. We find, therefore, that the unanticipated composition shock endogenously increases in response to the improvement in the global economic condition.

In contrast, as the right panel of Table 5 shows, none of the monetary policy surprises are significantly associated with the global economic variables at the five percent level of significance. This estimation result ensures that our anticipated monetary policy shocks are exogenous to global economic shocks left out of the VAR system.

The above analysis suggests that the simple use of the unanticipated changes in the unconventional monetary policy indicators (i.e., the monetary base and unconventional assets ratio) can lead to biased estimates of the policy effects (see Gertler and Karadi (2015) for details on the U.S. conventional monetary policy effects). In particular, the unanticipated monetary base shock, which was mainly utilized by Japanese VAR-based studies to measure unconventional monetary policy effects, is negatively associated with the global economic condition, which is not controlled in the VAR model. Hence, unlike the anticipated monetary base shock, the unanticipated shock captures the global economic condition and accordingly cannot be considered a "pure" monetary policy shock. Given this negative association with the global and U.S. economic conditions, the favorable effects of the unanticipated monetary base shock presumably arise from the coordination of central banks around the world, along with the global spillover effects from that coordination, such as the provision liquidity to malfunctioning financial markets. This may be one reason why the unanticipated monetary base shock has expansionary effects on real economic activity.

5.3. **Hypotheses about Unconventional Monetary Policy Effects** We have thus far found that our quantitative easing shocks, or the anticipated monetary base 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 composition 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 three inter-related hypotheses about the unconventional policy effects, to explore in 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. According to Romer and Romer (2000), Ellingsen and Söderstrom (2001), Claus and Dungey (2012), Campbell et al. (2012), Nakamura and Steinsson (2018), and Munakata et al. (2019), monetary policy actions provide the public with signals of a 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.

The second hypothesis involves economic uncertainty and its effect in instilling 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 through reductions in 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)).[27] 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 can be explained along this line. Figure 6 reports estimated impulse responses of two uncertainty indexes, Japan's monetary policy uncertainty index (JMPU) and the volatility index Japan (JVIX), to the quantitative and qualitative monetary policy shocks. As this figure clearly shows, the quantitative easing shock can be expected to increase both the uncertainty indexes, while the qualitative easing shock can be expected to decrease them.[28]

The third hypothesis is based on the growing risk of a government debt crisis comparable to an aggressive expansion of the central bank's balance sheet. Some theoretical studies have pointed out that such a sovereign debt crisis risk can lower not only the government bond yield, but also the output (e.g., Kozlowski et al. (2015)), the rate of output growth (e.g., Kobayashi and Ueda (2018)), and the price level (e.g., Saito (2019)). Given that Japan's gross government debt exceeds 200% of the nominal GDP, this third hypothesis, which conjectures a loss of market confidence in government debt that forces the government

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

[28] We found that the short-term policy rate shock under planning balance sheet operations did not affect the two uncertainty indexes, while the policy rate shock followed by the quantitative and qualitative policy shocks decreased them. This result is consistent with the findings reported in Subsections 4.3 and 5.1.

to collect large tax revenues, seems to convincingly account for the contractionary effects of the quantitative easing.[29]

6. Conclusion Previous VAR-based studies have evaluated the central bank's balance sheet operations in an unconventional monetary policy by assuming either that the central bank uses monetary aggregates such as the monetary base and excess reserves as unconventional monetary policy measures, or that the underlying unconventional monetary policy shocks can be captured collectively by a single monetary policy shock. Hence, the previous studies that make these assumptions neglect to distinguish between quantitative and qualitative monetary policy shocks, which prevents them from correctly disentangling the policy effects. In the present study we proposed a new method to separately identify the quantitative and qualitative monetary policy shocks, as well as the short-term policy rate shock, using the unconventional monetary policy the Bank of Japan has kept in place since 1999.

Rather than assuming how a policy indicator responds to an associated policy shock, our method for identifying shocks makes only one assumption, namely, that agents revise their expectations about the path of a policy indicator in accordance with the central bank's announcement of its scheduling action for the indicator. In this sense, our method is agnostic in identifying a particular type of policy shock relating to a monetary policy measure. By demonstrating that the quantitative and qualitative policy measures differ from the policy rate, with neither showing any immediate responses to the central bank's announcement, we have determined that the existing identification methods that cause unconventional policy measures to immediately respond are unsuited for identifying the associated policy shocks.

By defining the two unconventional policy shocks as anticipated shocks, we observe in a robust manner that 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,

[29] Cúrdia and Woodford (2011) theoretically demonstrated that while quantitative easing is likely to be ineffective, qualitative easing due to the central bank's targeted asset purchases can be effective when financial markets are disrupted (see also Chen et al. (2012)). In terms of the risk-taking of Japanese commercial banks in lending, Nakashima et al. (2020) empirically showed that the BOJ's qualitative easing stimulated bank risk-taking, while the quantitative easing did not.

whereas the quantitative easing shock, which involves a gradual increase in the size of the BOJ's balance sheet, does not. In future research we will explore why these two unconventional policy shocks yield such different policy effects along the lines suggested in this paper.

Appendix: Variable Definitions

- Monetary base (MB): seasonally adjusted series, monthly average, retrieved from the Bank of Japan statistics.

- Composition ratio of the BOJ's unconventional assets to total assets (COMP): the BOJ's unconventional assets are defined as the sum of the BOJ's holdings of Japanese Government Bonds, commercial papers (from February 2009), corporate bonds (from March 2009), asset-backed securities (from July 2003 to September 2006), stocks held as trust property (from November 2002), Index-Linked Exchange Traded Funds held as trust property (from December 2010), and Japan Real Estate Investment Trusts held as trust property (from December 2010) (end of month), retrieved from the Bank of Japan statistics. The BOJ's total assets (end of month) retrieved from the Bank of Japan statistics.

- Short-term policy rate (SR): uncollateralized overnight call rate, monthly average, retrieved from the Bank of Japan statistics.

- Stock price index (SP): Nikkei Stock Average (Nikkei225) index (end of month) retrieved from NIKKEI NEEDS FINANCIAL QUEST.

- Long-term government bond yield (10YJGB): 10-year Japanese government bond yields (end of month) retrieved from NIKKEI NEEDS FINANCIAL QUEST.

- Commercial bank holdings of risky assets (BRISK): difference between the risky assets and safe assets held by commercial banks. Risky assets are defined as the sum of the commercial bank holdings of bank loans, stocks, corporate bonds, and foreign securities (end of month) retrieved from the Bank of Japan statistics. Safe assets are defined as the commercial bank holdings of Japanese government bonds (end of month), retrieved from the Bank of Japan statistics. We obtain seasonally adjusted series using the Census X-12.

- GDP gap (GGAP): Quarterly GDP gap series retrieved from the Bank of Japan statistics and interpolated to obtain monthly observations.

- Consumer price index (CPI): consumer price index, excluding fresh foods (2015=100), consumption-tax-adjusted series for the period from April 1998 to December 2014, retrieved from the Ministry of Internal Affairs and Communications. We obtain seasonally adjusted series using the Census X-12.

- Oil price (OIL): Crude Oil Prices: West Texas Intermediate (WTI) (monthly average) retrieved from FRED.

- Global index of industrial production (GIP): World Industrial Production, excluding construction (Import-Weighted, 2010=100), retrieved from HAVER ANALYTICS.

- U.S. economic policy uncertainty index (USEPU): A news-based policy uncertainty index retrieved from the following website: http://www.policyuncertainty.com/.

- U.S. TED spread (USTED): the spread between the 3-Month LIBOR based on US dollars and 3-Month Treasury Bill (monthly average) retrieved from FRED.

- Federal funds rate (FFR): effective federal funds rate (monthly average) retrieved from FRED, shadow federal funds rate series of Wu and Xia (2016) from January 2009 to November 2015, retrieved from Jing Cynthia Wu's website: https://sites.google.com/view/jingcynthiawu/shadow-rates.

- Japan's monetary policy uncertainty index (JMPU): Japan's Monetary Policy Uncertainty Index constructed by Arbatli et al. (2017), retrieved from the following website: http://www.policyuncertainty.com/.

- Japan's volatility index (JVIX): Volatility Index Japan, retrieved from the following website: http://wwwmmds.sigmath.es.osaka-u.ac.jp/en/activity/vxj.php (monthly average).

REFERENCES

[1] Aastveit, K., G. Natvik, and S. Sola, 2013, "Economic Uncertainty and the Effectiveness of Monetary Policy," *mimeo.*

[2] Ahn, S., and A. Horenstein, 2013, "Eigenvalue Ratio Test for the Number of Factors," *Econometrica*, 81, 1203–1227.

[3] Arbatli, E., S. Davis, A. Ito, N. Miake, and I. Saito, 2017, "Policy Uncertainty In Japan," *NBER Working Paper*, No. 23411.

[4] Bai, J., and S. Ng, 2002, "Determining the Number of Factors in Approximate Factor Models," *Econometrica*, 70, 191–221.

[5] Barsky, R., and E. Sims, 2011, "News Shocks and Business Cycles," *Journal of Monetary Economics*, 58, 273–289.

[6] Baumeister, C., and L. Benati, 2013, "Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound," *International Journal of Central Banking*, 9, 165–212.

[7] Bekaert, G., M. Hoerova, and M. Duca, 2013, "Risk, Uncertainty, and Monetary Policy," *Journal of Monetary Economics*, 60, 771–788.

[8] Bernanke, B., and A. Blinder, 1992, "The Federal Funds Rate and the Channels of Monetary Transmission," *American Economic Review*, 82, 901–921.

[9] Bernanke, B., and I. Mihov, 1998, "Measuring Monetary Policy," *Quarterly Journal of Economics*, 113, 869–902.

[10] Bernanke, B., and V. Reinhart, 2004, "Conducting Monetary Policy at Very Low Short-Term Interest Rates," *American Economic Review*, 94, 85–90.

[11] Bernanke, B., and V. Reinhart, and B. Sack, 2004, "Monetary Policy Alternatives at the Zero Bound: An Empirical Assessment," *Brookings Papers on Economic Activity*, 35, 1–100.

[12] Brunnermeier, M., and Y. Koby, 2019, "The Reversal Interest Rate," *mimeo.*

[13] Campbell, J., C. Evans, J. Fisher, and A. Justiniano, 2012, "Macroeconomic Effects of Federal Reserve Forward Guidance," *Brookings Papers on Economic Activity*, 43, 1–80.

[14] Chen, H., V. Cúrdia, and A. Ferrero, 2012, "The Macroeconomic Effects of Large-Scale Asset Purchase Programmes," *Economic Journal*, 122, 289–315.

[15] Christiano, L., M. Eichenbaum, and C. Evans, 1996, "The Effects of Monetary Policy Shocks: Evidence from the Flow of Funds," *The Review of Economics and Statistics*, 78, 16–34.

[16] Claus, E., and M. Dungey, 2012, "U.S. Monetary Policy Surprises: Identification with Shifts and Rotations in the Term Structure," *Journal of Money, Credit and Banking*, 44, 1443–1453.

[17] Cochrane, J., and M. Piazzesi, 2002, "The Fed and Interest Rate, A High-Frequency Identification," *American Economic Review*, 92, 90–95.

[18] Creal, D., and J. Wu, 2017, "Monetary Policy Uncertainty and Economic Fluctuations," *International Economic Review*, 58, 1317–1354.

[19] Cúrdia, V., and M. Woodford, 2011, "The Central-Bank Balance Sheet as an Instrument of Monetary Policy," *Journal of Monetary Economics*, 58, 54–79.

[20] Eggertsson, G., R. Juelsrud, L. Summers, and E. Getz Wold, 2019, "Negative Nominal Interest Rates and the Bank Lending Channel," *NBER Working Paper Series*, No. 25416.

[21] Ellingsen, T., and U. Söderstrom, 2001, "Monetary Policy and Market Interest Rates," *American Economic Review*, 91, 1594–1607.

[22] Faust, J., 1998, "The Robustness of Identified VAR Conclusions about Money," *Carnegie-Rochester Conference Series on Public Policy*, 49, 207–244.

[23] Faust, J., E. Swanson, and J. Wright, 2004, "Identifying VARs Based on High Frequency Futures Data," *Journal of Monetary Economics*, 51, 1107–1131.

[24] Foley-Fisher, N., R. Ramcharan, and Y. Edison, 2016, "The Impact of Unconventional Monetary Policy on Firm Financing Constraints: Evidence from the Maturity Extension Program," *Journal of Financial Economics*, 122, 409–429.

[25] Francis, N., M. Owyang, J. Roush, and R. DiCecio, 2014, "A Flexible Finite-horizon Alternative to Long-run Restrictions with an Application to Technology Shock," *Review of Economics and Statistics*, 96, 638–647.

[26] Gagnon, J., M. Raskin, J. Remache, and B. Sack, 2011, "The Financial Market Effects of the Federal Reserve's Large-Scale Asset Purchases," *International Journal of Central Banking*, 7, 3–43.

[27] Gambacorta, L., B. Hofmann, and G. Peersman, 2014, "The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis," *Journal of Money, Credit, and Banking*, 46, 615–642.

[28] Gertler, M., and P. Karadi, 2015, "Monetary Policy Surprises, Credit Costs, and Economic Activity," *American Economic Journal: Macroeconomics*, 7, 44–76.

[29] Gürkaynak, R., and J. Wright, 2012, "Macroeconomics and the Term Structure," *Journal of Economic Literature*, 50, 331–367.

[30] Gürkaynak, R., B. Sack, and E. Swanson, 2005a, "The Sensitivity of Long-Term Interest Rates to Economic News: Evidence and Implications for Macroeconomic Models," *American Economic Review*, 95, 425–436.

[31] Gürkaynak, R., B. Sack, and E. Swanson, 2005b, "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," *International Journal of Central Banking*, 1, 55–93.

[32] Gürkaynak, R., B. Sack, and E. Swanson, 2007, "Market-Based Measures of Monetary Policy Expectations," *Journal of Business and Economic Statistics*, 25, 201–212.

[33] Hayashi, F., and J. Koeda, 2018, "Exiting from QE," *Quantitative Economics*, *forthcoming*.

[34] Honda, Y., and Y. Kuroki, 2006, "Financial and Capital Markets' Response to Changes in the Central Bank's Target Interest Rate: The Case of Japan," *Economic Journal*, 116, 812–842.

[35] Honda, Y., and Y. Kuroki, and M. Tachibana, 2013, "An Injection of Base Money at Zero Interest Rates: Empirical Evidence from the Japanese Experience 2001-2006," *Japanese Journal of Monetary and Financial Economics*, 1, 1–24.

[36] Inoue, T., and T. Okimoto, 2008, "Were There Structural Breaks in the Effects of Japanese Monetary Policy? Re-Evaluating Policy Effects of the Lost Decade," *Journal of the Japanese and International Economies*, 22, 320–342.

[37] Iwata, S., and S. Wu, 2006, "Estimating Monetary Policy Effects When Interest Rates are Close to Zero," *Journal of Monetary Economics*, 53, 1395–1408.

[38] Jordà, O., 2005, "Estimation and Inference of Impulse Responses by Local Projections," *American Economic Review*, 95, 161–182.

[39] Joyce, M., A. Lasaosa, I. Stevens, and M. Tong, 2011, "The Financial Market Impact of Quantitative Easing in the United Kingdom," *International Journal of Central Banking*, 7, 113–161.

[40] Joyce, M., D. Miles, A. Scott, and D. Vayano, 2012, "Quantitative Easing and Unconventional Monetary Policy: An Introduction," *Economic Journal*, 122, 271–288.

[41] Kapetanios, G., H. Mumtaz, I. Stevens, and K. Theodoridis, 2012, "Assessing the Economy-Wide Effects of Quantitative Easing," *Economic Journal*, 122, 316–347.

[42] Kimura, T., and J. Nakajima, 2016, "Identifying Conventional and Unconventional Monetary Policy Shocks: A Latent Threshold Approach," *The B.E. Journal of Macroeconomics*, 16, 277–300.

[43] Kobayashi, K., and K. Ueda, 2018, "Secular Stagnation under the Fear of a Government Debt Crisis," *mimeo*.

[44] Kozlowski, J., L. Veldkamp, and V. Venkateswaran, 2015, "The Tail that Wags the Economy: The Origin of Secular Stagnation," *NBER Working Paper Series*, No. 21719.

[45] Krishnamurthy, A., and A. Vissing-Jorgensen, 2011, "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy," *Brookings Papers on Economic Activity*, 42, 215–228.

[46] Kuttner, K., 2001, "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market," *Journal of Monetary Economics*, 47, 523–544.

[47] Milani, F., and J. Treadwell, 2012, "The Effects of Monetary Policy "News" and "Surprises"," *Journal of Money, Credit and Banking*, 44, 1667–1692.

[48] Miyao, R., 2000, "The Role of Monetary Policy in Japan: A Break in the 1990s?," *Journal of the Japanese and International Economies*, 14, 366–384.

[49] Miyao, R., 2002, "The Effects of Monetary Policy in Japan," *Journal of Money, Credit, and Banking*, 34, 376–392.

[50] Miyao, R., and T. Okimoto, 2017, "The Macroeconomic Effects of Japan's Unconventional Monetary Policies," *RIETI Discussion Paper Series*, 17-E-065.

[51] Munakata, K., H. Oi, and Y. Ueno, 2019, "Monetary Policy Framework and Information Effect: Evidence from Japanese Data," *mimeo*.

[52] Nakamura, E., and J. Steinsson, 2018, "High Frequency Identification of Monetary Non-Neutrality: The Information Effect," *Quarterly Journal of Economics*, 133, 1283–1330.

[53] Nakashima, K., 2006, "The Bank of Japan's Operating Procedures and the Identification of Monetary Policy Shocks: A Reexamination Using the Bernanke-Mihov Approach," *Journal of the Japanese and International Economies*, 20, 406–433.

[54] Nakashima, K., M. Shibamoto, and K. Takahashi, 2020, "Risk-Taking Channel of Unconventional Monetary Policies in Bank Lending," *RIEB Discussion Papers*, DP2017-24.

[55] Okina, K., and S. Shiratsuka, 2004, "Policy Commitment and Expectation Formations: Japan's Experience under Zero Interest Rates," *North American Journal of Economics and Finance*, 15, 75–100.

[56] Ramey, V., 2016, "Macroeconomic Shocks and Their Propagation," In: Taylor, J., and H. Uhlig (Eds), *Handbook of Macroeconomics, vol. 2A*, 71–162, Elsevier, Amsterdam, Netherlands.

[57] Rodnyansky, A., and O. Darmouni, 2017, "The Effects of Quantitative Easing on Bank Lending Behavior," *The Review of Financial Studies*, 30, 3858–3887.

[58] Rogers, J., C. Scotti, and J. Wright, 2014, "Evaluating Asset-Market Effects of Unconventional Monetary Policy: A Multi-Country Review," *Economic Policy*, 29, 3–50.

[59] Romer, C., and D. Romer, 2000, "Federal Reserve Information and the Behavior of Interest Rates," *American Economic Review*, 90, 429–457.

[60] Romer, C., and D. Romer, 2004, "A New Measure of Monetary Shocks: Derivation and Implications," *American Economic Review*, 94, 1055–1084.

[61] Rudebusch, G., 1998, "Do Measures of Monetary Policy in a VAR Make Sense?," *International Economic Review*, 39, 907–931.

[62] Saito, M., 2019, "The Realization of Persistent Mild Deflations and the Expectation of Sudden Price Surges: Japan's Long-run Deflation in the Current and Price Surges in the Postwar," *mimeo*.

[63] Schenkelberg, H., and S. Watzka, 2013, "Real Effects of Quantitative Easing at the Zero Lower Bound: Structural VAR-based Evidence from Japan," *Journal of International Money and Finance*, 33, 327–357.

[64] Shibamoto, M., 2016, "Source of Underestimation of the Monetary Policy Effect: Reexamination of the Policy Effectiveness in Japan's 1990s," *The Manchester School*, 84, 795–810.

[65] Shibamoto, M., and M. Tachibana, 2017, "The Role of Monetary Policy on the Macroeconomy at the Interest-rate Lower Bound," *mimeo*.

[66] Shiratsuka, S., 2010, "Size and Composition of the Central Bank Balance Sheet: Revisiting Japan's Experience of the Quantitative Easing Policy," *Monetary and Economic Studies*, 28, 79–106.

[67] Stock, J., and M. Watson, 2012, "Disentangling the Channels of the 2007-2009 Recession," *Brookings Papers on Economic Activity*, 44, 81–135.

[68] Stock, J., and M. Watson, 2018, "Identification and Estimation of Dynamic Causal Effects in Macroeconomics," *Economic Journal*, 128, 917–948.

[69] Swanson, E., 2011, "Let's Twist Again: A High-frequency Event-study Analysis of Operation Twist and Its Implications for QE2," *Brookings Papers on Economic Activity*, 42, 151–207.

[70] Swanson, E., 2018, "Measuring the Effects of Federal Reserve Forward Guidance and Asset Purchases on Financial Markets," *NBER Working Paper Series*, No. 23311.

[71] Tsuruga, T., and S. Wake, 2019. "Money-financed Fiscal Stimulus: The Effects of Implementation Lag," *Journal of Economic Dynamics and Control*, 104, 132–151.

[72] Ueda, K., 2012, "The Effectiveness of Non-Traditional Monetary Policy Measures: The Case of the Bank of Japan," *Japanese Economic Review*, 63, 1–22.

[73] Ugai, H., 2007, "Effects of the Quantitative Easing Policy: A Survey of Empirical Analyses," *Monetary and Economic Studies*, 25, 1–48.

[74] Weale, M., and T. Wieladek, 2016, "What are the Macroeconomic Effects of Asset Purchases?," *Journal of Monetary Economics*, 79, 81–93.

[75] Wright, J., 2012, "What does Monetary Policy do to Long-Term Interest Rates at the Zero Lower Bound?," *Economic Journal*, 122, 447–466.

[76] Wu J., and F. Xia, 2016, "Measuring the Macroeconomic Impact of Monetary Policy at the Zero Lower Bound," *Journal of Money, Credit and Banking*, 48, 253–291.

[77] Zeev, N., C. Gunn, and H. Khan, 2017, "Monetary News Shocks," *mimeo.*

Table 1: The Number of Common Factors Underlying the Changes in Financial Market at the MPM

Number of Factors: k	0	1	2	3	4
$BN(k)$	2.98	2.94	3.06	2.89	2.95
$AH(k)$	n.a.	1.05	0.89	1.09	0.52

Notes: $BN(k)$ denotes the Bai and Ng (2002) information criteria, defined as follows;

$$BN(k) = \log(V(k)) + k\left(\frac{n+T}{nT}\right)\log\left(\frac{nT}{n+T}\right),$$

where n is the number of variables in factor model (1): $n = 12$. T is the number of observations. $V(k)$ is the sum of squared residuals divided by nT. $AH(k)$ denotes the Ahn and Horenstein (2013) information criteria, defined as follows;

$$AH(k) = \frac{\log(V(k-1))/\log(V(k))}{\log(V(k))/\log(V(k+1))}.$$

Table 2: Results for the Distributed Lag Regression of Each Monetary Policy Indicator on Monetary Policy Surprises

	Change in Policy Indicator			Level in Policy Indicator		
	Δ MB	Δ COMP	Δ SR	MB	COMP	SR
$H = 0$	2.91	4.57	13.48	1.03	4.89	17.91
	[0.41]	[0.21]	[0.00]	[0.79]	[0.18]	[0.00]
$H = 1$	3.67	5.23	25.83	1.40	5.93	31.71
	[0.72]	[0.52]	[0.00]	[0.97]	[0.43]	[0.00]
$H = 2$	8.54	17.88	33.74	6.45	19.59	47.90
	[0.48]	[0.04]	[0.00]	[0.69]	[0.02]	[0.00]
$H = 6$	20.75	27.74	81.40	26.97	31.06	96.60
	[0.47]	[0.15]	[0.00]	[0.17]	[0.07]	[0.00]
$H = 12$	54.41	61.23	67.15	69.19	72.11	107.94
	[0.05]	[0.01]	[0.00]	[0.00]	[0.00]	[0.00]
$H = 24$	126.97	527.22	288.39	171.72	470.89	394.72
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]

Notes: The distributed lag regression model is specified as equation (4). This table shows Chi-square statistics (p-values in brackets) resulting from tests of the null hypothesis: $r_h^j = 0$ for all $j = 1, 2, 3$ and $h = 0, \cdots, H$.

Table 3: Results for the Regression of Each VAR Innovation on Monetary Policy Surprises

	VAR Innovation: u_t							
	MB	COMP	SR	SP	10YJGB	BRISK	GGAP	CPI
PS^1	-2.68†	-0.19	-0.95**	0.03	-4.79**	-0.05	-0.01	0.04
	(1.62)	(0.22)	(0.35)	(0.49)	(1.71)	(0.27)	(0.01)	(0.19)
PS^2	-1.34	-0.27	0.96*	-3.85**	-0.93	-0.47	0.01	0.16
	(2.20)	(0.29)	(0.38)	(0.82)	(1.40)	(0.43)	(0.02)	(0.21)
PS^3	-1.02	-0.37	1.50*	2.16**	0.47	0.40	0.02	0.18
	(3.88)	(0.48)	(0.75)	(0.83)	(2.56)	(0.64)	(0.02)	(0.30)
χ^2	3.38	1.69	11.54	29.87	10.98	1.96	3.09	1.03
	[0.34]	[0.64]	[0.01]	[0.00]	[0.01]	[0.58]	[0.38]	[0.79]

Notes: The regression model is specified as equation (10). Values in parentheses are robust standard errors. **, *, and † indicate significance at the 1, 5, and 10% levels, respectively. χ^2 indicates Chi-square statistics (p-values in brackets) resulting from tests of the null hypothesis that estimated coefficients on the three monetary policy surprises, PS^1, PS^2 and PS^3, are jointly zero for each VAR innovation u_t.

Table 4: Forecast Error Variance Decomposition of Monetary Policy Indicators

Policy Indicator	Monetary Base			Composition			Short-term Rate		
Policy Shock	QN	QL	SR	QN	QL	SR	QN	QL	SR
$h = 0$	0.83	0.17	99.00	9.60	16.34	74.06	36.22	53.29	10.49
$h = 12$	88.03	1.87	10.10	11.01	81.54	7.45	63.54	16.08	20.38
$h = 24$	94.68	2.97	2.36	28.87	65.36	5.77	54.64	27.88	17.47
$h = 36$	97.20	1.67	1.13	40.16	54.83	5.01	53.00	30.00	17.00
$h = 48$	97.70	1.66	0.64	48.06	47.67	4.27	51.97	31.36	16.67

Notes: This table shows the estimated percentage share of the forecast error variance of each monetary policy indicator attributable to each monetary policy shock for h months ahead.

Table 5: Forecast Error Variance Decomposition of Monetary Policy Indicators under Alternative Identification

Policy Indicator	Monetary Base			Composition			Short-term Rate		
Policy Shock	QN	QL	SR	QN	QL	SR	QN	QL	SR
h =0	0.25	98.63	1.11	47.54	21.78	30.68	0	0	100
h =12	57.76	5.39	36.85	34.51	18.63	46.86	42.84	3.68	53.48
h =24	66.76	1.66	31.58	39.33	14.76	45.94	56.87	3.80	39.34
h =36	71.36	1.18	27.46	50.64	11.52	37.84	53.81	9.51	36.68
h =48	74.15	1.22	24.63	56.19	10.17	33.65	46.12	18.85	35.04

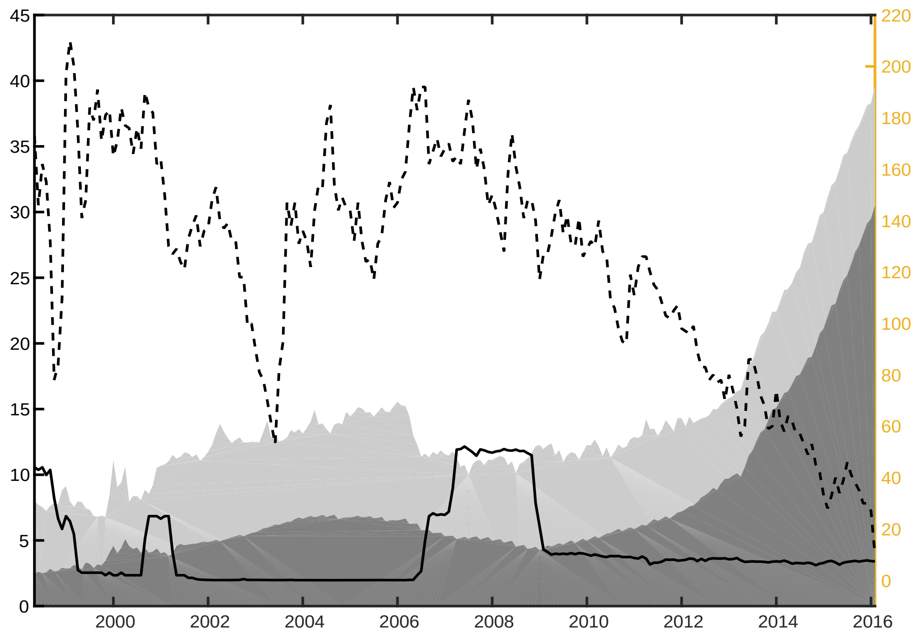
Notes: This table shows the estimated percentage share of the forecast error variance of each monetary policy indicator attributable to each monetary policy shock for h months ahead.

Table 6: Results for the Regression of Alternative Instruments on Global Economic Factors

	VAR Innovation			Monetary Policy Surprise		
	MB	COMP	SR	PS^1	PS^2	PS^3
Oil	-3.49	-1.45	-0.73	0.24	-0.07	0.52
	(23.74)	(1.91)	(2.27)	(0.62)	(0.44)	(0.36)
GIP	-5.59**	0.00	0.52	-0.04	-0.03	0.07
	(3.56)	(0.18)	(0.39)	(0.10)	(0.06)	(0.04)
USEPU	15.93*	-1.16*	-0.19	0.26	0.19	-0.17
	(8.06)	(0.51)	(0.79)	(0.23)	(0.15)	(0.11)
USTED	2.10	0.02	1.65	-0.44	0.56	0.16
	(7.33)	(0.60)	(1.22)	(0.32)	(0.41)	(0.12)
FFR	-6.67	-0.53	-0.58	-0.18	-0.43	-0.02
	(13.26)	(0.75)	(0.99)	(0.26)	(0.25)	(0.13)
χ^2	8.04	6.18	4.99	4.44	6.67	7.25
	[0.15]	[0.29]	[0.42]	[0.49]	[0.25]	[0.20]

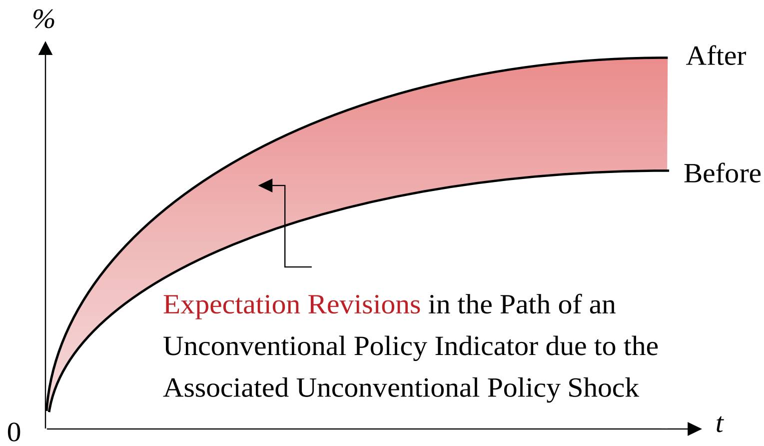
Notes: This table shows the estimated coefficients in equations (23) and (24). Values in parentheses are robust standard errors. ** and * indicate significance at the 1 and 5% levels, respectively. χ^2 indicates Chi-square statistics (p-values in brackets) resulting from tests of the null hypothesis that the estimated coefficient on the global economic factors are jointly zero.

Figure 1: Size, Unconventional Assets, Call Rate, and Long-term Bond Yield



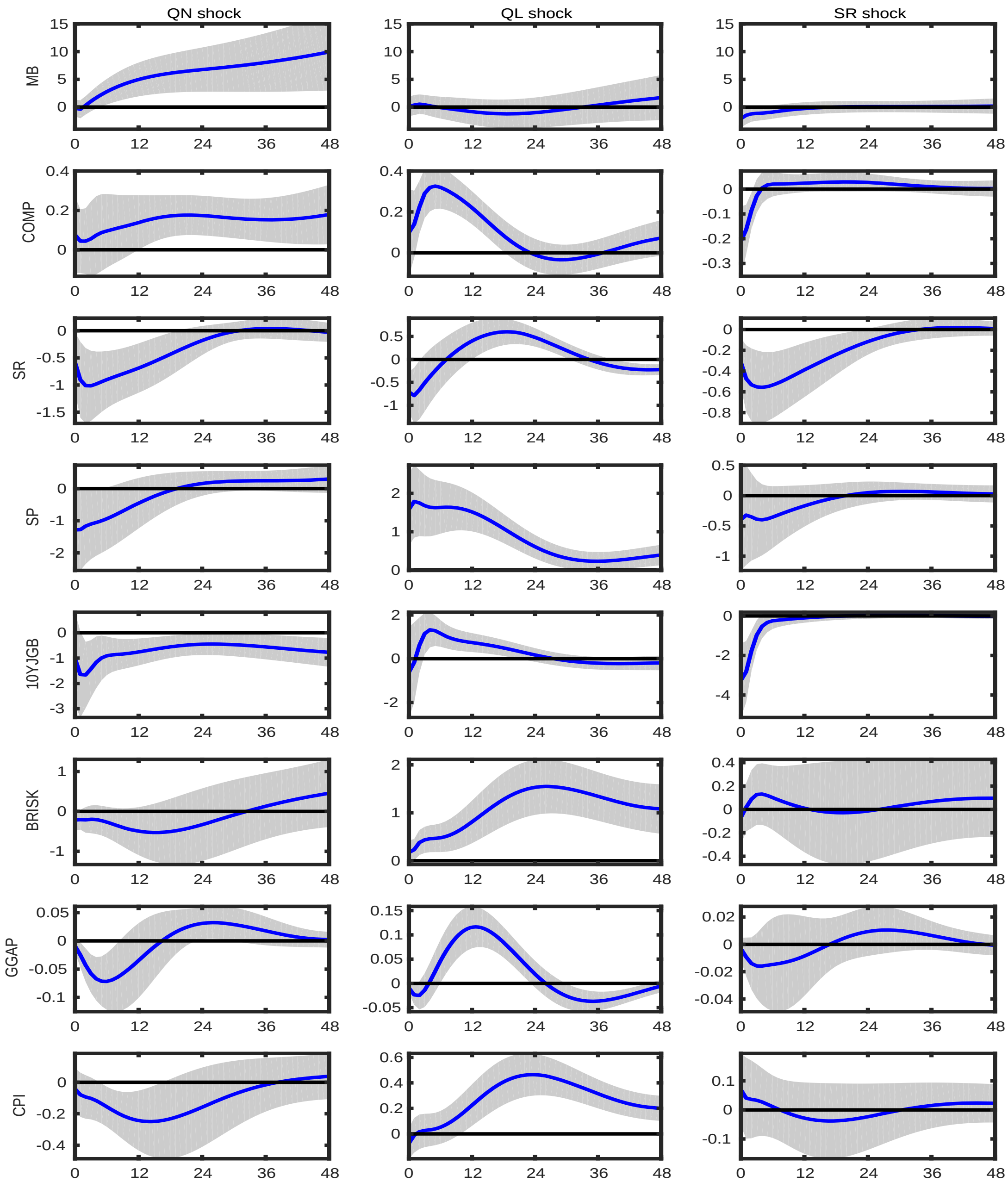
Notes: The dark gray and light gray shadows indicate the amounts of unconventional assets and conventional assets held by the Bank of Japan, respectively. The amounts are shown in units of 100 trillion Yen on the left-hand scale. Unconventional Assets include Exchange-Traded Funds (ETF), Real Estate Investment Trusts (REIT), corporate bonds, commercial paper, long-term government bonds, and asset-backed securities. Conventional assets include other assets such as short-term government bonds. The plotted and dashed lines indicate the call rate and the 10-year Japanese government bond yield, respectively. The amounts are shown in units of b.p. (100%) on the right-hand scale.

Figure 2: Expectation Revisions Just After the Public Statement



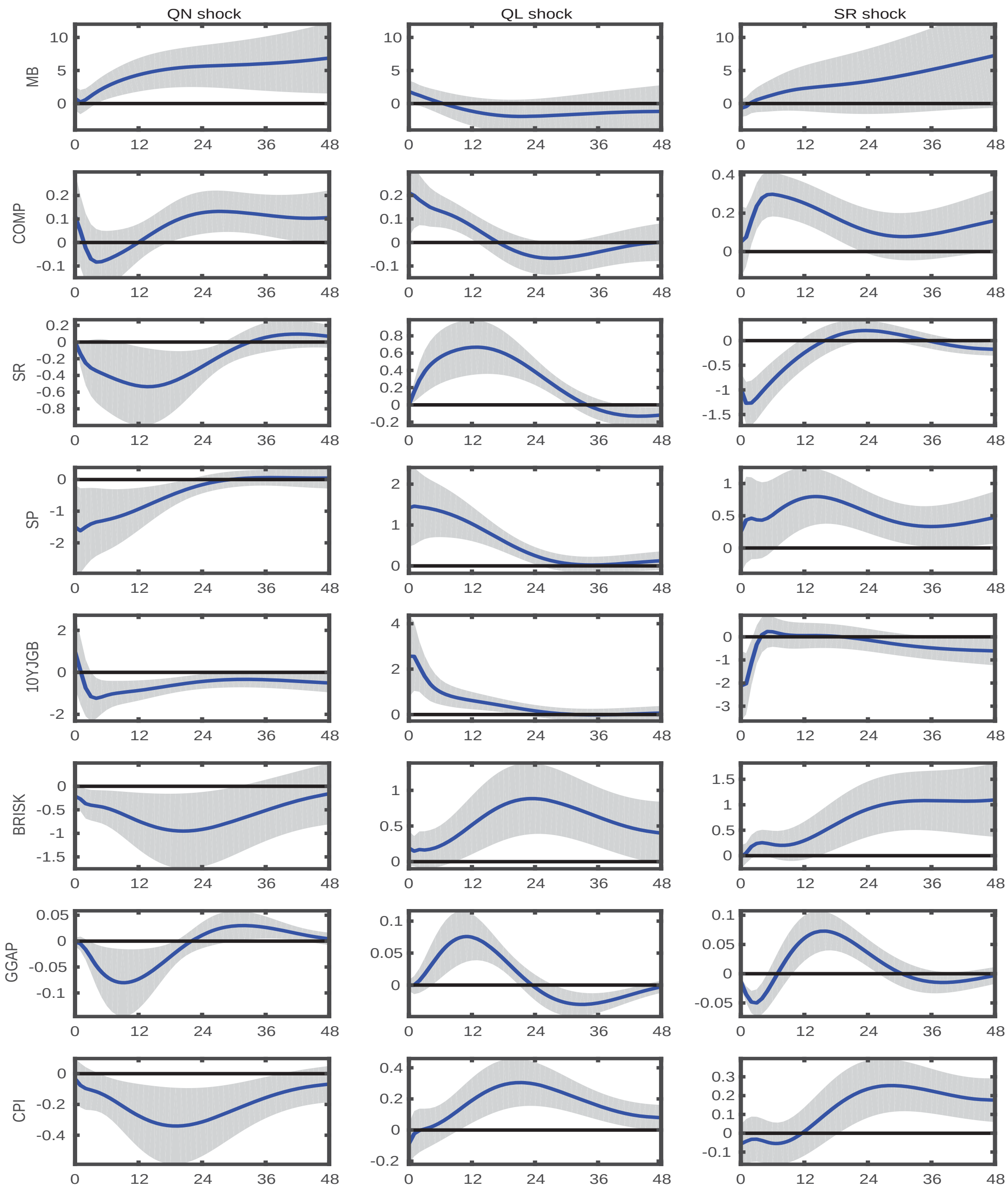
Notes: The shaded area illustrates the revisions of an agents' expectations about the current and future paths of the two unconventional policy indicators (MB and COMP) at the time of the central bank's public statement, which correspond to the denominator in equation (15). The vertical line (%) indicates a percentage change in each policy indicator, and the horizontal line (t) indicates a time after the public statement. The MFEV approach identifies the quantitative and qualitative shocks as shocks that best explain the expectation revisions shown in the shaded area.

Figure 3: Impulse Responses to the Quantitative Easing, Qualitative Easing, and Short Rate Shocks



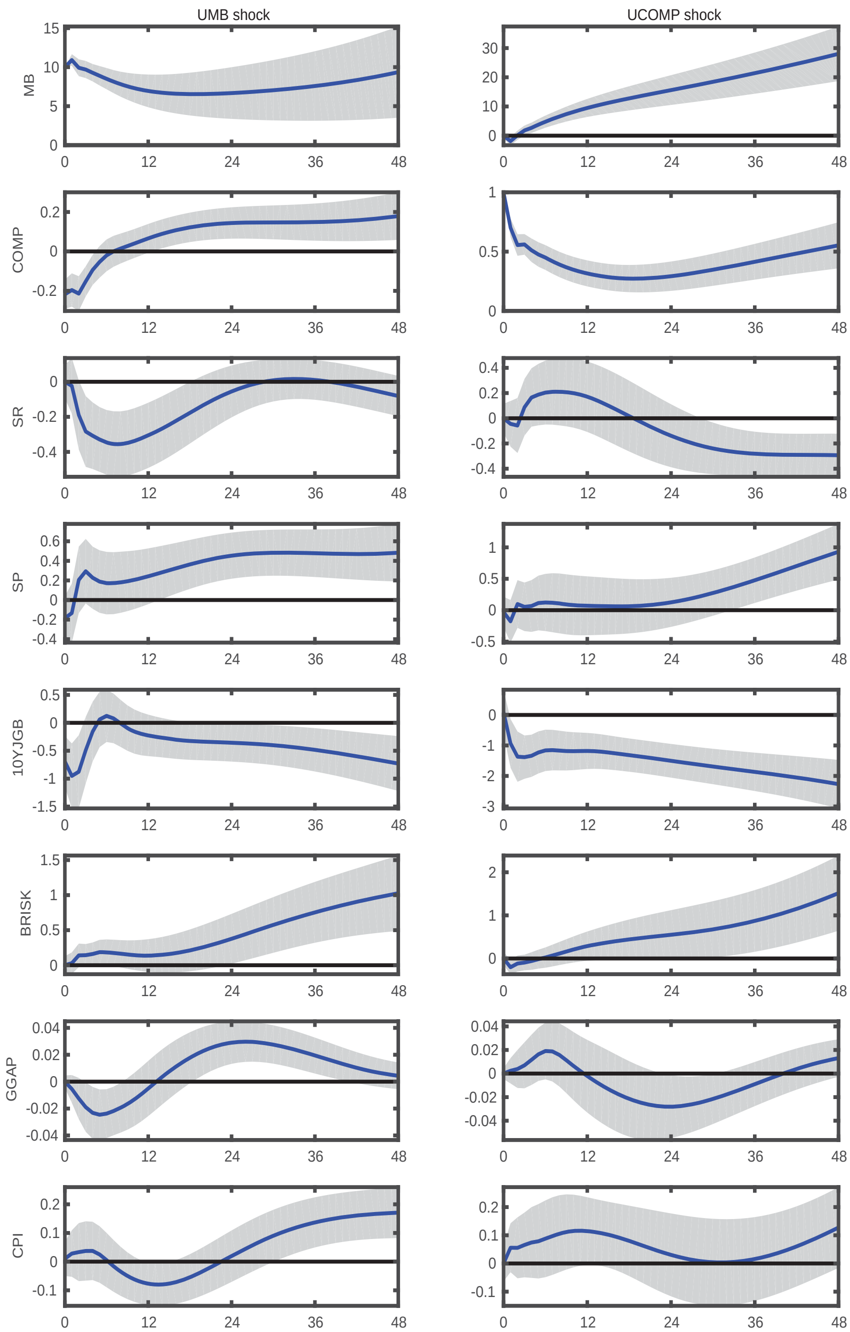
Notes: See Section 3 for details on the identification of each of the monetary policy shocks. The solid lines represent the point estimates of the impulse responses to a quantitative monetary policy shock in the eight-variable VAR model. The shaded areas represent the ± one standard error confidence band calculated by the bootstrap method with 1000 replications. The bootstrap with external instruments involves resampling from the instruments.

Figure 4: Impulse Responses to the Monetary Policy Shocks under Alternative Identification



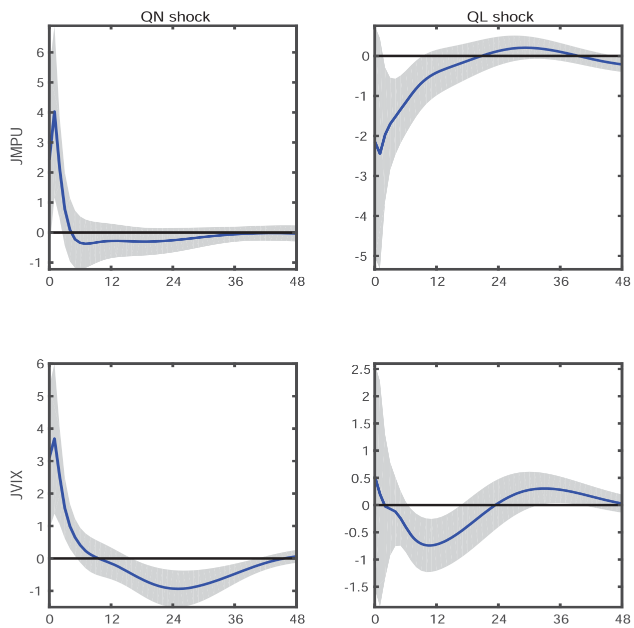
Notes: Subsection 5.1 discusses the details of identification of the monetary policy shocks. Also see the *Notes* to Figure 3.

Figure 5: Impulse Responses to Unanticipated Policy Shocks



Notes: Subsection 5.2 discusses the details of the identification of the unanticipated monetary policy shocks. Also see the *Notes* to Figure 3.

Figure 6: Impulse Responses of Uncertainty Indicators



Notes: The solid lines represent the point estimates of the impulse responses of the monetary policy uncertainty indicator (upper row) and VIX (lower row) in Japan. The impulse responses of the two uncertainty variables are obtained as their responses to the quantitative and qualitative easing shocks, by including each of the indicators into the eight-variable VAR model and employing the identification method developed in Section 3. Also see the *Notes* to Figure 3.