The effects of unconventional monetary policy in Japan: New evidence from Time-varying parameter VAR analysis

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Abstract

This paper investigates the macroeconomic effects of unconventional monetary policies by estimating a time-varying parameter structural vector auto-regression (TVP-VAR) using Japanese monthly data beginning with the implementation of quantitative easing in 2001. The results of the empirical study can be summarized in four points. First, the impulse responses of output to a positive monetary policy shock rose during the period of quantitative easing (March 2001–July 2006) but declined after the comprehensive monetary easing began (October 2010–July 2015). Second, the impulse responses of inflation to a positive monetary policy shock became stably positive after the introduction of inflation targeting in January 2013. Third, the impulse responses of stock prices to positive monetary policy shocks rose each time an unconventional monetary policy was adopted. Finally, the recovery of the credit transmission channel might be attributed to the level of non-performing loans remaining low. The third result implies that increased stock prices from a monetary policy shock are primarily affected by foreign capital because foreign capital responds more strongly than domestic capital to unconventional monetary policy.

Keywords: Monetary policy; Transmission mechanism; Time-varying parameter structural vector auto-regression model; Quantitative easing; Inflation targeting; Quantitative qualitative easing

1. Introduction

Finally, Japan's prolonged deflation is ending, which is primarily the result of the policies implemented by the Abe administration that are commonly known as Abenomics. Japanese monetary policy changed to combat deflation and the economic downturn that resulted after the economic bubble burst. For example, a zero interest rate policy was implemented from February 1999 to August 2001, quantitative easing (QE) was implemented from March 2001 to March 2006 and comprehensive monetary easing (CME) was implemented beginning in October 2010. This monetary policy temporarily raised prices and improved the economy but could not do so permanently. Abenomics consists of three arrows: a bold monetary policy, a flexible fiscal policy and a growth strategy to encourage private investment. The Bank of Japan (BOJ) introduced an annual inflation rate target of 2% in January 2013 as part of its bold monetary policy. Additionally, the BOJ announced that they were introducing quantitative qualitative monetary easing (QQE) to achieve the inflation target. As a result, stock prices improved and a strong yen depreciated immediately following the introduction of QQE.

Although QQE increased stock prices and depreciated the yen, it has had only a negligible impact on the real economy, i.e., on the growth rate, wages and prices. Moreover, there has been a great deal of discussion of late regarding the impact of unconventional monetary policy on the macroeconomy. Honda et al. (2007) and Harada and Mashijima (2010) published well-known empirical analyses of the effects of such unconventional monetary policies on the real economy and on transmission channels in Japan. Both papers analyzed the impact of QE on the macroeconomic variables—"especially, output and prices"—and transmission channels using vector auto-regression (VAR) during the QE period (March 2001–February 2006). Unsurprisingly, both papers claimed that the impulse responses of output to a positive monetary policy shock rose during the QE period. With regard to transmission channels, Honda et al. (2007) note that the strongest route is stock prices, whereas Harada and Mashijima (2010) posit that the main route is through asset prices—"like stock prices and land prices"—and the business conditions of banks. However, these papers did not analyze the effects of unconventional monetary policies (such as QQE) in recent years, and their sample size was only 60; it is

possible that this small sample size led to estimation errors. Therefore, this paper uses data from a longer period—March 2001 to July 2015. The features of this study can be summarized in two points. First, the data period includes the Abenomics period, which began in 2012 with the Abe administration. Second, we used time-varying parameter structural vector auto-regression (TVP-VAR) to investigate the regime change.

The empirical results of this study can be summarized in the following four points. First, the impulse responses of output to a positive monetary policy shock rose during the period in which QE was implemented (March 2001–July 2006) but declined after CME was implemented (October 2010–July 2015). Second, the impulse responses of inflation to a positive monetary policy shock became stably positive after inflation targeting was introduced in January 2013. Third, the impulse responses of stock prices to a positive monetary policy shock rose every time that an unconventional monetary policy was adopted. Finally, the recovery of the credit transmission channel might be attributed to the level of non-performing loans (NPL) remaining low. We highlight the inflow of foreign capital as the cause of the first and third results. As a result, we emphasize the following three points about monetary policy. First, it is important for Japan to explain its monetary policies well for the benefit of foreign traders to increase the likelihood that monetary policies will achieve their aims. According to trends in the distributed percentage of market value owned by type of shareholder, unconventional monetary policy tends to affect foreign investors more than domestic investors. Moreover, the percentage of foreign investors has tended to increase, and it stands at approximately 30 percent over the past three years. Therefore, if the government does not do what it says—or if it otherwise creates anxiety about the Japanese economy or finance among foreign investors—stock prices will decline. Hence, the BOJ should announce its monetary policy with a strong focus on foreign investors to minimize risk in the stock transmission channel, and the government should clarify the direction of fiscal consolidation so that foreign investors do not construe the BOJ's purchases of government bonds as monetization. Second, Japan must continue to target inflation. The results of the analysis in this paper show that the impulse responses of inflation to a positive monetary policy shock become stably positive after the introduction of inflation targeting. Therefore, the BOJ should

continue to target inflation to overcome deflation regardless of whether price stability is achieved. Third, it is possible that European QE may not lead to an increase in bank lending. The European Central Bank (ECB) began implementing QE in March 2015, but the NPL ratio in Europe was 9.2 percent, which is higher than the NPL ratio in Japan was when QE was implemented. The empirical results show that if the ECB is aiming to utilize the credit transmission channel, it should decrease NPL.

This paper is organized as follows. Section 2 describes Japanese monetary policies following implementation of QE. Section 3 summarizes the previous studies concerning monetary policy and TVP-VAR. Section 4 describes the data set and estimates using TVP-VAR. Finally, section 5 presents our conclusions.

2. Japanese monetary policy

After Japan's bubble economy of the 1980s burst, the BOJ reduced its official discount rate nine times between 1991 and 1995. As a result, the official discount rate was 0.5 percent and the Japanese economic growth rate was over 2 percent through the mid-1990s. Unsurprisingly, this rate of growth could not endure. The main cause of Japan's long economic downturn was the increase in financial institutions' NPL ratios. Although the BOJ decreased its overnight call rate from 0.5 percent to 0.25 percent in September 1998, the Japanese economy was still not improving. With this in mind, the BOJ introduced the zero interest rate policy (ZIRP) in February 1999, reducing the overnight call rate to nearly zero. Upon implementation of this policy, the economy improved based on increased demand from foreign countries. Therefore, the BOJ decided to lift the ZIRP in August 2000. In this section, we describe the history of Japanese monetary policy after implementing QE.

2.1 Quantitative easing (March 2001–July 2006)

After lifting the ZIRP, the Japanese economy declined as a result of the collapse of the IT bubble and its NPL problem. Thus, the BOJ decided to introduce QE in March 2001. The features of QE can be summed up in the following two points. First, the policy instrument changed from the interest rate to BOJ current account balances (CABs). Second, the BOJ promised that QE would continue "until the consumer price index (excluding perishables, on a nationwide statistics) registers stably a zero percent or an increase year on year." This was the first time in the history of the world that QE was used to ease the market.

Initially, the target for the outstanding balance was established at approximately 5 trillion yen. However, the BOJ increased the target many times, reaching 30-35 trillion yen in January 2004. As a result, the overnight call rate fell to zero percent and remained close to zero. In March 2006, the BOJ decided to lift QE because the economy had recovered and the consumer price index (CPI) was now positive. In addition, the BOJ lifted the ZIRP in July 2006, increasing the overnight call rate to 0.25 percent.

2.2 Comprehensive monetary easing (October 2010–April 2013)

After ending QE in March 2006, private financial institutions decreased their outstanding current account balances at the BOJ to legally required reserve levels. However, the Lehman Brothers bankruptcy led to a stronger yen and deflation in Japan. Therefore, the BOJ introduced CME in October 2010. The three features of Japan's CME are as follows. First, the target of the overnight call rate was set to approximately 0 to 0.1 percent. Second, the BOJ clarified the policy's time horizon based on its understanding of medium- to long-term price stability. Third, the BOJ established an asset purchase program under which it purchased various financial assets, such as government securities, commercial paper (CP), corporate bonds, exchange-traded funds (ETFs), and Japanese real estate investment trusts (J-REITs). This monetary policy not only clarified the policy time horizon but also introduced the asset purchase program; therefore, it was unconventional in terms of method. In addition, the budget for the asset purchase program increased several times, receiving 101 trillion yen in December 2012.

2.3 Quantitative qualitative easing (April 2013 -)

Although CME was introduced to tackle the stronger yen and deflation, it could not support the recovery. Therefore, the BOJ announced a price stability goal for the medium- to long-term and set a range of 2 percent or lower in terms of the year-to-year rate of change in the CPI and, more specifically, initially set a goal of 1 percent. However, since the policy was misunderstood to be inflation targeting, stock prices increased and the exchange rate weakened, which was referred to as the Valentine shock. However, the situation changed completely when the BOJ announced that it was not targeting inflation. Moreover, when Prime Minister Noda announced that the House of Representatives was dissolving in November 2012, stock prices jumped, and the exchange rate weakened because of expectations surrounding Abe, president of the Liberal Democratic Party. Abe became Prime Minster in December 2012 and thereafter created a new economic policy, which is referred to commonly as Abenomics. Abenomics consists of three pillars: a bold monetary policy, a flexible fiscal policy, and a growth strategy designed to encourage private investment. This policy aims squarely at overcoming deflation and the economic

downturn. Initially, Prime Minister Abe requested that the BOJ ease the market as a bold monetary policy, and the BOJ decided to introduce a price stability target of 2% in January 2013. In addition, the BOJ introduced QQE in April 2013. The three features of this policy are as follows. First, the policy instrument changed from the uncollateralized overnight call rate to the monetary base, and the BOJ then announced that the monetary base would double in two years. Second, the BOJ set the inflation target at 2 percent in terms of the year-on-year rate of change in the CPI, and this goal will be quickly achieved. Third, the BOJ purchased a large quantity of Japanese government bonds (JGBs) and increased its risky asset, ETF and J-RIET purchases to achieve the inflation target. QQE is a significant monetary policy in Japan because it not only increased the purchase amount and extended the average remaining maturity of JGBs in comparison with the QE but also introduced inflation targeting.

After implementation of QQE, the Nikkei Stock Average increased nearly 50 percent and the yen weakened within 2 years to almost 30 percent of its value (as measured against the U.S. Dollar) compared to the period of the Noda administration. However, the BOJ decided to expand QQE in October 2014 (which is referred to as the "Halloween shock" in Japan) due to tax increases in April 2014 and lower crude oil prices. The features of this expansion can be summed up in the following three points. First, the BOJ accelerated the pace of increase in the monetary base (the increase was approximately 80 trillion yen annually). Second, the BOJ expanded its long-term JGB purchases and extended the average remaining maturity of JGB purchases (the outstanding value of long-term JGBs is approximately 80 trillion yen annually, and the average remaining maturity of JGB purchases will extend nearly 7-10 years). Third, the BOJ increased its asset purchases and raised its target (the BOJ began purchasing ETFs, which are connected to the JPX-Nikkei Index 400). As a result, the increase in stock prices and the decrease in the exchange rate of the yen have further accelerated.

3. Previous studies

After the bubble economy burst in the mid-1990s, the Japanese economy was in decline due to deflation. By the early 2000s, although the economy was gradually improving, monetary policy had been altered due to the rupture of the IT bubble in the early 2000s, the bankruptcy of Lehman Brothers in 2008, the ZIRP from 1999 to 2000, QE from 2001 to 2006, CME beginning in 2010, and QQE beginning in 2013. This section summarizes previous studies addressing monetary policy and TVP-VAR.

3.1 Monetary policy's effects on macroeconomic and financial market variables

This subsection summarizes the previous studies that have addressed monetary policy in Japan, which investigated the effects of monetary policy on macroeconomic and financial market variables. The analysis of monetary policy is performed using two methods. One method does not consider the effects of regime change on monetary policy and uses VAR with a constant parameter. The other method considers the effects of regime change on monetary policy, whereby researchers are able to analyze only the time period in which they are interested. Papers representing the first method include Harada and Kwon (2005) and Kitaoka et al. (2013). Representative papers of the latter method include Kimura et al. (2002), Sadahiro (2005), Fujiwara (2006), Honda et al. (2007), Harada and Mashijima (2010), Iwata (2010), Honda and Tachibana (2011) and Hayashi and Koeda (2014). Table 1 summarizes the salient aspects of these papers.

Honda et al. (2007) analyze the effects of QE in Japan (and, in particular, on QE's effects on outputs, prices and the transmission channel) using VAR. Initially, these authors estimate the VAR using three variables—output, prices and the target level of the CABs—to help them analyze the effects of monetary policy on output and prices during QE. As a result, these authors show that the impulse responses of prices to a positive monetary policy shock do not have a noticeable effect; however, the impulse responses of output to a positive monetary policy shock involve a sustainable rise. Next, these authors estimate the VAR with four variables by adding variables related to the stock market (such as stock prices, the exchange rate, and bank lending and long-term interest rate) so that they can analyze its effect on output. Thus, these authors show the following

two results. First, QE affects output mainly through the stock transmission channel. Second, the results are consistent with the portfolio rebalancing effect because QE slightly lowers the yen's exchange rate and decreases bank lending.

Harada and Mashijima (2010) generate a more comprehensive analysis than Honda et al. (2007) by adding variables. Specifically, they analyze QE's effect on the economy and its transmission channels using VAR with Japanese monthly data from March 2001 to February 2006. Initially, they estimate the VAR with three variables—output, prices and monetary base—to analyze the effect of monetary policy on output and prices during QE. As a result, they claim that the monetary base has a significantly positive effect on output and that output increases prices. Next, they estimate the VAR with four variables by adding a variable such as the nominal effective exchange rate, the amount of bank lending, bank stock prices, apartment prices or the long-term interest rate so that they might analyze its effects on the economy. As a result, these authors show that an increase in the monetary base affects macroeconomic variables mainly through asset prices, stock prices and land prices, and the financial health of their bank (bank stock prices).

Honda and Tachibana (2011) estimated a longer range of data than the data used by Honda et al. (2007) to address a larger number of samples. The main differences between the new study and Honda et al. (2007) are the following two points. First, Honda and Tachibana (2011) employ data that cover the QE period. Second, they use two dummy variables to represent political regime change. The period employed by Honda and Tachibana (2011) spans from January 1996 to March 2010 and estimates the following three VAR. First, they measure the VAR with five variables—prices, output, overnight call rate, stock prices and outstanding balance of current accounts at the BOJ—multiplied by the dummy variable, which was assigned the value of one during the QE period. Second, these authors use the VAR with six variables by adding one variable to the VAR with five variables. The added variable is CABs multiplied by the dummy, which was assigned the value of one during the period other than the QE period. Third, they use the VAR with seven variables by adding one variable to the VAR with six variables. The added variable is CABs multiplied by the dummy, which was assigned the value of one

during the periods before and after QE. As a result, they showed that QE does not affect prices but that it has a significant positive effect on output and stock prices. Thus, they support the asset transmission channel.

Kitaoka et al. (2013) verify the effects of QE by following the Honda et al. (2007) study and using Japanese monthly data from January 2001 to December 2012. Specifically, they analyze the effect of QE using four models—VAR in level, VAR in difference, vector error-correction (VEC) models and Bayesian vector auto-regression (BVAR) models—with five variables: the monetary base, prices, the exchange rate, the Tokyo stock price index (TOPIX) and output. The results show that the impulse response of output to a positive monetary policy shock was not confirmed in the VEC model and the VAR in difference; however, it had a significantly positive effect in the VAR in level and the BVAR. In addition, these authors showed that the impulse responses of prices to a positive monetary policy shock decreased everywhere (known as the price puzzle); thus, they are skeptical of the effectiveness of QE.

3.2 TVP-VAR[1]

The VAR technique has been used by many researchers to analyze the economy since Sims proposed it in 1980. However, because the parameter of the general VAR is constant across time, Canova (1993), Sims (1993) and Stock and Watson (1996) developed a new model of the VAR to address the critique that it should consider the interrelationship among the economic variables in the analysis, which is the so-called Lucas critique (Lucas, 1976). Following these authors, Cogley and Sargent (2001) analyzed the macro analysis after World War Ⅱ in the United States using a model in which the parameter varies with time. However, Sims (2001) and Stock (2001) criticized the Cogley and Sargent (2001) model because it assumes that the variance of structural shocks is always constant. Therefore, Cogley and Sargent (2005) performed a similar analysis that assumed the variance of structural shock as a stochastic volatility (SV) model. Then, Primiceri (2005) changed the constant to a time-varying simultaneous correlation parameter of structural shocks, and the current type of TVP-VAR was completed. The use

[1] Nakajima (2011) summarized the history of TVP-VAR.

of the TVP-VAR has increased in popularity recently in Japan. Representative papers include Nakajima et al. (2010), Nakajima and Watanabe (2011), and Kimura and Nakajima (2016). Kimura and Nakajima (2016) analyzes the effects of conventional and unconventional monetary policy on the economy using TVP-VAR with a latent threshold; the conventional period spans from the first quarter of 2001 to the first quarter of 2006, whereas the unconventional period is from the first quarter of 2010 to the third quarter of 2012. They estimated five variables in their model, including inflation, output gap, short-term interest rate, bank reserves and the long-term interest rate, so that they could analyze the effects of monetary policy on output and prices. Consequently, they showed the following two results. First, the impulse responses of an output gap and inflation to a negative monetary policy shock were positive during the period of a conventional monetary policy. However, the responses of an output gap and inflation gradually became weak after the bubble economy burst. Second, the impulse responses of an output gap and inflation to a positive monetary policy shock rise during the period of unconventional monetary policy, but its effects are uncertain, as both credible intervals are so wide.

As we indicate above, TVP-VAR is appropriate for analyzing the variation in the interrelationship among variables, such as structural change or policy change. This characteristic contributes to our analysis because we use data from a long period of time (our data include a number of monetary policy changes). In addition, Nakajima (2011) published the code of TVP-VAR on the Internet, and we use it in this paper.

4 Empirical analysis

In this section, we analyze the effects of unconventional monetary policy on the macroeconomic variables and transmission mechanism. Specifically, we estimate the effects of unconventional monetary policy following Honda et al. (2007), who initially reveal the effects of QE on output and prices using VAR with three variables—output, prices and the target level of the CABs—with monthly Japanese data from March 2001 to February 2006. These authors estimate VAR with four variables by adding a variable related to the stock market. As a result, they conclude that QE has a positive effect on output and that the main QE transmission channel is the stock price channel. However, Honda et al. (2007) did not analyze the effects of unconventional monetary policy (i.e., QQE) in recent years, and their sample size was only 60 because they estimated only QE. Therefore, we use a longer span of data from March 2001 to July 2015, and we use TVP-VAR to consider the impact of regime change on monetary policy.

4.1 Data and priors

In this paper, we use monthly data from March 2001 to July 2015 for output (y), prices (p), current account balances at BOJ (m), stock price (k), exchange rate (e), and bank lending (b).[2] The sources of data are summarized in the Appendix (see Table 2). Table 3 shows the differences in results between this paper and Honda et al. (2007).[3] In addition, we use only stock price, exchange rate and bank lending as financial market variables in this paper.[4]

Figure 3 shows the changes in these variables during the observation period. The vertical lines are the dates on which QE ended, the beginning of CME and the beginning of QQE, from left to right. Output increased after QE was implemented, but it began to decrease over time due to the subprime mortgage crisis that began in the middle of 2007.

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[2] All variables are in logarithm form (multiplied by 100). In addition, we assume the identification ordering of the output, prices, the current account balances at BOJ and the financial market variables same as Honda et al. (2007). We estimate four alternative orderings, and we obtained similar results.

[3] Figures 1 and 2 show the comparison view of these differences.

[4] Honda et al. (2007) use the LIBOR and the long-term swap rate, but they show that these variables do not work as well as the transmission channel.

Furthermore, it fell sharply before and after the Lehman Brothers bankruptcy in September 2008. However, it has been stable since CME began, with the exception of the Great East Japan Earthquake that occurred in March 2011. Prices rose after 2007 due to the rise in crude oil prices, in addition to grain prices having affected energy-related goods such as gasoline and kerosene. However, prices fell after the Lehman Brothers bankruptcy and remained at a low level due to a drop in durable consumer goods prices. In addition, prices began to rise gradually just before the inflation targeting was introduced in January 2013 and rose especially sharply after the consumption tax increased from 5 percent to 8 percent in April 2014. Current account balances at the BOJ continued to increase after introduction of CME and QQE, although the balances had been stable at a lower position. Stock prices began to decline following the onset of the subprime mortgage crisis occurred in 2007. Additionally, although they had been stable at the lower position, they rose after the Abe administration took power in December 2012. Although the exchange rate had weakened, it gained strength before and after the Lehman Brothers bankruptcy in 2008. However, it has weakened against since the onset of the Abe administration. Bank lending had decreased during QE but began to increase after the NPL ratio stabilized in 2006. Although it had declined temporarily because of the global economic deterioration, it has increased since the Abe administration took power.

To determine the number of lags, we use the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). We consider both characteristics and we use the average of the AIC and BIC. As a result, the lags of the stock price model and the bank-lending model are determined to be 2 and the lag of the exchange rate model is 3. In addition, the prior distribution of the TVP-VAR is assumed to be a diagonal matrix. The prior distributions are as follows:

$$(\sum_{\beta})_i^{-2} \sim \text{Gamma}(20, 10^{-4}), \quad (\sum_{a})_i^{-2} \sim \text{Gamma}(4, 10^{-4}), \quad (\sum_{h})_i^{-2} \sim \text{Gamma}(4, 10^{-4})$$

Furthermore, according to the convergence diagnostics (CD) of Geweke (1998) and inefficiency factors, we use simulated data by drawing 10,000 samples after the initial

1,000 samples are discarded[5].

4.2 TVP-VAR[6]

We explain the TVP-VAR in this subsection. The TVP-VAR is a type of VAR in which the parameter can vary with time. The TVP-VAR model defined as:

$$A_t y_t = F_{1t} y_{t-1} + \cdots + F_{st} y_{t-s} + u_t \qquad t = s+1, \ldots, n \tag{1}$$

where y_t is the k×1 vector of observed variables ($y_t = (y_{1t}, \ldots, y_{kt})$), and A_t, $F_{1t}, \ldots, F_{st}$ are k×k matrixes of time-varying coefficients. The disturbance u_t is a k×1 structural shock, and we assume that $u_t \sim N(0, \Phi_t)$. Then, this form can be written as for reduced form as follows:

$$\begin{aligned} y_t &= B_{1t} y_{t-1} + \cdots + B_{st} y_{t-s} + \varepsilon_t \\ \varepsilon_t &\sim N(0, \Omega_t) \qquad t = s+1, \ldots, n \end{aligned} \tag{2}$$

where $B_{it} = A_t^{-1} F_{it}$ and $\varepsilon_t = A_t^{-1} u_t$ for $i = 1, \ldots, s$. ε_t is a k×1 error term vector. Then, the variance of ε_t was performed a Cholesky decomposition to impose recursive restriction,

$$\Omega_t = A_t^{-1} \Sigma_t \Sigma_t^{'} \, A_t^{-1'} \tag{3}$$

where A_t is a k×k lower triangular matrix in which the diagonal elements are equal to one,

$$A_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ a_{21t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1t} & \cdots & a_{k,k-1,t} & 1 \end{bmatrix}$$

[5] Table 4 shows the estimation results computed using the MCMC algorithm (posterior means, standard deviations, 95% credible intervals, Geweke convergence diagnostics statistics and inefficiency).

[6] See Nakajima (2011) and Primiceri (2005) for further details on the TVP-VAR methodology.

and Σ_t is the k×k diagonal matrix,

$$\Sigma_t = \begin{bmatrix} \sigma_{1t} & 0 & \dots & 0 \\ 0 & \sigma_{2t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & \sigma_{kt} \end{bmatrix}$$

Now, we rewrite model (2) and (3) as follows:

$$\begin{aligned} y_t &= X_t\beta_t + A_t^{-1}\Sigma_t e_t \\ e_t &\sim N(0, I_k) \end{aligned} \tag{4}$$

where β_t is a $k^2s \times 1$ vector and is obtained by stacking elements in the rows of $B_{1t}, \dots, B_{st}$. In addition, we define $x_t = I_k \otimes (y_{t-1}', \dots, y_{t-s}')$ in equation (4) (where $\otimes$ denotes the Kronecker product). Next, let $a_t = (a_{21t}, a_{32t}, a_{41t}, \dots, a_{k,k-1,t})'$ be a stacked vector of the lower-triangular elements in A_t and $h_t = (h_{1t}, \dots, h_{kt})'$ with $h_{jt} = log\sigma_{jt}^2$. Now, we assume the parameters in equation (4) follow a random walk process as follows:

$$\begin{aligned} \beta_{t+1} &= \beta_t + u_{\beta t} \\ a_{t+1} &= a_t + u_{at} \\ h_{t+1} &= h_t + u_{ht} \end{aligned} \qquad \begin{pmatrix} \varepsilon_t \\ u_{\beta t} \\ u_{at} \\ u_{ht} \end{pmatrix} \sim N\left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix}\right),$$

for $t = s+1, \dots, n$ *where* $\beta_{s+1} \sim N(\mu_{\beta 0}, \sum_{\beta 0}), a_{s+1} \sim N(\mu_{a0}, \sum_{a0})$ *and* $h_{s+1} \sim N(\mu_{h0}, \sum_{h0})$.

In addition, we used the Bayesian inference to estimate the above equation because the TVP-VAR model cannot estimate a posterior distribution by the generally maximum likelihood method due to several latent variables. Therefore, most TVP-VAR models use the Markov Chain Monte Carlo (MCMC) method[7].

4.3 Estimation results

Figures 4, 5 and 6 show the impulse responses of macroeconomic variables and financial market variables to a positive monetary policy shock. Figure 4 shows the QE period, Figure 5 shows during and after the CME period and Figure 6 shows the entire

[7] See Nakajima (2011) and Kitaoka et al. (2013) for more details.

sample period. The lines in the Figures represent the responses: the dotted line represents three months, the dashed line denotes half a year, the solid line represents a year and a chain line denotes two years. In addition, the vertical lines in the Figures represent the dates that the target level of the CABs and the Asset purchase fund rose. Table 5 shows the dates of policy changes, the announced targets of the CABs and the amount of the asset purchase program.

As a result, we note four interesting points. First, an unconventional monetary policy shock raises stock prices. In response to an unconventional monetary policy shock, stock prices increased at the beginning of the QE period and remained flat and positive, even after the target level of the CABs stabilized. In addition, stock prices increased notably before and after 2012 due to the influence of foreign capital. Based on Figure 7, we see the following two points. First, the stock holding ratio of domestic financial institutions and domestic institutional investors were gradually reduced during QE and remained at a low level after that period. Second, the share of foreign investors began to increase gradually in the middle of QE and reached its peak at the end of QE. The reason for the first result is that domestic financial institutions adjusted their stock holdings after the Financial Services Agency introduced limits on shareholdings in January 2001. Therefore, domestic institutional investors began to sell their shares in 2003. The second reason is that new participants, such as Steel Partners and the Children's Investment Fund, entered the Japanese stock market and there was an increase in floating stock because domestic financial institutions and domestic institutional investors reduced their stock holdings. After QE began, the share of foreign investors was highest, and it increased significantly after the Abe administration formed a government. (The percentage of foreign investors has increased by approximately 30 percent in the past three years.) In addition, the share of foreign investors markedly increased during the period of an unconventional monetary policy. In summary, foreign capital responds more strongly than domestic capital to unconventional monetary policy. Thus, we assume that an increase in stock prices from a monetary policy shock will be driven primarily by foreign capital. Second, an unconventional monetary policy improved output during QE, but its effectiveness was lost after QE ended, primarily due to foreign capital (for reasons

described in the first point). Based on Figure 7, at the beginning of QE, foreign investment ranked third. However, it gradually increased during QE, reaching first place by the end of QE. By contrast, the percentage of foreign investors has largely maintained a first-place ranking since CME began, and recently, it is far ahead of other investors. Therefore, it is assumed that most profits from equity securities were earned by foreign investors after CME was implemented, unlike the QE period. Thus, an unconventional monetary policy shock does not have a positive effect on output despite an increase in stock prices. Third, NPL may have disrupted the credit transmission channel. Figure 8 shows that the NPL ratio fell to 3 percent or less before and after QE. In addition, Figure 6 shows that the impulse response of bank lending to a positive monetary policy shock became positive after the QE period ended. Therefore, the NPL correlated with bank lending. Finally, the impulse responses of inflation to a positive monetary policy shock become stably positive after inflation targeting was introduced in January 2013. Based on Figures 4, 5 and 6, the impulse responses of inflation were unstable during QE and became negative before and after the CME. The main reason for the negative responses is assumed to be the low level of consumer sentiment caused by poor employment conditions and the declining wage trend. However, the impulse responses of inflation rose gradually before and after the Abe administration took office. Moreover, the impulse responses of inflation became positive after inflation targeting was introduced. This result is attributed to positive expectations for a change of government with Prime Minister Abe.

5. Conclusion

We analyze the effects of unconventional monetary policy on the real economy and examine its transmission mechanisms using TVP-VAR, and we have generated the following four results. First, the impulse responses of output to a positive monetary policy shock rose during the QE period (March 2001–July 2006) but declined after implementation of CME (October 2010–July 2015). Second, the impulse responses of inflation to a positive monetary policy shock became stably positive after inflation targeting was introduced in January 2013. Third, the impulse responses of stock prices to a positive monetary policy shock rose during the period of each unconventional monetary policy. Fourth, the recovery of the credit transmission channel might be attributed to the fact that the level of NPL remained low.

We identified the inflow of foreign capital as the cause of the first and third results. Figure 7 shows that foreign capital responds more strongly than domestic capital to an unconventional monetary policy. Therefore, an increase of stock prices from a monetary policy shock will primarily be driven by foreign capital. In addition, Figure 7 shows that the stock holding ratio of foreign investors was in the middle of an upswing during the QE period, but it primarily ranked first after implementation of CME. Thus, the effects of an unconventional monetary policy on output does not work as well on and after CME as it does for QE. Next, we show that the NPL ratio correlated with the credit channel. Based on Figures 6 and 8, the impulse responses of bank lending became positive after the NPL ratio slipped under 3 percent because commercial banks were reluctant to lend additional funds, as they had significant NPL.

Specifically, the empirical results show the following three points. First, it is important to provide information concerning Japan's monetary policy to foreign traders to allow monetary policy to be implemented effectively. As we described above, the impulse responses of stock prices to a positive monetary policy shock rose every time that an unconventional monetary policy was adopted, and the central reason is foreign capital. The percentage of foreign investors tended to increase to approximately 30 percent over the past three years. Therefore, if the government does not do what it says, or if the anxiety about the Japanese economy spreads to foreign investors, it appears that

stock prices will decline. However, although the impulse responses of output to a positive monetary policy shock were negative after implementing CME, it rose gradually after 2012. Therefore, it is possible that the output becomes positive if the BOJ continues QQE. The BOJ should announce the direction of its monetary policy with a focus toward foreign investors to reduce the risk to the stock transmission channel, and the government should clarify its direction in fiscal consolidation so that foreign investors do not believe the BOJ is buying government bonds to monetize the yen. Second, targeting inflation affects prices. Based on Figure 5, the impulse responses of inflation to a positive monetary policy shock became stably positive after introduction of inflation targeting. Therefore, the BOJ should continue to use inflation targeting for overcoming deflation whether or not the price stability target is achieved. Third, there is a great possibility that Europe's QE implementation will not affect bank lending. The ECB began their QE implementation in March 2015, but the NPL ratio in Europe was 9.2 percent higher than the NPL ratio in Japan at the time of QE implementation. Based on our empirical results, the NPL ratio is correlated with the credit channel in Japan. Therefore, if the ECB aims to utilize the credit channel, they should reduce their NPL.

We revealed certain implications involving monetary policy. However, due to space limitations, we estimated only three financial market variables—stock price, exchange rate and bank lending—when analyzing the transmission mechanism. In addition, we use TVP-VAR—which is not a very popular method—to consider regime change in monetary policy. Therefore, it is possible that we are missing an important variable, the transmission mechanism, and the empirical results will change if we use another method. Hence, a variety of variables that use a more common approach, such as the Latent Threshold Model or Markov-Switching Model, should be used to increase the robustness of our results.

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Appendix

Table 1: The results of previous studies that estimate the effects of monetary policy

Paper name	Methods	Variable	Periods	Effect on output	Effect on prices
Harada and Kwon (2005)	VAR	7 variables	Jan 1999-Dec 2004	↑	↑
Kitaoka et al. (2013)	VAR	5 variables	Jan 2001-Dec 2012	—	↓
Kimura et al. (2002)	Bayesian VAR	4 variables	Q2 1971-Q2 1985	↑	↑
			Q3 1985-Q1 2002	—	—
Sadahiro (2005)	VEC model	6 variables	Jan 1986-Apr 1995	↑	↑
			Jan 1996-Sep 2004	↑	↓
Fujiwara (2006)	Markovswitching VAR	3 variables	Jan 1985-Dec 1997	↑	↑
			Jan 1998−Dec 2003	↑	↑
		4 variables	Jan 1985-Dec 1999	↑	↑
			Jan 2000-Dec 2003	—	—
Honda et al. (2007)	VAR	3 variables	Mar 2001-Feb 2006	↑	—
Harada and Mashijima (2010)	VAR	3 variables	Mar 2001-Mar 2006	↑	↑
Iwata (2010)	Nonlinear VAR	5 variables	Positive interest rate policy	↑	—
			Zero interest rate policy	—	—
			Quantitative easing policy	↑	—
Honda and Tachibana (2011)	VAR with some dummy	5 variables	I	↑	—
		6 variables	II	↑	—
		7 variables	III	↑	—
Hayashi and Koeda (2014)	Regime-switching SVAR	4 variables	Conventional monetary policy	—	↓
			Unconventional monetary policy	↑	↑

Note: "—" indicates it does not have substantial effect.

Table 2: Data[8]

	Variable	Description	Source
Macroeconomic variables	Output	Index of Industrial Production (IIP) : Seasonally adjusted series, 2010 average=100	Website of Ministry of Economy, Trade and Industry
	Prices	Consumer Price Index excluding perishables (core CPI) : Seasonally adjusted by using Census X-12, 2010 average=100	Website of Ministry of Internal Affairs and Communications
Monetary policy variable	Current account balances at the BOJ	The outstanding balance of current accounts inside the average of the monetary base	Website of BOJ
Financial market variables	Stock price	Nikkei Stock Average: End of month	Website of BOJ
	Exchange rate	Real effective exchange rate: March 1973=100	Website of BOJ
	Bank lending	Loans and discounts of banks, seasonally adjusted by using Census X-12	Website of BOJ

Table 3: The main differences in data between this paper and Honda et al. (2007)

	Honda et al. (2007)	This Paper
Monetary policy variable	The target level of the current account balances at the BOJ	The outstanding balance of the current accounts at the BOJ
Prices	Core CPI : Seasonally adjusted series, 2000 average = 100	Core CPI : Seasonally adjusted by using Census X-12, 2010 average=100

[8] We use tax increase dummy against prices when we adjusted by using Census X-12. In addition, we checked the robustness of our results to use of alternative measures, which include the Tokyo Stock Price Index (TOPIX), nominal effective exchange rates and bank lending including credit union. Then, we obtained similar results.

Table 4: Results of the posterior estimates

3-variable model (Output, prices and current account balances at the BOJ)

Parameter	Mean	Stdev.	95 percent interval	CD	inefficiency
sb1	0.0023	0.0003	[0.0018 , 0.0029]	0.71	12.52
sb2	0.0023	0.0003	[0.0018 , 0.0029]	0.17	10.68
sa1	0.005	0.0013	[0.0032 , 0.0082]	0.129	33.03
sa2	0.0055	0.0015	[0.0034 , 0.0096]	0.302	61.62
sh1	0.5804	0.1044	[0.4012 , 0.8116]	0.844	21.93
sh2	0.0056	0.0016	[0.0035 , 0.0097]	0.661	46.53

4-variable model (adding stock price)

Parameter	Mean	Stdev.	95 percent interval	CD	inefficiency
sb1	0.0023	0.0003	[0.0018 , 0.0029]	0.168	9.22
sb2	0.0023	0.0003	[0.0018 , 0.0029]	0.189	10.49
sa1	0.0051	0.0012	[0.0033 , 0.0081]	0.355	42.13
sa2	0.0054	0.0015	[0.0033 , 0.0087]	0.278	52.73
sh1	0.5794	0.1001	[0.4043 , 0.7970]	0.324	21.74
sh2	0.0053	0.0014	[0.0033 , 0.0088]	0.449	46.35

4-variable model (adding exchange rate)

Parameter	Mean	Stdev.	95 percent interval	CD	inefficiency
sb1	0.0023	0.0003	[0.0018 , 0.0029]	0.444	9.16
sb2	0.0023	0.0003	[0.0018 , 0.0028]	0.174	7.92
sa1	0.0048	0.0011	[0.0032 , 0.0073]	0.055	26.36
sa2	0.0056	0.0016	[0.0034 , 0.0095]	0.373	42.43
sh1	0.5687	0.1131	[0.3800 , 0.8232]	0.592	21.69
sh2	0.0057	0.0016	[0.0035 , 0.0098]	0.94	53.75

4-variable model (adding bank lending)

Parameter	Mean	Stdev.	95 percent interval	CD	inefficiency
sb1	0.0023	0.0003	[0.0018 , 0.0029]	0.147	10.67
sb2	0.0023	0.0003	[0.0018 , 0.0028]	0.235	7.27
sa1	0.0048	0.0011	[0.0031 , 0.0075]	0.523	32.86
sa2	0.0055	0.0018	[0.0034 , 0.0093]	0.274	49.91
sh1	0.5869	0.1045	[0.4044 , 0.8082]	0.921	18.95
sh2	0.0056	0.0017	[0.0034 , 0.0100]	0.138	52.88

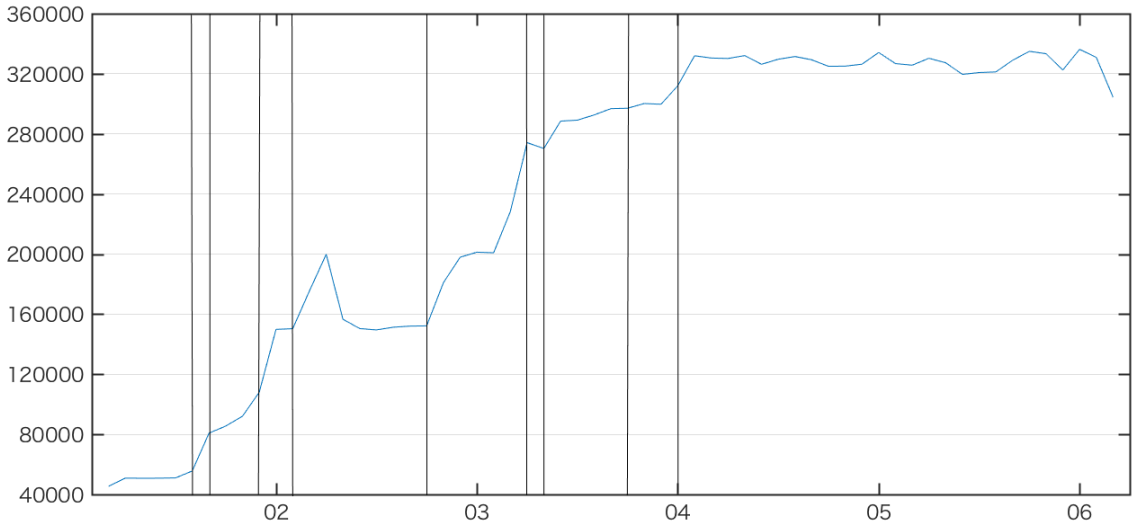
Table 5: Policy changes during QE and after CME

Date		The target level of the CABs
2001	14-Aug	Around 6 trillion yen (600 billion yen)
	18-Sep	Above 6 trillion yen
	19-Dec	Around 10 to 15 trillion yen (800 billion yen)
2002	28-Feb	Around 10 to 15 trillion yen (1 trillion yen)
	30-Oct	Around 15 to 20 trillion yen (1.2 trillion yen)
2003	8-Apr	Around 17 to 22 trillion yen
	30-Apr	Around 22 to 27 trillion yen
	20-May	Around 27 to 30 trillion yen
	10-Oct	Around 27 to 32 trillion yen
2004	20-Jan	Around 30 to 35 trillion yen

Date		The amount of the asset purchase program
2011	14-Mar	40 trillion yen
	4-Aug	50 trillion yen
	27-Oct	55 trillion yen
2012	14-Feb	65 trillion yen
	27-Apr	70 trillion yen
	19-Sep	80 trillion yen
	30-Oct	91 trillion yen
	20-Dec	101 trillion yen

Note: The phrase in parentheses indicates the outright purchase of long-term JGBs (per month).

Figure 1: The transition of the outstanding balances of the current accounts at the BOJ



Note: The vertical line denotes the dates the target level of the current account balances at the BOJ increased.

Figure 2: A comparison of the seasonally adjusted by using Census X-12 and the seasonally adjusted series

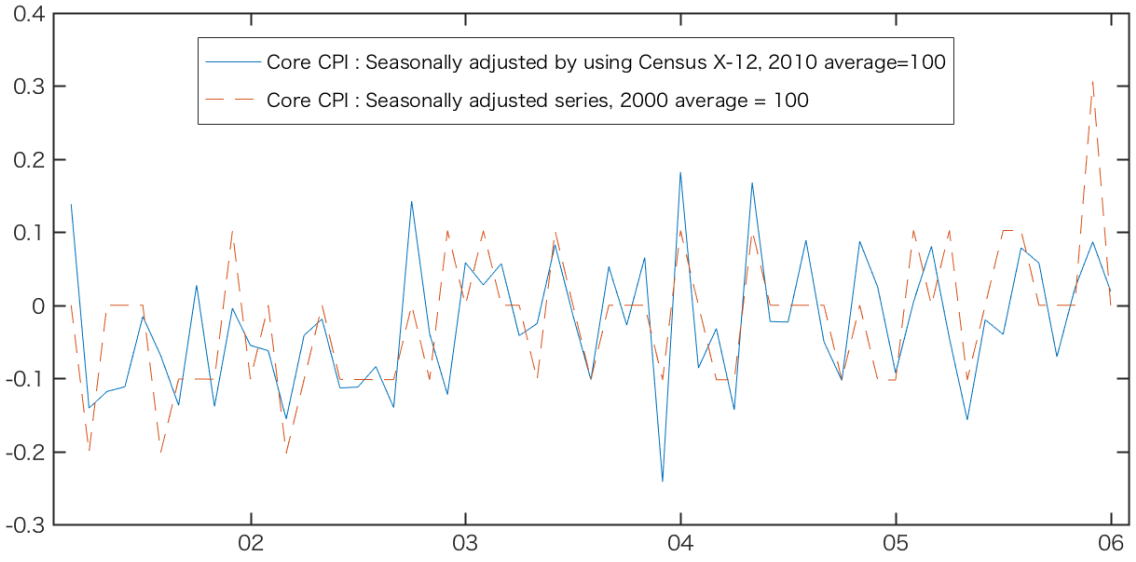


Figure 3: Time Series Data (March 2001–July 2015)

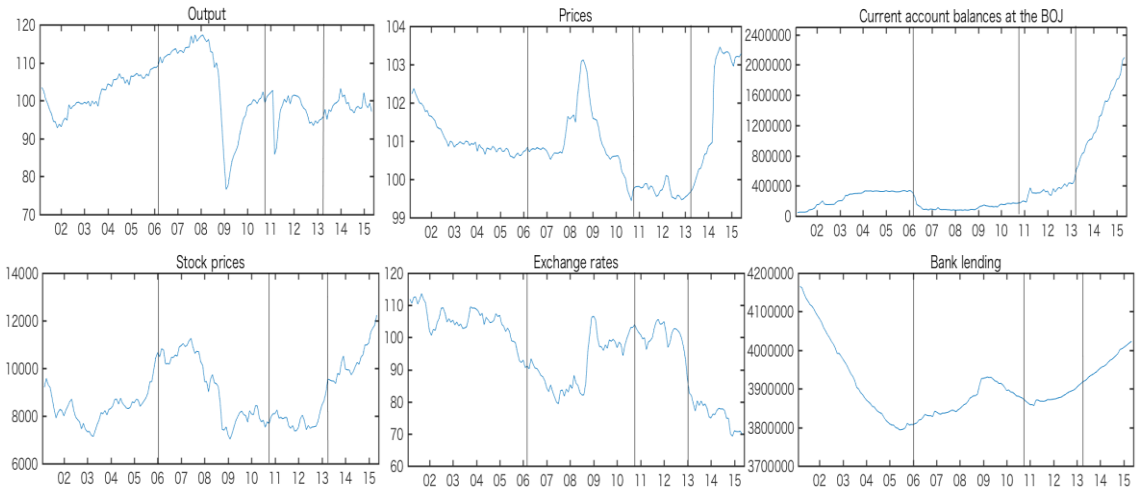


Figure 4: Impulse responses to a positive monetary policy shock (during QE)

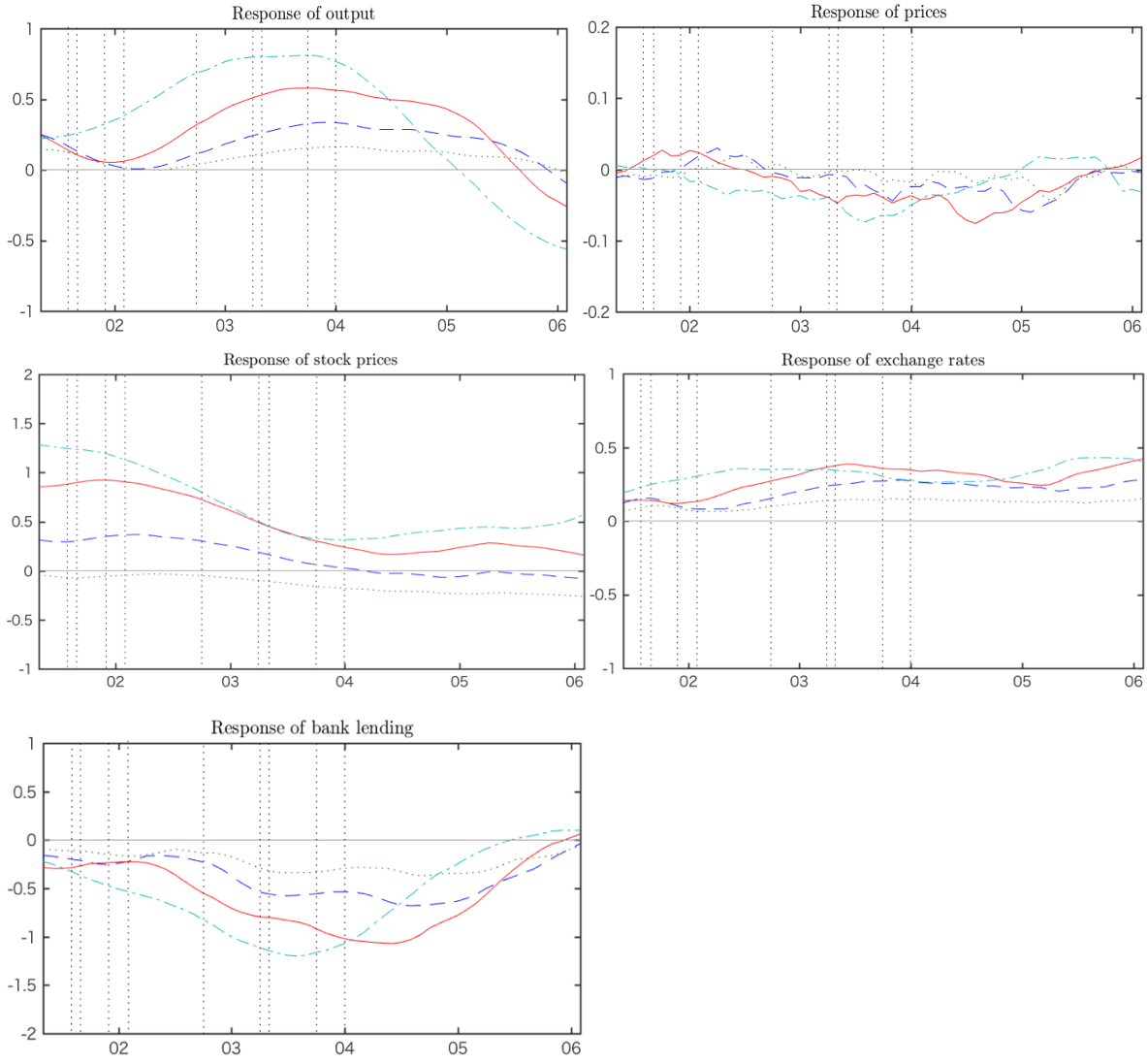


Figure 5: Impulse responses to a positive monetary policy shock (after CME)

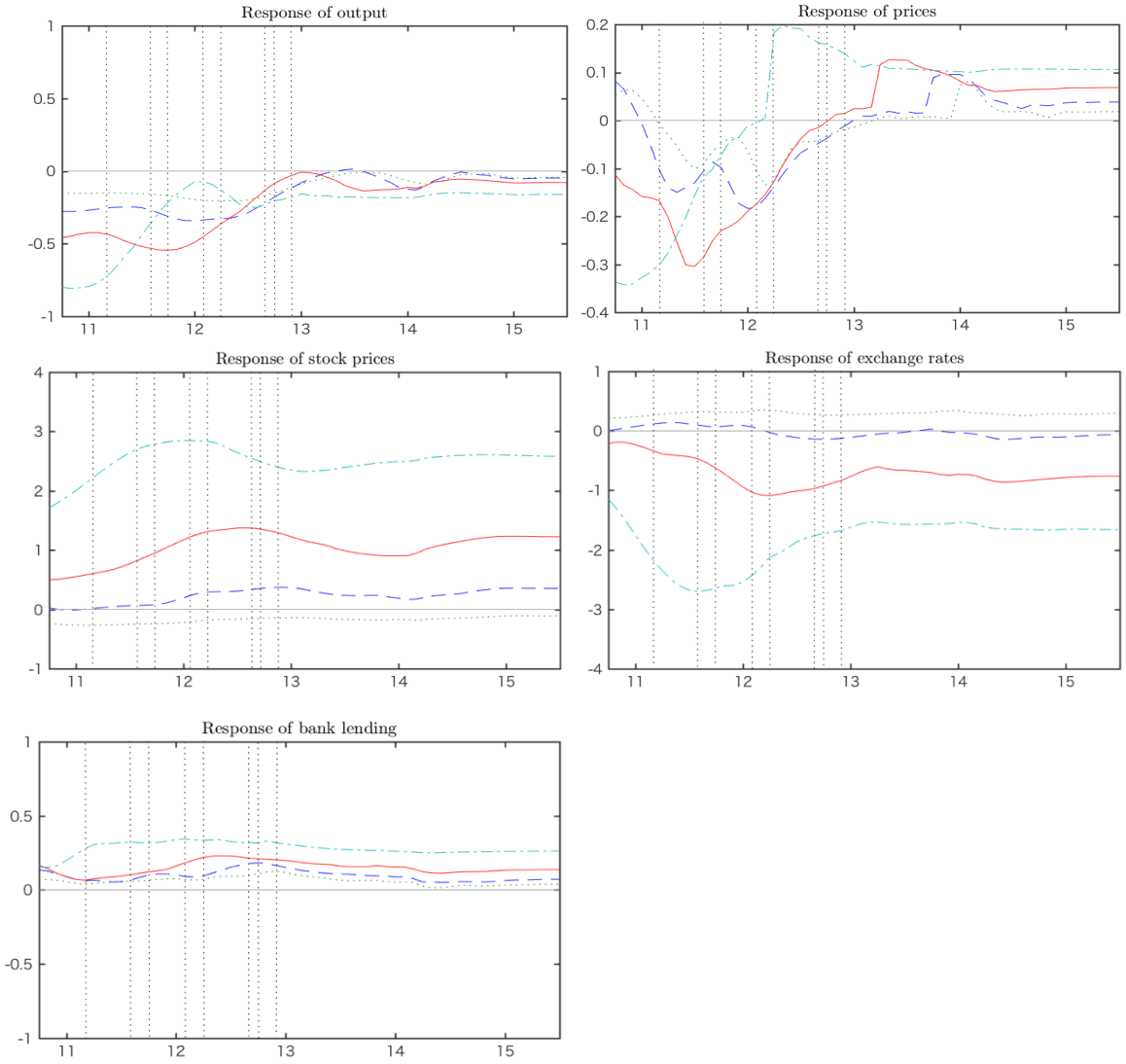


Figure 6: Impulse responses to a positive monetary policy shock (all periods)

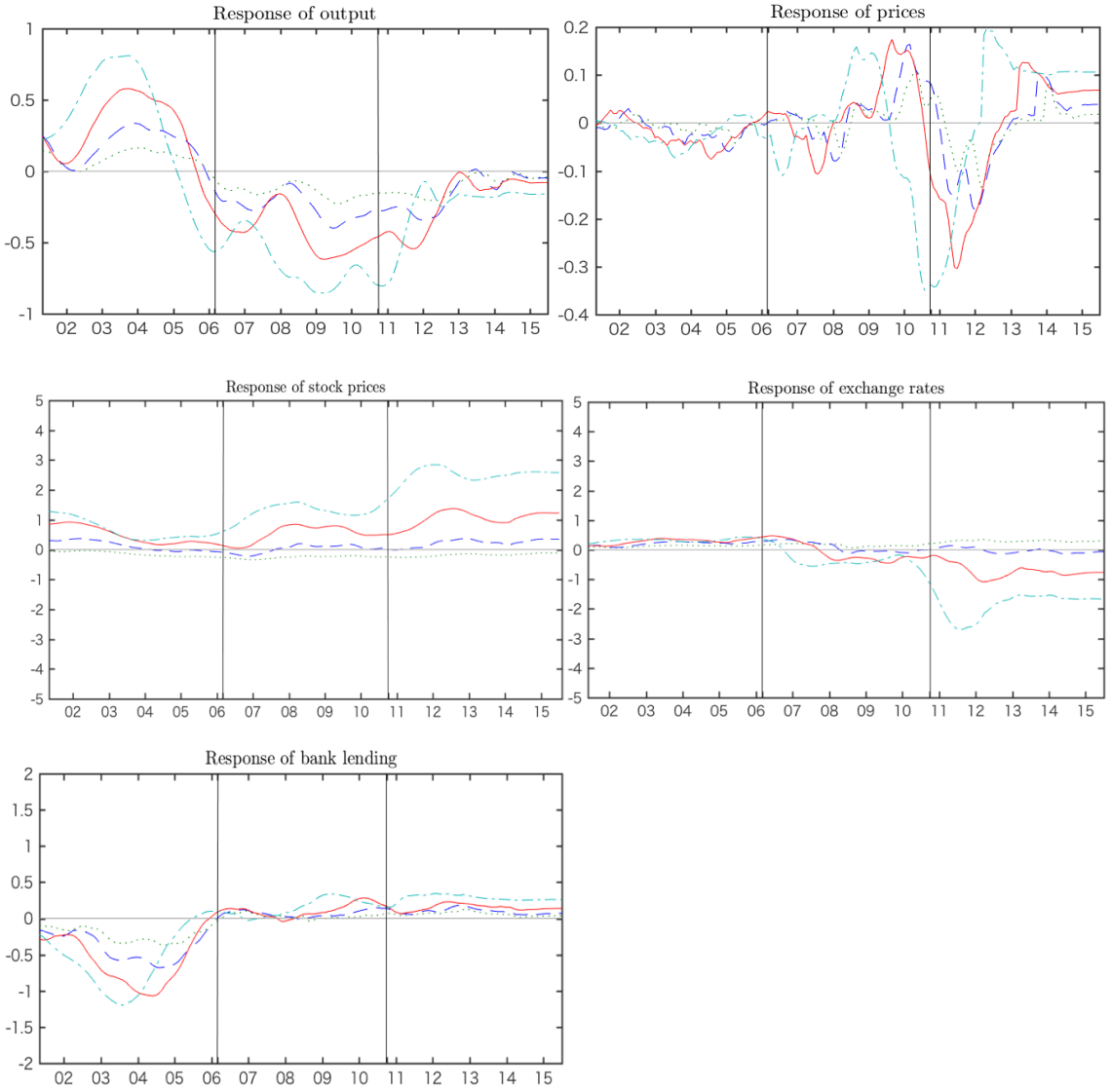
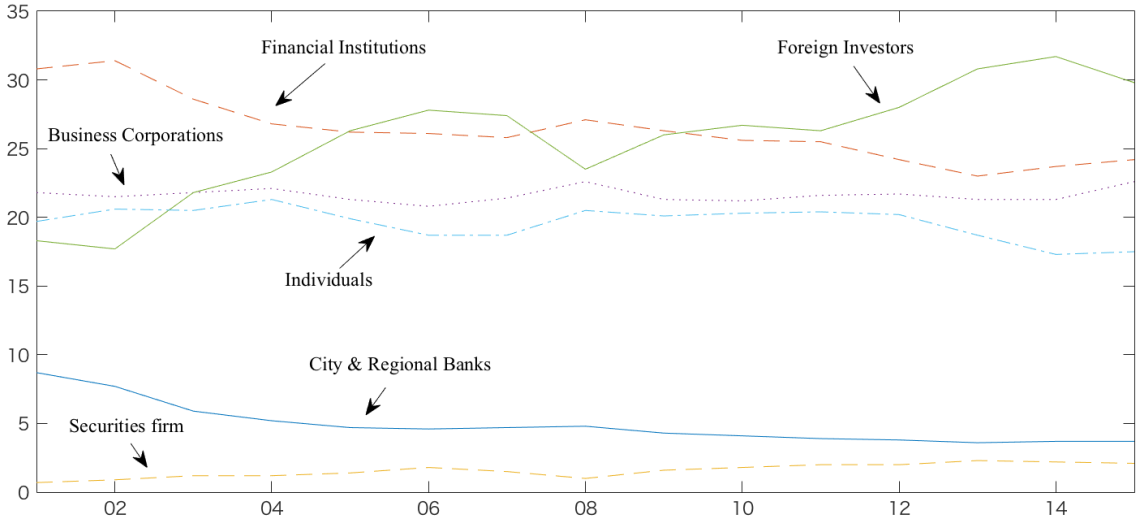
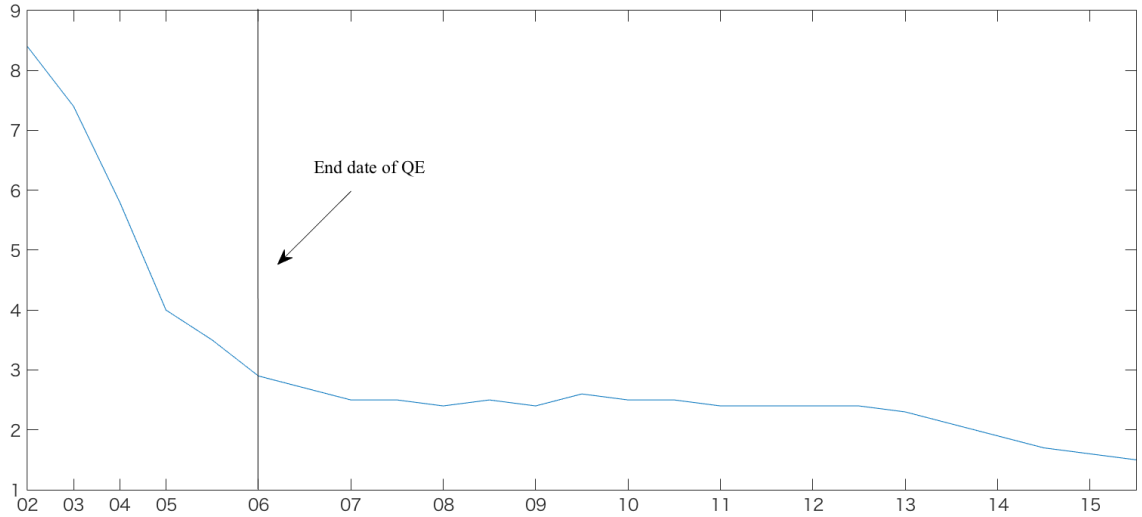


Figure 7: Distribution percentage of market value owned by type of shareholders



Source: The Japan Exchange Group, "2015 Share Ownership Survey".

Figure 8: Non-performing loans ratio in Japan



Source: The Financial Services Agency, Status of Non-Performing Loans, "Transition of Loans Based on the Financial Reconstruction Act", All Banks.