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HOW DOES UNCONVENTIONAL MONETARY POLICY INFLUENCE THE ECONOMY IN JAPAN?

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ABSTRACT

This paper investigates the transmission mechanism of unconventional monetary policies by estimating a time-varying parameter structural vector auto-regression (TVP-VAR) model 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 accumulated impulse responses of stock prices and exchange rates to a positive monetary policy shock are significant increases and significant depreciation, respectively, in the early days of all unconventional monetary policy periods. Second, a monetary policy shock does not increase bank lending for all unconventional monetary policies. Third, the relationship between an increase in stock prices and the depreciation of exchange rates and increase in GDP has changed since the beginning of Abenomics. Fourth, the accumulated impulse responses of the inflation rate to a positive monetary policy shock became a significant increase during and after the comprehensive monetary easing in October 2010 due to the clarification of the policy duration, and the responses become remarkable after inflation targeting was introduced in January 2013. The first and second results imply that the main transmission channel of unconventional monetary policy in Japan is stock prices and the exchange rate.

Contribution/ Originality: This study contributes in the existing literature that we analyze not only the effect on the real economy but also the transmission channel after CME was introduced in October 2010, including the Abenomics period, which began in 2012 with the Abe administration.

1. INTRODUCTION

Japan's prolonged deflation is finally ending, primarily because of Abe's administration policies, which 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 (ZIRP) 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. Although this monetary policy temporarily raised prices and improved the economy, it 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 percent in

January 2013 as part of its bold monetary policy. Additionally, the BOJ announced that it was introducing quantitative and qualitative monetary easing (QQE) to achieve its inflation target in April 2013. 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 and wages. Moreover, there has been a great deal of discussion of late regarding the impact of unconventional monetary policy on the macroeconomy. Honda *et al.* (2013) and Harada and Masujima (2009) published well-known empirical analyses of the effects of such unconventional monetary policies on both the real economy and transmission channels in Japan. Both papers analyzed the impact of QE on macroeconomic variables— "especially, output and prices"—and transmission channels using vector auto-regression (VAR) during the QE period (March 2001-February 2006). Then, both papers claimed that the impulse responses of output to a positive monetary policy shock rose during the QE period. With respect to transmission channels, Honda *et al.* (2013) note that the strongest route is stock prices, whereas Harada and Masujima (2009) posit that the main route is through asset prices (stock prices and condominium prices) and the business condition of banks (bank stock prices). However, these papers did not analyze the effects of unconventional monetary policies in recent years (such as QQE), 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 November 2016. The purpose of this study is to answer the following two questions. First, does unconventional monetary policy influence the real economy? Second, how does unconventional monetary policy influence the real economy? In addition, the main feature of this study is that we analyze not only the effect on the real economy but also the transmission channel after CME was introduced in October 2010, including the Abenomics period, which began in 2012 with the Abe administration (including expanding QQE in October 2014, QQE with a negative interest rate in January 2016 and QQE with yield curve control in September 2016). Moreover, we compare the QE period, CME period and QQE period.

The empirical results of this study can be summarized in the following four points. First, the accumulated impulse responses of stock prices and the exchange rate to a positive monetary policy shock are a significant increase and a significant depreciation, respectively, in the early days of all unconventional monetary policy periods. Second, the monetary policy shock does not increase bank lending in all unconventional monetary policy periods. Third, the relationship between the increase in stock prices and the decrease in exchange rates and the increase in GDP has changed since the beginning of the Abenomics. Fourth, the accumulated impulse responses of the inflation rate to a positive monetary policy shock became a significant increase upon and after CME in October 2010 due to the clarification of the policy duration, and the responses become remarkable after inflation targeting was introduced in January 2013. As a result, we emphasize the following four points with respect to monetary policy. First, since the responses of GDP began to rise significantly after the monetary policy shock significantly raised stock prices and lowered the exchange rate, the unconventional monetary policy influenced GDP through stock prices and the exchange rate. Second, there is a possibility that the policy is not working for credit transmission channel – quantitative easing increased bank lending, and an increase in bank lending increases GDP – as the central bank generally expected. Third, it is possible that the above third empirical result implies an upturn in business through the improvement in the fundamentals of the public and private sectors – QQE is different from QE and CME in that past unconventional monetary policy (QE and CME) influenced GDP temporally (as a temporary tonic) through a rise in stock prices and a depreciation of the exchange rate. Fourth, it is important to clarify the target inflation and commit to clarifying the inflation rate so that the central bank operates the inflation rate as a policy means.

This paper is organized as follows. Section 2 describes Japanese monetary policies following the 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 economic bubble 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 more than 2 percent through the mid-1990s. However, this rate of growth could not last. 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 did not improve. For that reason, the BOJ introduced the ZIRP in February 1999, reducing the overnight call rate to nearly zero. However, the BOJ decided to lift the ZIRP in August 2000 mainly due to the improving economy based on increased demand from foreign countries. In this section, we describe the history of Japanese monetary policy after implementing QE.

2.1. Quantitative Easing (March 2001– March 2006)

After lifting the ZIRP, the Japanese economy declined because 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 history that QE was employed 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[1]. 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) had become 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 CABs 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 and Qualitative Monetary 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 as inflation targeting, stock prices increased and the exchange rate weakened, an event that 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

[1] For more detail, see Table 1.

House of Representatives was dissolving in November 2012, stock prices jumped and the exchange rate weakened because of expectations surrounding Abe, the president of the Liberal Democratic Party. Abe became Prime Minster in December 2012 and thereafter created a new economic policy common referred to as Abenomics, which 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 percent 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 approximately 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 (an event referred to as the "Halloween shock" in Japan) because of tax increases in April 2014 and lower crude oil prices. The features of this expansion can be summarized 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 increased 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.

In January 2016, the BOJ introduced QQE with a negative interest rate because of a drop in crude oil prices and a considerable decline in Chinese stock prices. This monetary policy has two features. First, the outstanding balance of each financial institution's current account at the bank will be divided into three tires, to each of which a positive interest rate, a zero interest rate, or a negative interest rate will be applied, respectively. Second, the BOJ extended the average remaining maturity of JGB purchases (by nearly 7-12 years). In addition, the BOJ introduced QQE with yield curve control in September 2016. With respect to the short-term policy interest rate, the BOJ applied a negative interest rate of minus 0.1 percent to the Policy-Rate Balances in current accounts. With respect to the long-term interest rate, the BOJ purchased JGBs so that 10-year JGB yields would yield approximately zero percent.

3. PREVIOUS STUDIES

This section summarizes previous studies of monetary policy and TVP-VAR. Specifically, section 1 summarizes previous studies that analyzed the effects of unconventional monetary policy using VAR. In particular, we explain the focus on how unconventional monetary policy influences the economy. Section 2 summarizes previous studies of 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 can 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). Papers representing the second method include Kimura *et al.* (2003); Sadahiro (2005); Fujiwara (2006); Honda *et al.* (2013); Harada and Masujima (2009); Iwata (2010); Honda and Tachibana (2011); Hayashi and Koeda (2014) and Schenkelberg and Watzka (2013). Table 2 summarizes the salient aspects of these papers.

Honda *et al.* (2013) analyze the effects of QE in Japan (especially QE's effects on outputs, prices and the transmission channel) using VAR. Initially, these authors estimate the VAR using three variables—industrial production index, 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 financial market variable (such as stock prices, the exchange rate, bank lending or short- to long-term nominal interest rates) so that they can analyze its effect on output. Thus, these authors show that the QE affects output primarily through the stock transmission channel.

Harada and Masujima (2009) generate a more comprehensive analysis than Honda *et al.* (2013) 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—indices of all industry activity, 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 stock prices, exchange rate, bank lending, bank stock prices, apartment prices or long-term interest rates in order to analyze its effects on the economy. As a result, these authors show that an increase in the monetary base affects macroeconomic variables primarily through asset prices (stock prices and apartment prices) and the financial health of the banks (bank stock prices).

Honda and Tachibana (2011) estimated a longer range of data than the data used by Honda *et al.* (2013) to address a larger number of samples. There are two primary differences between the new study and Honda *et al.* (2013). 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 has a significant positive effect on output and stock prices. Thus, they support the asset transmission channel.

Kimura and Nakajima (2016) verify the effects of QE by following Honda *et al.* (2013) 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 the industrial production index. 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 on the VAR in level and the BVAR. In addition, these authors showed that prices' impulse responses 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

The VAR technique has been used by many researchers to analyze the economy since Sims (1980) 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; this 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 of the TVP-VAR has recently increased in popularity in Japan. Representative papers include Nakajima *et al.* (2010); Franta (2011); Nakajima and Watanabe (2011); Kimura and Nakajima (2016) and Michaelis and Watzka (2017). Michaelis and Watzka (2017) analyze the effect of unconventional monetary policy on the GDP and core CPI using TVP-VAR with Japanese quarterly data from the first quarter of 1996 to the third quarter of 2015. Specifically, they compare three points— the responses of ZIRP (1993: Q3), QE (2003: Q3) and Abenomics (2014: Q3)—using four variables: core CPI, GDP, the monetary base and the exchange rate[2]. As a result, they showed that the impulse responses of core CPI to a positive monetary policy shock rose at all points, and the responses appear to be more significant at the Abenomics point. In addition, the impulse responses of GDP to a positive monetary policy shock rose at all points—the QE point and the Abenomics point do not significantly increase—but the responses rose weakly at the Abenomics point compared with the ZIRP point and the QE point.

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 some monetary policy changes). In addition, we used TVP-VAR code to modify Nakajima (2011) code.

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 using five key variables: GDP, inflation rate, monetary base, long-term interest rate and financial market variables (such as stock prices, exchange rate or bank lending).

4.1. Data and Priors

In this paper, we use monthly data from March 2001 to November 2016 for GDP, inflation rate, monetary base, long-term interest rate, stock prices, exchange rate, and bank lending.[3] The sources of data are summarized in the

[2] Michaelis and Watzka (2017) focused on only the effects of unconventional monetary policy on GDP and the core CPI. Their paper is different from our paper; they do not focus on how does unconventional monetary policy influences the real economy. Therefore, they do not include long-term interest rates and financial market variables, such as stock prices or bank lending.

[3] The logarithms of GDP, monetary base, stock prices, exchange rate and bank lending are taken, and then the first differences are taken. Furthermore, we assume the identification ordering as GDP, inflation rate, monetary base, long-term interest rate and the financial market variables. We estimate four alternative orderings and obtain similar results.

Appendix (see Table 3). Figure 1 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. To determine the number of lags, we use the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). We considered both characteristics, and we used the average of the AIC and BIC. As a result, all models are determined to be 5. In addition, the prior distribution of the TVP-VAR is assumed to be a diagonal matrix in order to ensure estimation stability. The prior distributions are as follows:

$$(\Sigma_\beta)_i^{-2} \sim \text{Gamma}(40, 10^{-4}), (\Sigma_a)_i^{-2} \sim \text{Gamma}(4, 10^{-4}), (\Sigma_h)_i^{-2} \sim \text{Gamma}(4, 10^{-4})$$

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[4].

4.2. TVP-VAR[5]

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 is defined as:

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

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 the following reduced form:

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

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 performed a Cholesky decomposition to impose recursive restriction,

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

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

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

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

[5] See Primiceri (2005) and Nakajima (2011) for further details on the TVP-VAR methodology. In addition, there is a way to identify the model more strictly, for example as a latent threshold model with time-varying parameter (see Kimura and Nakajima (2016)) or a new kind of sign restriction in a TVP-VAR (see Michaelis and Watzka (2017)) However, such methods tend to cause extremely wide error bands (actually, most of the responses from Kimura and Nakajima (2016) and Michaelis and Watzka (2017) are nonsignificant). Therefore, we use the standard TVP-VAR.

and Σ_t is the k×k diagonal matrix,

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

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 $c_t, B_{1t}, \dots, B_{st}$. 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:

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

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

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 because of several latent variables. Therefore, most TVP-VAR models use the Markov Chain Monte Carlo (MCMC) method.

4.3. Estimation Results (Point Estimation)[6]

Figure 2 shows the accumulated median impulse responses of the macroeconomic and financial market variables to a positive monetary policy shock. The responses of GDP rise positively from 5 months to 15 months during the QE and QQE periods (Fig. 2A). In addition, there is a remarkable rise in GDP in the long term in 2003 and from 2014 to 2016; also, the appreciation rate of QQE is stronger than that of QE. Specifically, the accumulated median impulse responses of GDP decrease gradually after the peak in 2003. However, as can be seen from Figure

[6] The TVP-VAR has a weak point in its computation capabilities for large models. Therefore, it is common to decrease the number of variables, decrease lags, decrease the sample size, etc., to avoid this problem. Therefore, we estimate 18 periods in order to decrease the parameter in section 4.3 and 14 periods in section 4.4 – in general, VAR estimates 24 periods when using monthly data. If we remove a variable, decrease lags or shorten the estimation period, it easy to estimate 24 periods. However, we believe that this is the best way to reduce the parameter when considering the purpose of our analysis, the degree of impact on the result and its importance in the estimation. It can be presumed that there is no significant change if we estimate from 15 periods to 24 periods because Figure 3 shows that almost all point estimates become nonsignificant around 14 periods. Moreover, we can interpret that the responses are the level's responses because we take the first difference against variables when estimating the accumulated impulse responses. However, the responses of the inflation rate and the long-term interest rate are elastic because logarithms are not taken of the inflation rate and long-term interest rate.

2, the effect of the rise does not disappear during QQE. According to the responses of the inflation rate (Fig. 2B), the accumulated median impulse responses of the inflation rate to a positive monetary policy shock rise in the whole period. However, the degrees are different during QE, during CME and during QQE. The monetary policy shock has a small effect (both short and long term) on the inflation rate during QE. However, the effect on the gradual rise in the inflation rate in the long term during CME clarified the policy's time horizon based on the understanding of medium to long-term price stability in October 2010. In addition, the effect on the remarkable rise in the inflation rate after the QQE period introduced inflation targeting. According to the responses of the long-term interest rates (Fig. 2D), the monetary policy shock decreased the long-term interest rate, and the degrees are remarkable during the QE period and during the QQE period. In addition, this tendency is particularly apparent during the QQE period. According to the responses of stock prices (Fig. 2E), a monetary policy shock raises stock prices in the short term for the whole period. In addition, the accumulated median impulse responses of stock prices to a positive monetary policy shock rise not only in the short term but also over the long term during unconventional monetary policy periods. Specifically, the responses are positive in the short and long terms during the period from 2003 to 2006 and from 2013 to 2016. The effect of the rise (0.8) can be confirmed in all periods during QQE, whereas the effect of the rise declines gradually after a peak (0.6) in the year 2003 during QE. In addition, the effect of a rise during QQE is stronger than that during QE. According to the responses of the exchange rate (Fig. 2F), monetary policy shock decreases the exchange rate in the short term over the whole period. However, the effect of the decrease in the short term became weak during 2002 to 2006. In the other period, the monetary policy shock tended to decrease the exchange rate in the short term, and the exchange rate returns to zero or a positive level in the long term. In addition, the responses of exchange rates are weaker than those of stock prices. According to the responses of bank lending (Fig. 2G), a monetary policy shock decreases bank lending under unconventional monetary policy. In addition, the decrease in bank lending during QE (0.2) is relatively larger than during QQE (0.07).

4.4. Estimation Results (with 1SD Error Bands)[7]

Figure 3 shows the accumulated impulse responses of macroeconomic variables and financial market variables to a positive monetary policy shock with 1SD error bands.

Although the monetary policy shock raised stock prices significantly and decreased the exchange rate significantly in the short term between 2001 and 2002 during QE, the responses of GDP, the inflation rate and long-term interest rates did not see a significant effect. However, there was a significant rise in GDP in parallel with a significant increase in stock prices and a significant decrease in the exchange rate after 2003, with some lags. In addition, as the significant increase in stock prices and the significant decrease in the exchange rate became nonsignificant, the significant increase in GDP became nonsignificant gradually. Therefore, the estimation results show that QE at first caused a rise in stock prices and depreciation of the exchange rate, and then a rise in stock prices and a depreciation of the exchange rate influenced the GDP with some lags. In addition, as the monetary policy shock had no significant effect on stock prices and exchange rates, it has a gradual deteriorating effect on GDP. Furthermore, we obtain the result that monetary policy shock decreased bank lending significantly. This estimation result may be caused by non-performing loans. At that time, Japanese commercial banks had many non-performing loans. Therefore, although QE increased cash in Japanese commercial banks, Japanese commercial banks prioritized disposing of non-performing loans over increasing bank lending.

The monetary policy shock raised stock prices significantly and decreased the exchange rate significantly during the early days of the CME, in the same way as occurred during QE. In addition, there was a significant rise in GDP with some lags, as with QE after 2012. Therefore, the estimation results showed that QE first caused a rise in stock prices and a depreciation of the exchange rate, and then a rise in stock prices and a depreciation of the

[7] We do not put the responses of the first QE shock (March 2001) in Figure 3 because we set the lags.

exchange rate influenced the GDP with some lags during CME, as occurred with QE. Now, the main difference between the responses to QE and CME was the inflation rate. Although the responses of the inflation rate were nonsignificant during QE, the responses of the inflation rate began to rise significantly after introducing the CME. The cause of this result is the clarification of the policy duration from the CME.

The monetary policy shock raised stock prices significantly and decreased the exchange rate significantly during the early part of the QQE, as occurred with QE and CME. However, there are two differences between QQE and other unconventional monetary policies (QE and CME). The first is that the responses of GDP rise significantly during the early days of the QQE. The result is caused by the introduction of the QQE as an extension of the CME. Therefore, there is still an increasing effect on GDP, which was increased by a significant increase in stock prices and a significant depreciation of the exchange rate during the early part of the QQE. The second difference is that the significant increase in GDP remained despite the significant increase in stock prices and significant depreciation of the exchange rate, which became nonsignificant gradually. The cause of this result is that the increase in GDP is no longer a temporary rise that varies depending on the increase in stock prices and the depreciation of the exchange rate. Therefore, it is possible that GDP began to rise due to another factor.

5. CONCLUSION

We analyzed the transmission mechanisms of unconventional monetary policy using TVP-VAR and generated the following four results. First, the accumulated impulse responses of stock prices and the exchange rate to a positive monetary policy shock are a significant increase and significant depreciation in the early days of all unconventional monetary policy periods, respectively. According to Figure 3, GDP began to rise significantly with some lag after the monetary policy shock raised stock prices significantly and lowered the exchange rate significantly. Therefore, the unconventional monetary policy influenced GDP through stock prices and the exchange rate. However, the monetary policy shock does not decrease long-term interest rates significantly, except in the QQE in October 2014. Therefore, unconventional monetary policy does not influence stock prices and the exchange rate through the long-term interest rate, but through another variable. It is possible that unconventional monetary policy influenced stock prices and the exchange rate through a variable called expectation (e.g., the announcement effect). It may be that private business, domestic investors and foreign investors expect stock prices to rise and the exchange rate to depreciate with the announcement of unconventional monetary policy (introducing and expanding). As a result, private business, domestic investors and foreign investors buy and sell Japanese stock and yen, which causes a rise in stock prices and the depreciation of the exchange rate. However, we cannot discuss how unconventional monetary policy influenced stock prices and the exchange rate because a variable for expectation was not included in this estimation. Second, the monetary policy shock does not increase bank lending for all unconventional monetary policy. This result denies the existence of the route that the central bank generally expected, which is that quantitative easing increases bank lending, and an increase in bank lending causes an improvement of GDP. In our estimation, the credit transmission channel is not working when unconventional monetary policy is adopted in Japan. Third, the relationship between an increase in stock prices and the depreciation of the exchange rate and an increase in GDP has changed since the beginning of Abenomics. QE and CME first cause a rise in stock prices and the depreciation of the exchange rate, and then a rise in stock prices and the depreciation of the exchange rate influence the GDP with some lag. In addition, as the monetary policy shock loses its effect on stock prices and the exchange rate, the responses of GDP gradually become nonsignificant. By contrast, unlike QE and CME, as monetary policy shock lost its effect on stock prices and the exchange rate, the response of GDP was still significantly positive during QQE. It is possible that this result implies an upturn in business through the improvement of public and private sector fundamentals – QQE is different from QE and CME in that past unconventional monetary policy (QE and CME) influenced GDP temporally (as a temporary tonic) through a rise in stock prices and the depreciation of the exchange rate. Fourth, the impulse responses of the inflation rate to a positive monetary policy shock caused a significant increase upon and after the CME in October 2010 due to the clarification of the policy duration, and the responses become remarkable after inflation targeting was introduced in January 2013. Unlike QE, the inflation rate began to rise significantly after CME, which clarified the policy duration. In addition, according to Figure 2, the accumulated impulse responses of a rise in the inflation rate were remarkable after 2013, which saw the introduction of inflation targeting. These results show that it is important to clarify the inflation target and commit to clarifying the inflation rate so that the central bank can operate the inflation rate.

Our study estimated how unconventional monetary policy influences the real economy using the long-term interest rate, stock prices, the exchange rate and bank lending. As a result, we find that unconventional monetary policy influenced GDP through stock prices and the exchange rate. However, we could not determine how unconventional monetary policy influences stock prices and the exchange rate. The response of long-term interest rates is not significant, except in the expanding QQE in October 2014. Taking this result into account, it means that unconventional monetary policy does not influence stock prices and the exchange rate through the long-term interest rate but through another variable. One possibility is the variable of expectation – such as the expected inflation rate. However, the data for the expected inflation rate in Japan is only available after 2004. Therefore, we could not estimate the model including the expected inflation rate. One solution is to generate the expected inflation rate using the Carlson-Parkin Method modified by Hori and Terai (2005). Using this method, it may be possible to reveal how unconventional monetary policy influences stock prices and the exchange rate. However, this is a task for future research.

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Appendix

Table-1. Policy changes during QE and during 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	5-Mar	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 amount in parentheses indicates the outright purchase of long-term JGBs (per month).

Table-2. 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.* (2003)	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 20□4	↑	↓
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.* (2013)	VAR	3 variables	Mar 2001-Feb 2006	↑	—
Harada and Masujima (2009)	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	Regime-switching	4 variables	Conventional	—	↓

(2014)	SVAR		monetary policy		
			Unconventional monetary policy	↑	↑
Schenkelberg and Watzka (2013)	SVAR	5 vari□bles	Mar 1995-Sep 2010	↑	↑

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

Table-3. Data[8]

	Variable	Description	Source
Macroeconomic variables	GDP	Real Gross Domestic Product (Real GDP): Seasonally adjusted series, we interpo□ated monthly data from□quarterly data	Cabinet Office
	Inflation rate	Inflation Rate (Year on Year) excluding food and energy: 2010 average=100, we adjusted the tax increase effect following the BOJ	Ministry of Internal Affairs and Communications
Monetary policy variable	Monetary base	Monetary Base: Average amounts outstanding, seasonally adjusted series	Bank of Japan
Government bond yields	Long-term interest rate	10-year Japanese government bond yields	Ministry of Finance
Financial market variables	Stock price	Nikkei Stock Average: End of month	The Nikkei
	Exchange rate	Real effective exchange rate: March 1973=100	Bank of Japan
	Bank lending	Loans and discounts of banks, seasonally adjusted using Census X-12	Bank of Japan

Table-4. Results of the posterior estimates

Stock price model

Parameter	Mean	Stdev.	95 percent interval	CD	Inefficiency
sb1	0.0016	0.0001	[0.0014, 0.0019]	0.312	4.42
sb2	0.0016	0.0001	[0.0014, 0.0019]	0.888	3.19
sa1	0.0505	0.1824	[0.0036, 0.7063]	0.210	51.59
sa2	0.0056	0.0015	[0.0034, 0.0096]	0.397	47.54
sh1	0.3292	0.0979	[0.1683, 0.5347]	0.537	45.32
sh2	0.1617	0.0688	[0.0557, 0.3205]	0.176	77.45

Exchange rate model

Parameter	Mean	Stdev.	95 percent interval	CD	Inefficiency
sb1	0.0016	0.0001	[0.0014, 0.0019]	0.867	5.66
sb2	0.0016	0.0001	[0.0014, 0.0019]	0.778	6.23
sa1	0.0056	0.0017	[0.0034, 0.0098]	0.380	58.67
sa2	0.0057	0.0022	[0.0034, 0.0099]	0.739	79.58
sh1	0.3421	0.0737	[0.2213, 0.5072]	0.359	39.20
sh2	0.1015	0.0361	[0.0478, 0.1878]	0.689	113.94

[8] We checked the robustness of our results to the use of alternative measures, including the Tokyo Stock Price Index (TOPIX), nominal effective exchange rates and bank lending, including credit unions. We obtained similar results.

Bank lending model

Parameter	Mean	Stdev.	95 percent interval	CD	Inefficiency
sb1	0.0016	0.0001	[0.0014, 0.0019]	0.453	3.86
sb2	0.0016	0.0001	[0.0014, 0.0019]	0.197	6.13
sa1	0.0057	0.0016	[0.0035, 0.0098]	0.185	71.64
sa2	0.0057	0.0021	[0.0034, 0.0110]	0.276	88.06
sh1	0.3154	0.0651	[0.2042, 0.4538]	0.580	36.49
sh2	0.0928	0.0482	[0.0054, 0.2022]	0.258	195.87

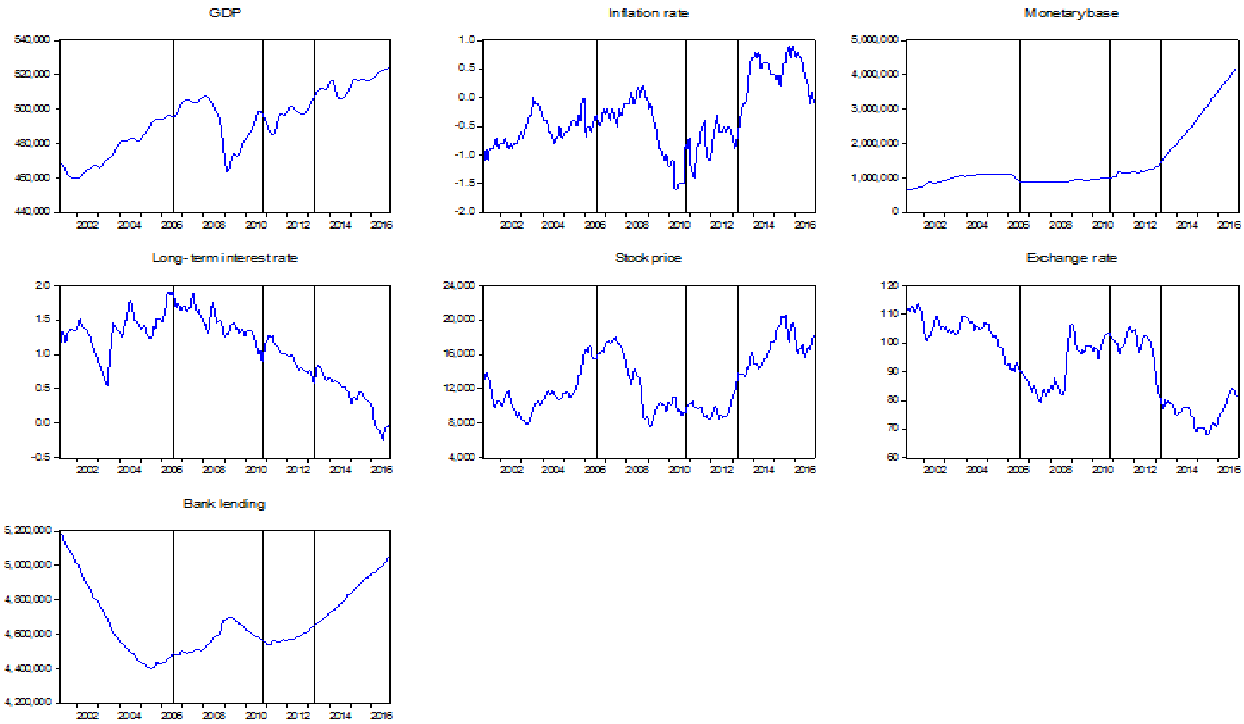
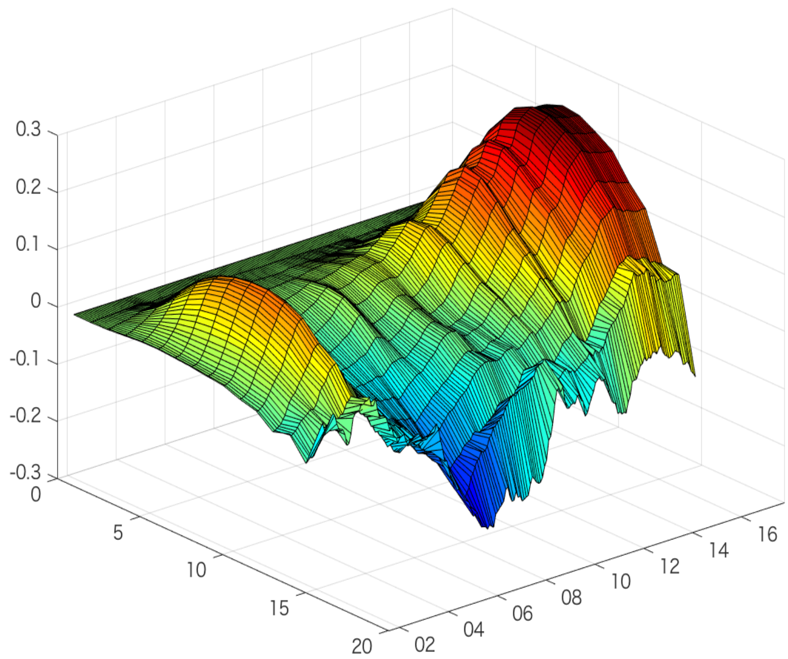
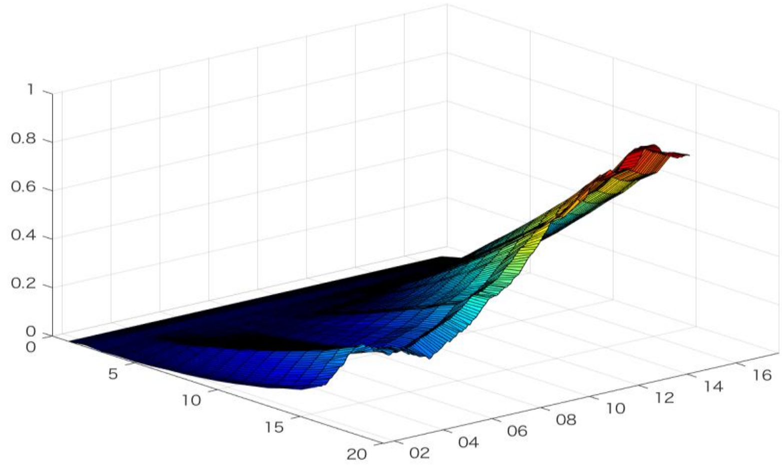


Figure-1. Time Series Data (March 2001–November 2016)

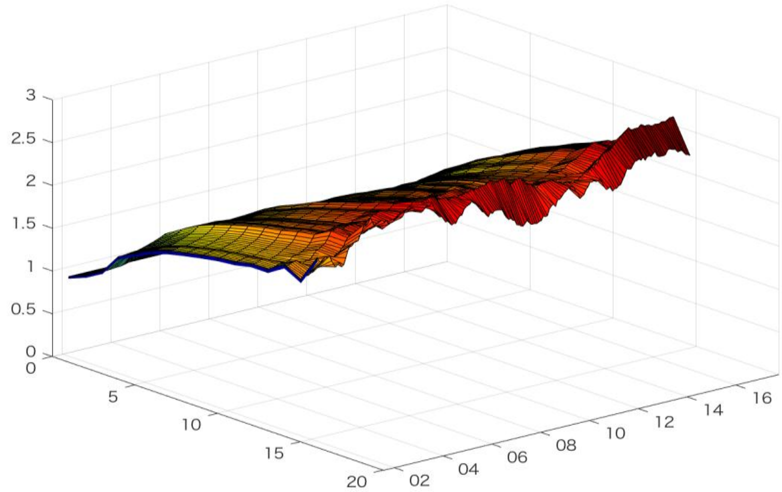
A) Responses of GDP



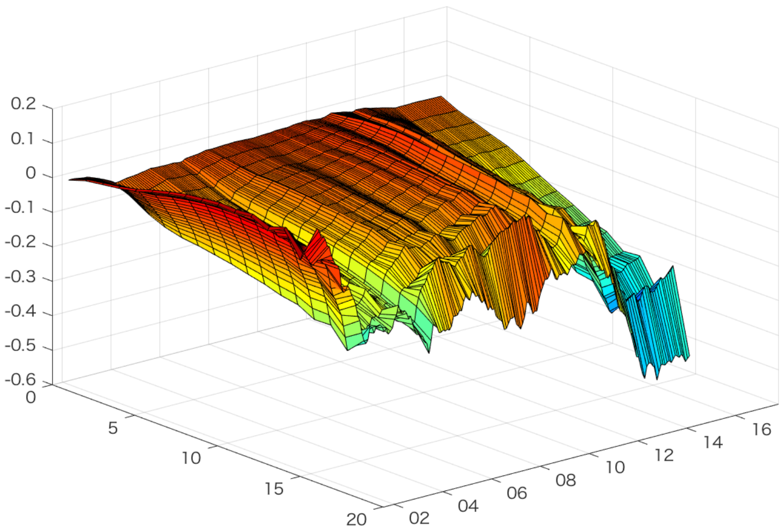
B) Responses of inflation rate



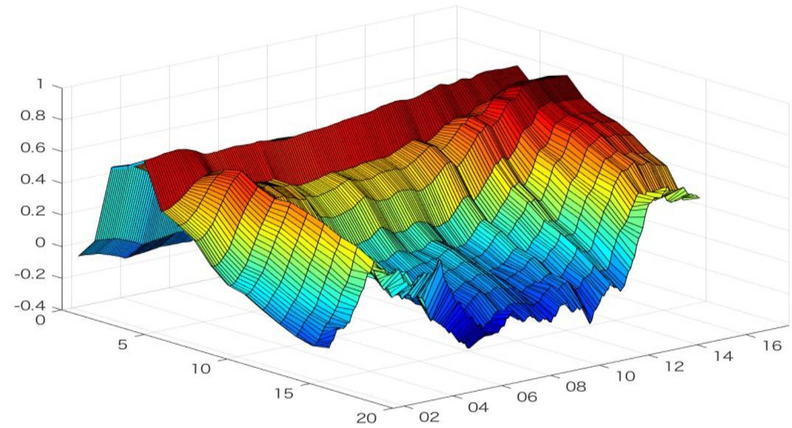
C) Responses of monetary base



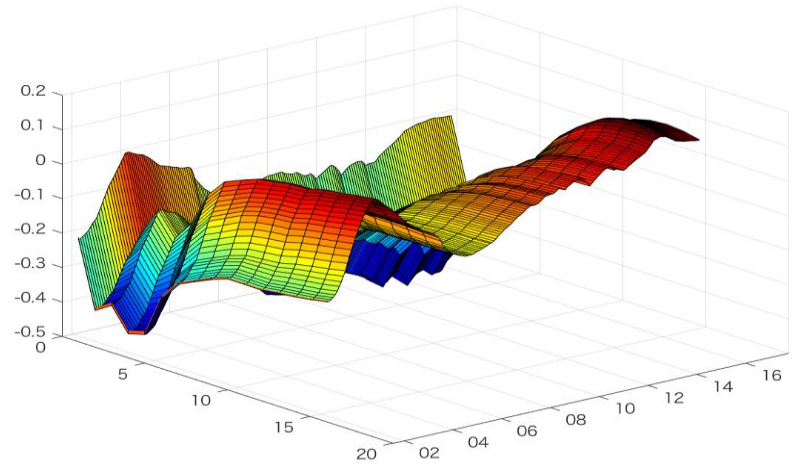
D) Responses of long-term interest rate



E) Responses of stock prices



F) Responses of exchange rate



G) Responses of bank lending

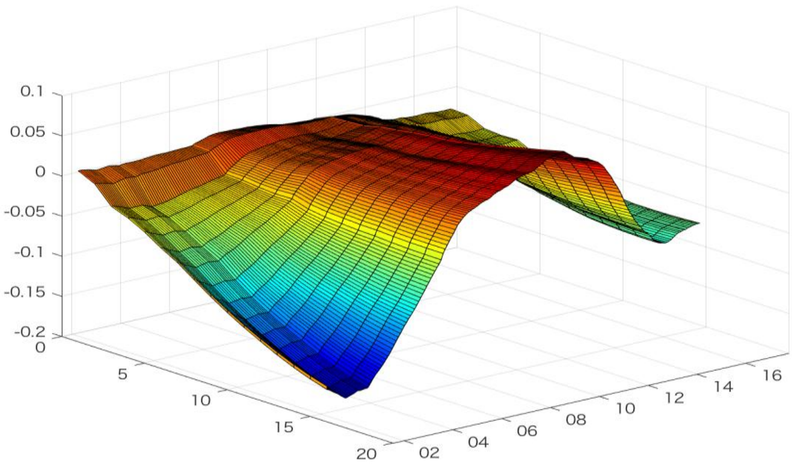
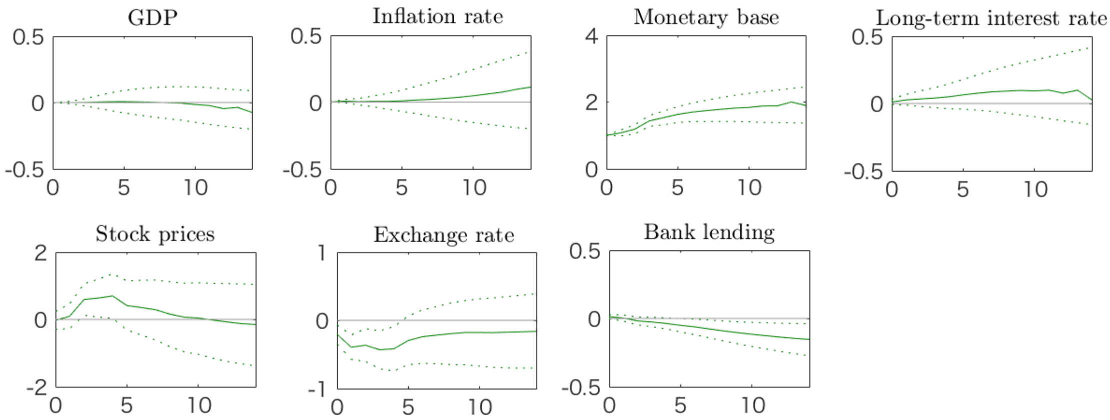


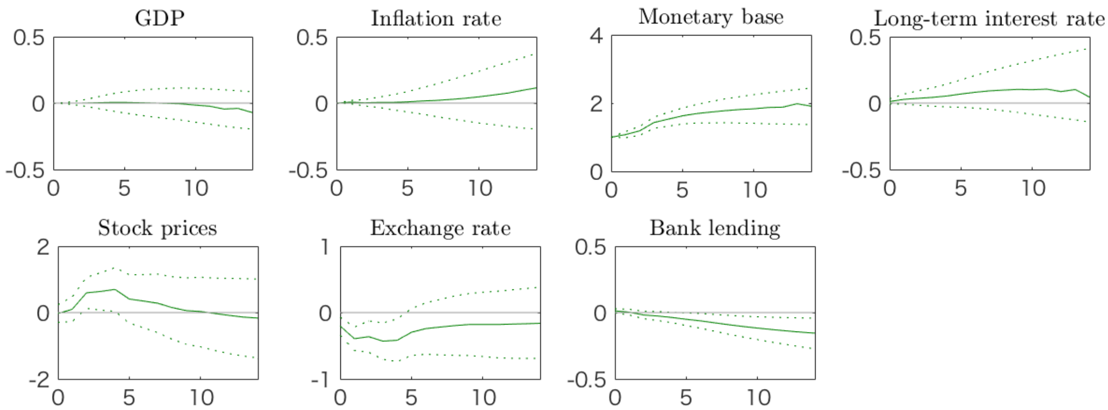
Figure-2. Accumulated median impulse response to a positive monetary policy shock[9]

[9] In Figure 2 and Figure 3, the responses of GDP, inflation rate, monetary base and long-term interest rate are from the stock prices model. There is not much difference in the responses of GDP, inflation rate and long-term interest rate between stock prices model and another two models.

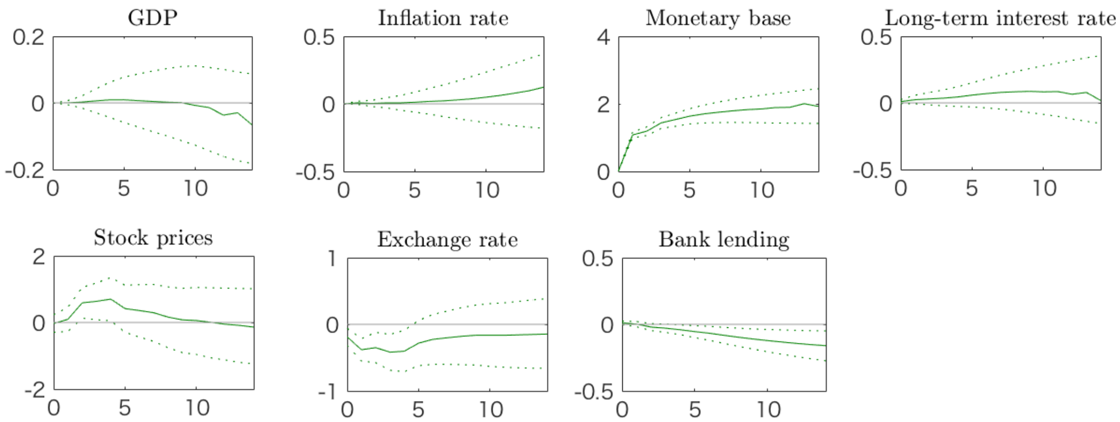
(i) August 2001



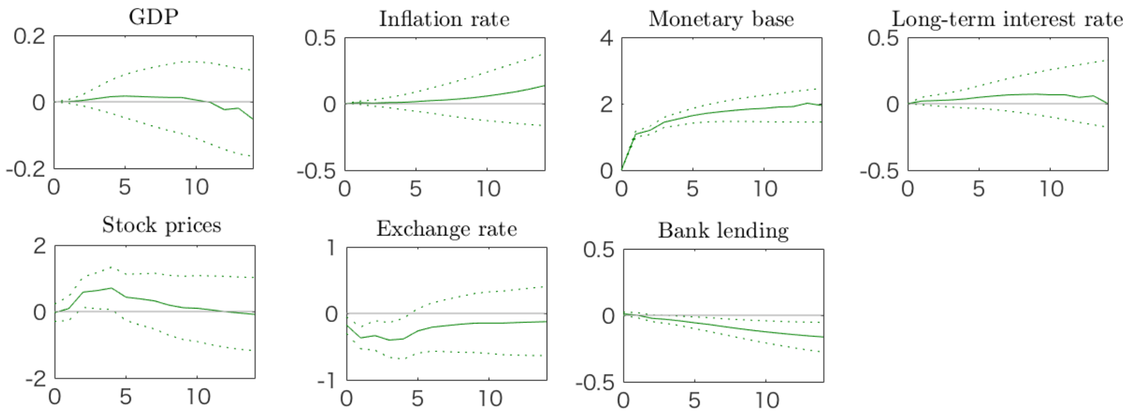
(ii) September 2001



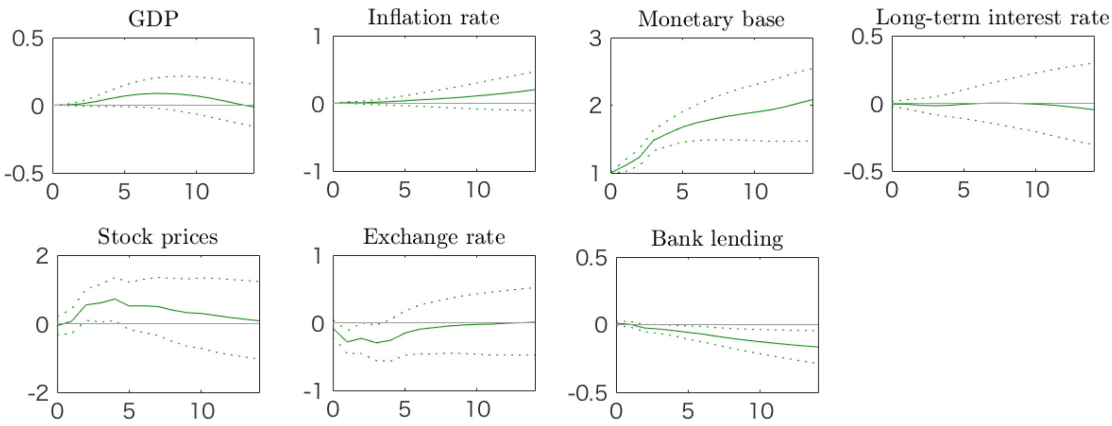
(iii) December 2001



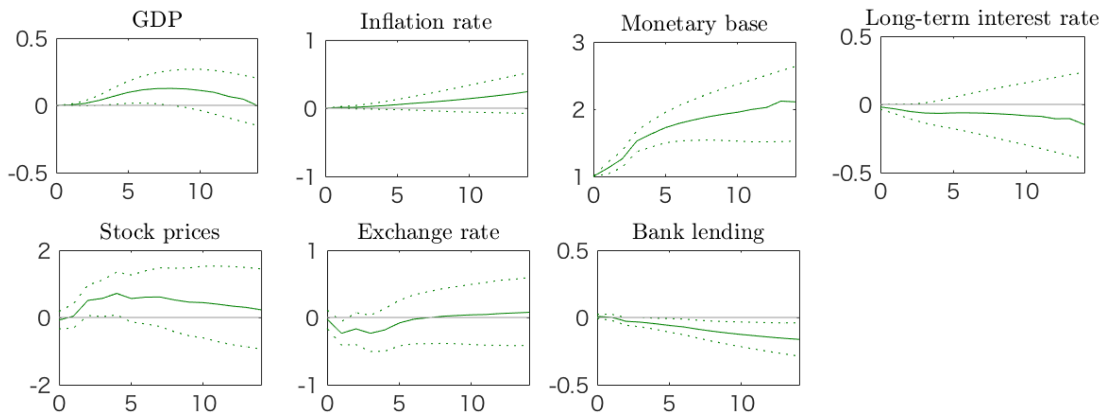
(iv) February 2002



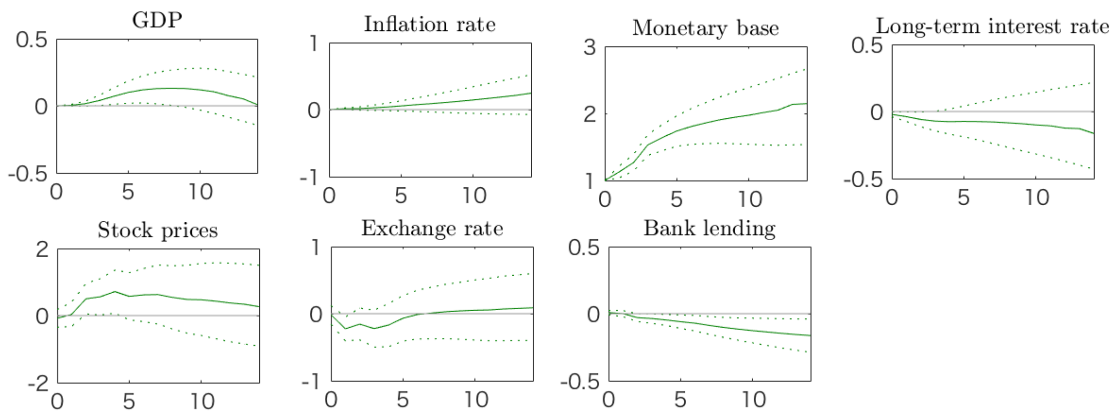
(v) October 2002



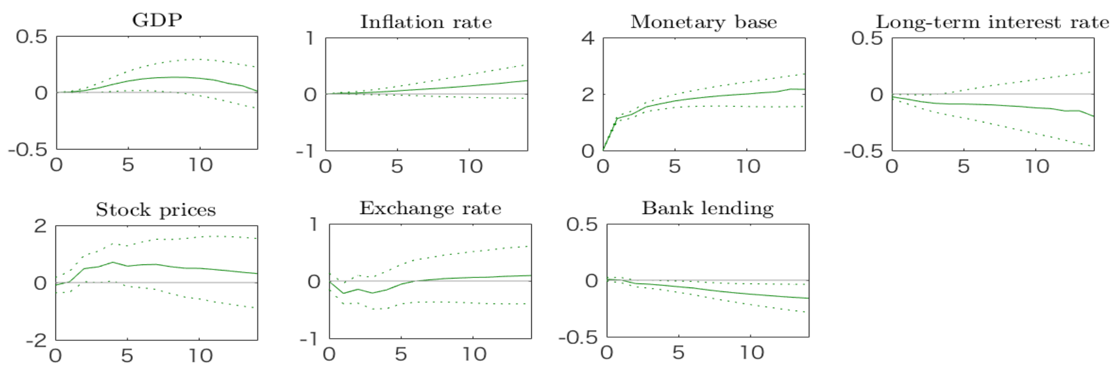
(vi) March 2003



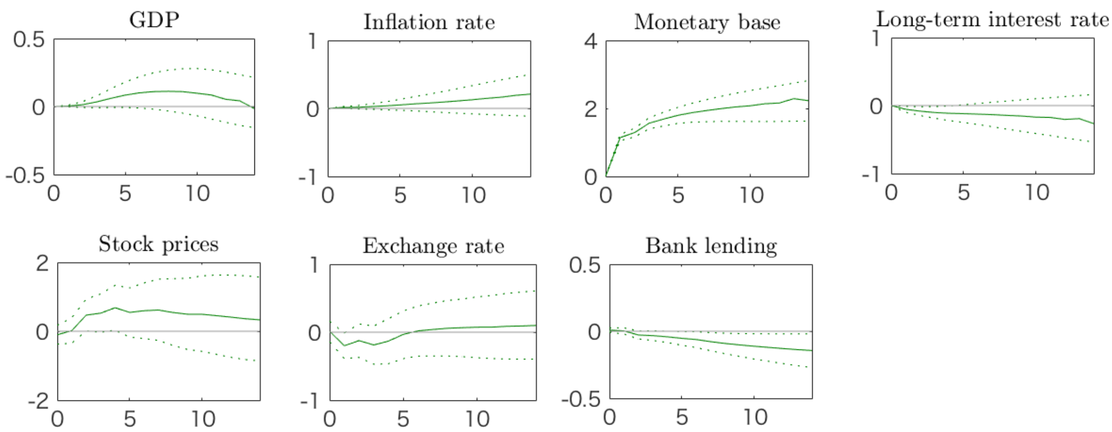
(vii) April 2003



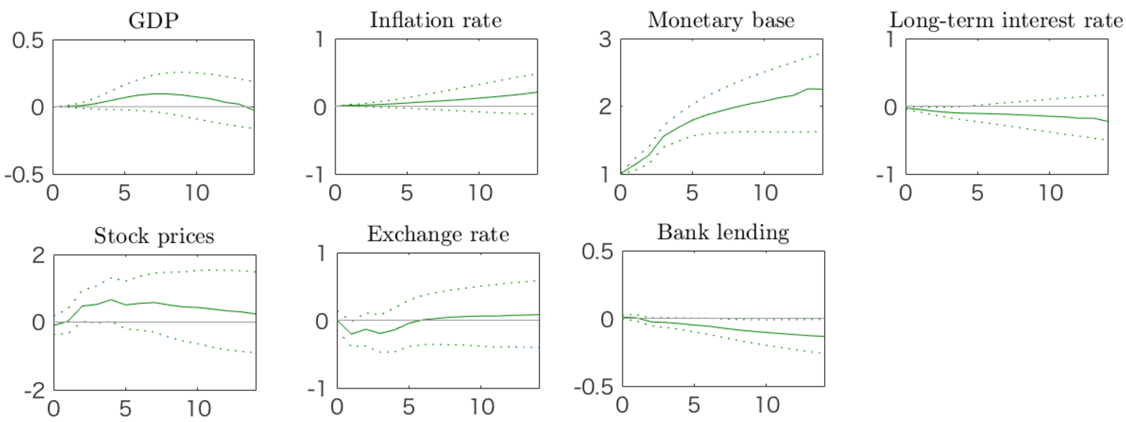
(viii) May 2003



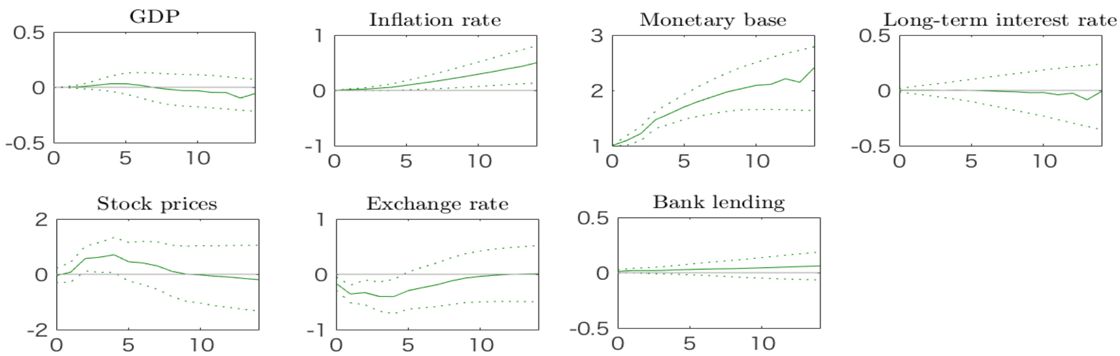
(ix) October 2003



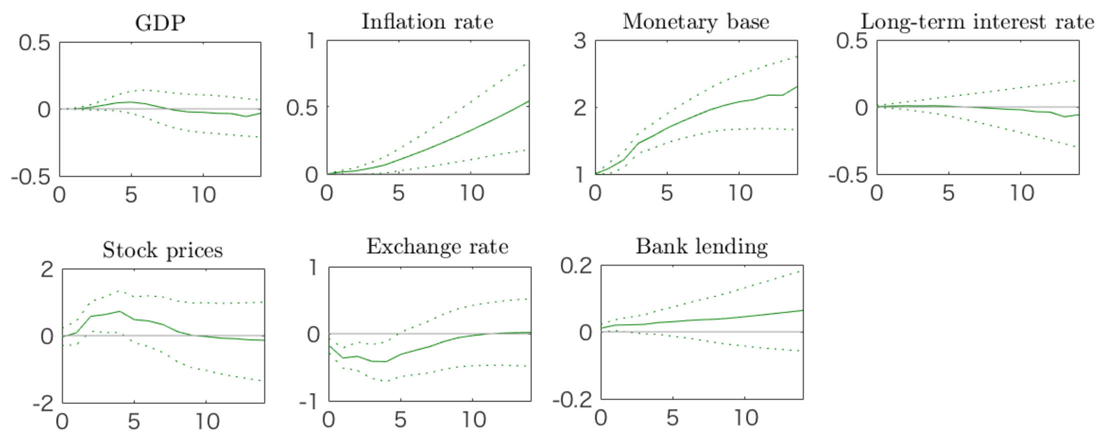
(x) January 2004



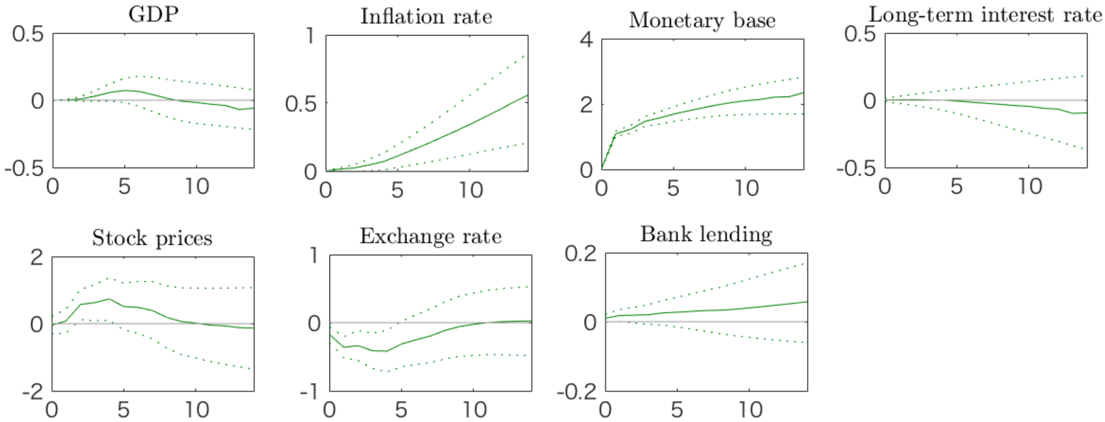
(xi) October 2010



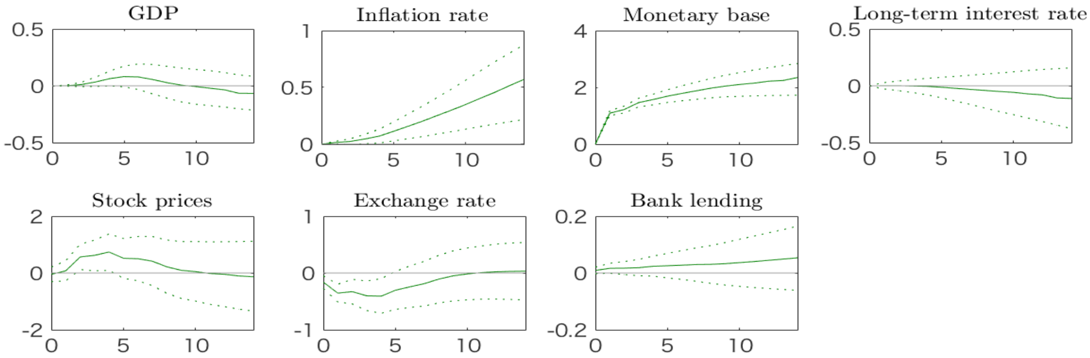
(xii) March 2011



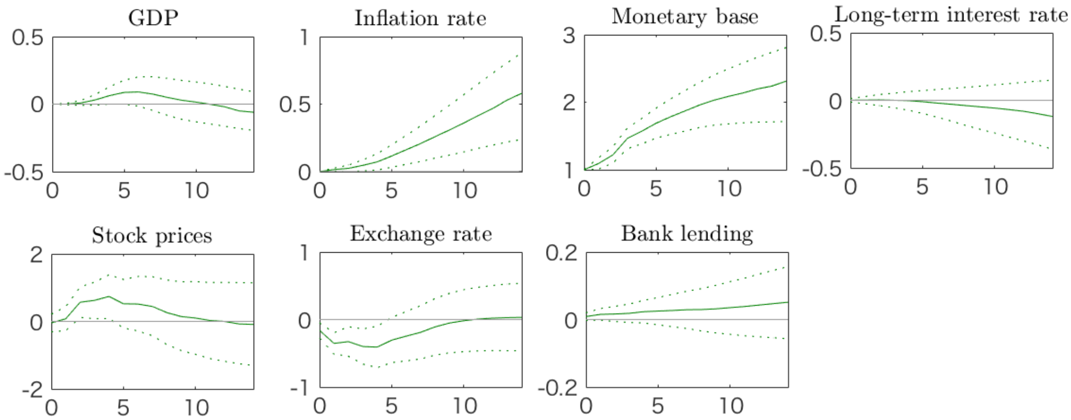
(xiii) August 2011



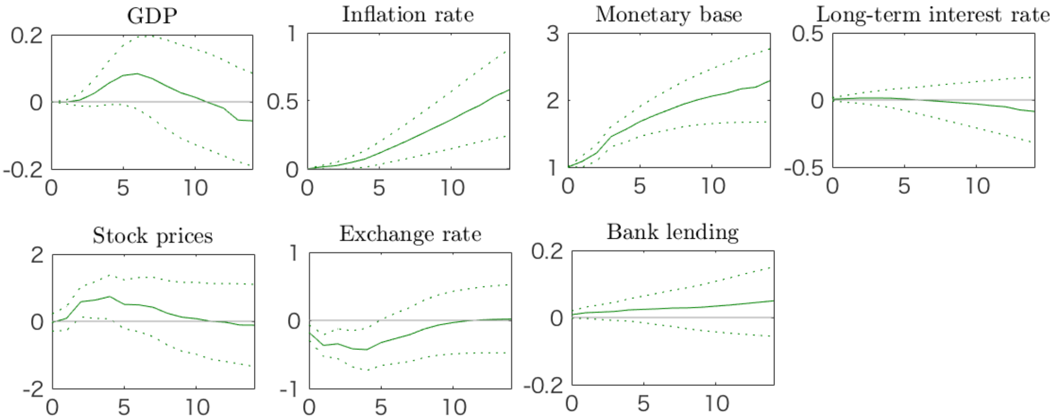
(xiv) October 2011



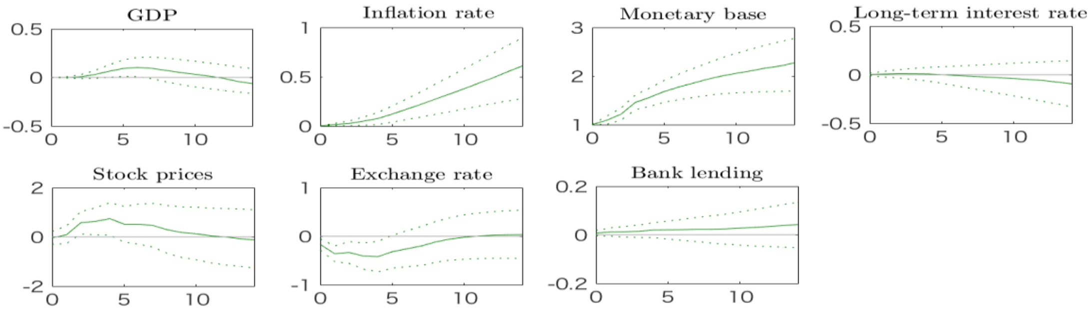
(xv) February 2012



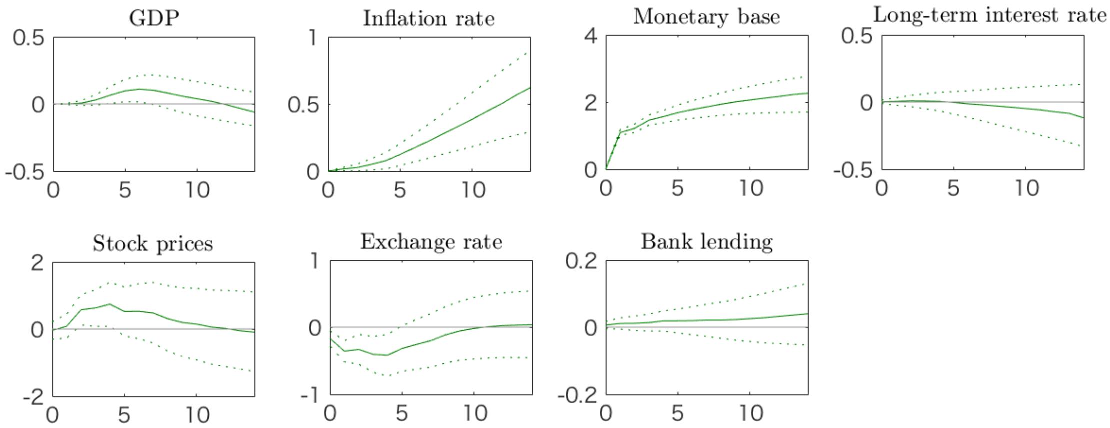
(xvi) April 2012



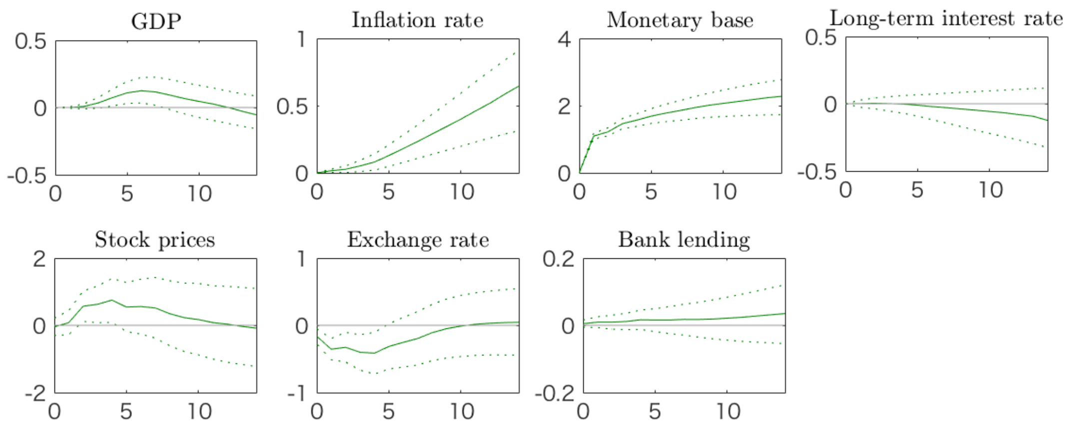
(xvii) September 2012



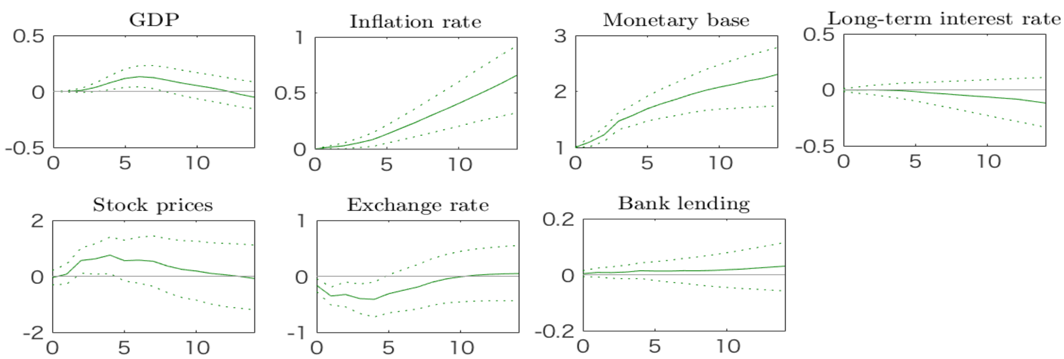
(xviii) October 2012



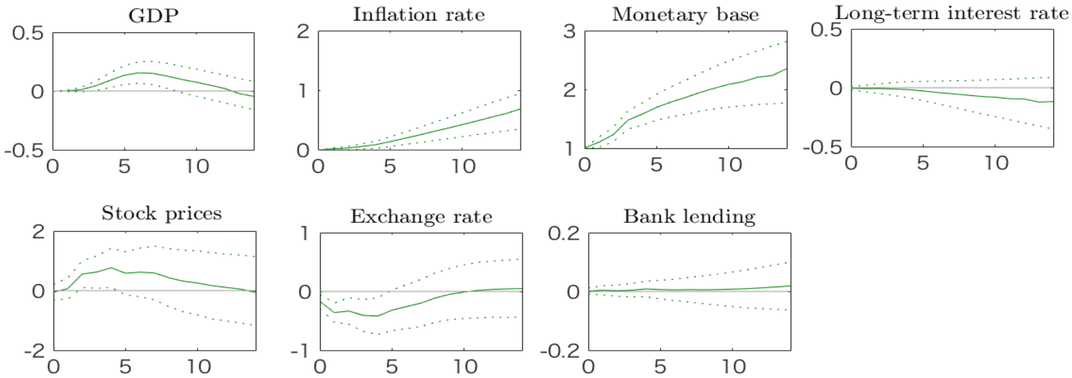
(xix) December 2012



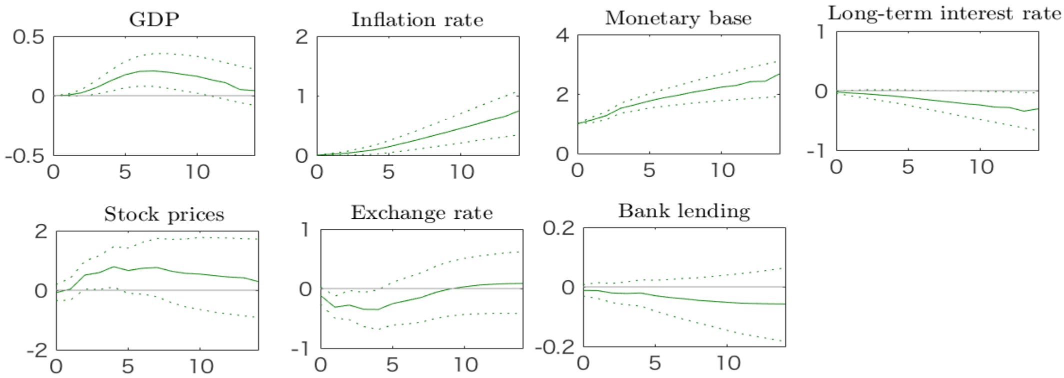
(xx) January 2013



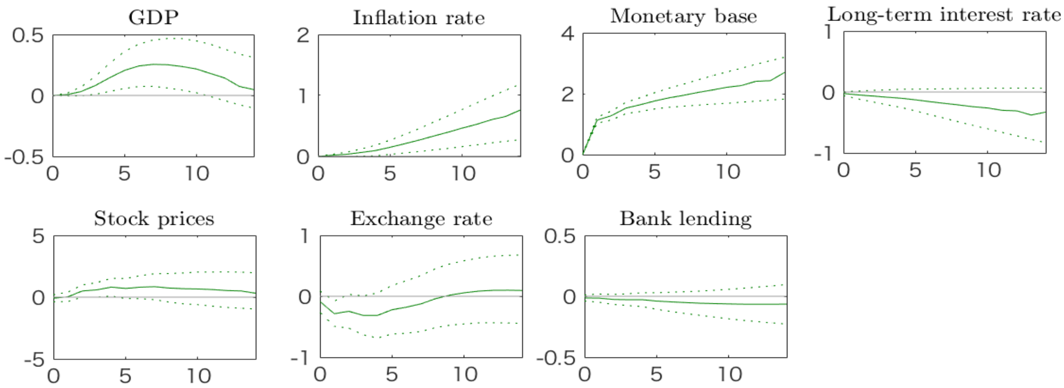
(xxi) April 2013



(xxii) October 2014



(xxiii) January 2016



(xxiv) September 2016

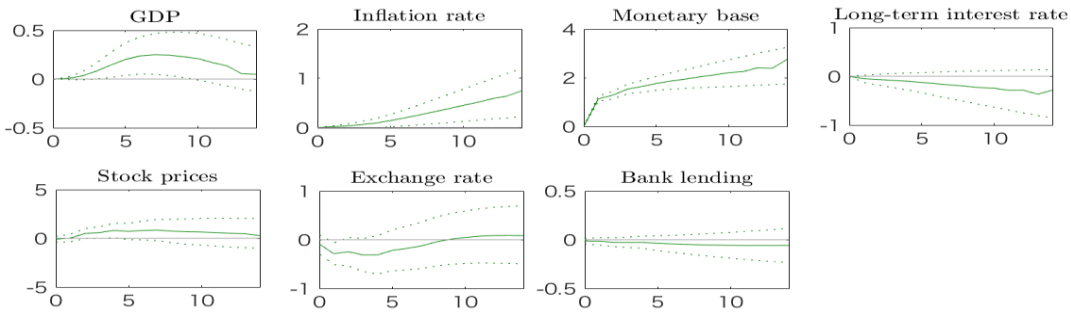


Figure-3. Accumulated median impulse response to a positive monetary policy shock with 1SD error bands