The Effects of Fiscal Policy under the Zero Lower Bound of Nominal Interest Rate in Japan: Time-Varying Parameters Vector Autoregression Approach✩

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Abstract

This study presents a new strategy for identifying unconventional monetary policy shocks in the framework of the time-varying parameters vector autoregression (TVP-VAR) model. We characterize monetary policy shocks at the zero lower bound (ZLB) of the short-term interest rate by combining the zero restrictions on the interest rate equation with the sign restrictions. Furthermore, this study investigates whether the effects of fiscal policy are enhanced during a ZLB period, as predicted by theory. The main findings are as follows. First, during a ZLB period, the volatility of short-term interest rates is quite small, while that of the monetary base is large. Second, unanticipated fiscal policy basically has positive time-varying effects on GDP. On the other hand, we cannot obtain the strong results that anticipated fiscal policy and monetary policy have a positive effects on GDP. Third, there is evidence that the effects of unanticipated fiscal policy increase during a ZLB period.

JEL classification: E62, E52, C11, C32

Keywords: Unconventional monetary policy; Fiscal policy; TVP-VAR model; sign restriction; MCMC

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1. Introduction

After recent financial crises (e.g., the Lehman shock and the Europe debt crisis) the authorities of major industrialized economies have been simultaneously implementing aggressive fiscal policies and monetary easing. In particular, the central banks of those economies have conducted quantitative easing (QE) at the zero lower bound (ZLB) of the nominal interest rate as a part of the unconventional monetary policy. There is continued active discussion and a growing literature on the effectiveness of those economic policies. The aim of this study is to evaluate the effects of these fiscal and monetary policies in Japan, by using the time-varying parameters vector autoregression (TVP-VAR) model developed by Primiceri (2005). As pointed out in several previous studies, Japan is “a front-runner of unconventional monetary policy (Kimura and Nakajima 2013)” and has experienced a zero interest rate for a sufficiently long time (Hayashi and Koeda 2013). In addition, a large number of fiscal stimulus packages have been implemented in Japan since the collapse of the bubble economy in the early 1990s. Therefore, the Japanese economy is an appropriate and interesting subject for our research. Additionally, the TVP-VAR model enables us to estimate the time-varying effects of these economic policies.

This study contributes to the existed literature as follows. First, we present a new method for identifying monetary policy at the ZLB of the nominal interest rate. There are several VAR analyses about Japanese monetary policy after QE. For example, Honda et al. (2007) identifies monetary policy shock by regarding the current account balances as the monetary policy instrument, and reports that QE increases output through the stock price channel. However, their sample period only covered the years 2001 to 2006 when the Bank of Japan conducted QE policy. On the other hand, Fujiwara (2006) and Inoue and Okimoto (2008) estimate a Markov-Switching VAR model using both conventional and unconventional monetary policy periods. They conclude that the regime change occurred in the late 1990s, and that the effectiveness of monetary policy seems to decrease after the structural change.

\footnote{Shioji (2000) and Miyao (2002) analyze Japanese monetary policy before QE.}
More recently, Hayashi and Koeda (2013) estimates the two-regime structural VAR model and incorporate the exit condition from zero interest rate policy, in which monetary policy regime changes when a certain condition about inflation rate is satisfied. They also found the expansionary effects of monetary policy on inflation and output. Similar to the studies using the TVP-VAR model, Nakajima (2011), Franta (2011), Nakajima et al. (2011) and Kimura and Nakajima (2013) also estimate the time-varying effect of monetary policy in Japan.

Although each previous study gives a sufficient attention to the identification of monetary policy, the characterization of the monetary policy under the ZLB of nominal interest rate can be improved. With exception to Franta (2011), monetary policy shock is commonly identified as a shock that lowers the interest rate (e.g., Fujiwara 2006, Inoue and Okimoto 2008, Nakajima 2013). Also, oftentimes interest rate shock and monetary base shock are identified separately (e.g., Hayashi and Koeda 2013, Kimura and Nakajima 2013). It seems to be inappropriate to identify monetary policy shock in this manner because there is no room to lower the interest rate in the ZLB period. In addition, a cut in the policy rate is usually performed through the supply of monetary base to the market, and thus monetary policy shock should be characterized by both monetary variables. The next point is related to the dynamics of the short-term interest rate in the ZLB. As noted in Nakajima (2011), the effects of structural shock are unlikely to work through the interest rate channel at the ZLB period because the policy rate falls to zero. Nevertheless, previous studies, with exception to Nakajima (2011) and Kimura and Nakajima (2013), allow the short-term interest rate to vary in response to structural shocks even in the ZLB. To resolve these difficulties, we incorporate zero restrictions into the short-term interest rate equation based on that of Nakajima (2011), and identify monetary policy shock as a combination of the interest rate and the monetary base, following Franta (2011).

More precisely, by using sign restrictions, monetary policy shock is characterized as a shock that lowers the short-term interest rate and raises the monetary base, and a nonnegativity constraint is imposed on the short term interest rate. Intuitively, the nonnegativity
constraint eliminates the possibility that the interest rate falls more than the observed rates in response to monetary policy shock. On the other hand, zero restrictions on the coefficient and contemporaneous relations in the interest rate equation allow the interest rate to be fixed during the ZLB period. By combining the above two methodologies, we are able to identify the effects of monetary policy under the ZLB of nominal interest rate.

In addition to presenting the new identification for monetary policy, this study also contributes to the literature by analyzing the effects of fiscal policy. Specifically, we focus on the effects of fiscal policy at the ZLB. This is motivated by the theoretical prediction presented by Braun and Waki (2006), Christiano et al. (2011), and Eggertsson (2010), in which it is theoretically shown that the effects of fiscal policy are enhanced at the ZLB. We investigate whether this theoretical prediction can be observed empirically. Although Gerba and Hauzenberger (2013) tried to estimate the fiscal and monetary interactions in the US by using a TVP-VAR model, they did not specifically identify monetary policy under the ZLB. To my knowledge, there are no studies regarding the Japanese economy that analyze the time-varying effects of fiscal policy using the TVP-VAR model. Following Mountford and Uhlig (2009), we identify both unanticipated and anticipated fiscal policy shock based on the sign restrictions.

The results obtained in this study are summarized as follows. First, in the ZLB period, the volatility of the short-term interest rate is estimated to be fairly small and the volatility of the monetary base is quite large. Second, the results of an impulse response function (IRF) analysis show that unanticipated fiscal policy persistently has positive effects on output, and these effects change during the sample period. Third, we are able to confirm that the effects of fiscal policies are enhanced during the ZLB period, as is theoretically predicted by Christiano et al. (2011) and Eggertsson (2010).

The rest of this study is organized as follows. In Section 2, we explain the empirical framework adopted in this study. Specifically, we describe the TVP-VAR model with sign restrictions, the identification strategy, and the Bayesian technique used in this study. Section 3 presents the data and the specifications employed in this study. Section 4 shows the
2. Empirical methodology

2.1. TVP-VAR model

This study employs the TVP-VAR model developed by Primiceri (2005). For a \( k \)-dimensional vector of endogenous variables, \( y_t = (y_{1t}, \cdots, y_{kt})' \), the structural-form VAR model with time-varying parameters is formulated as

\[
A_t y_t = B_{1t} y_{t-1} + \cdots + B_{st} y_{t-s} + u_t, \quad t = s + 1, \cdots, T,
\]

where \( u_t \) denotes the vector of structural shocks, which is distributed according to a \( k \)-dimensional normal distribution with mean 0 and time-varying covariance matrix \( \Sigma_t \Sigma_t' \),

\[
\Sigma_t = \begin{pmatrix}
\sigma_{1t} & 0 & \cdots & 0 \\
0 & \ddots & \ddots & \vdots \\
\vdots & \ddots & \ddots & 0 \\
0 & \cdots & 0 & \sigma_{kt}
\end{pmatrix}.
\]
Multiplying both side of (1) by $A_t^{-1}$ yields the reduced-from VAR model:

$$y_t = C_{1t}y_{t-1} + \cdots + C_{st}y_{t-s} + A_t^{-1}\Sigma\varepsilon_t$$  \hspace{1cm} (5)

$$\varepsilon_t \sim N(0, I_k)$$  \hspace{1cm} (6)

where $C_{it} = A_t^{-1}B_{it}(i = 1, \cdots, s)$ and $\varepsilon_t$ is a vector of structural shocks that normalized to be of variance 1. Defining $\beta_t = [vec(C_{1t})', \cdots, vec(C_{at})']' (k^2 s \times 1)$ and $X_t = I_k \otimes (y_{t-1}', \cdots, y_{t-s}')$, where $\otimes$ denotes the Kronecker product, (5) can be rewritten as

$$y_t = X_t\beta_t + A_t^{-1}\Sigma\varepsilon_t.$$  \hspace{1cm} (7)

Subsequently, we set the process for the time-varying parameters. Let $a_t$ be a stacked vector of the lower triangular elements in $A_t$ and $h_t = (h_{1t}, \cdots, h_{kt})'$ with $h_{it} = \ln(\sigma^2_{it})$. As suggested by Primiceri (2005), we assume that the time-varying parameters evolve according to a random walk process:

$$\beta_{t+1} = \beta_t + u_{\beta t},$$  \hspace{1cm} (8)

$$\alpha_{t+1} = \alpha_t + u_{\alpha t},$$  \hspace{1cm} (9)

$$h_{t+1} = h_t + u_{ht},$$  \hspace{1cm} (10)

for $t = s + 1, \cdots, T$. Moreover, the model innovations are assumed to follow a joint normal distribution, as shown:

$$\begin{pmatrix}
\varepsilon_t \\
u_{\beta t} \\
u_{\alpha t} \\
u_{ht}
\end{pmatrix} \sim N\left(0, \begin{pmatrix} I_k & 0 & 0 & 0 \\
0 & \Sigma_{\beta} & 0 & 0 \\
0 & 0 & \Sigma_{\alpha} & 0 \\
0 & 0 & 0 & \Sigma_{h}\end{pmatrix}\right),$$  \hspace{1cm} (11)

where the variance-covariance structure for the innovations of the time-varying parameters ($\Sigma_{\beta}, \Sigma_{\alpha}, \Sigma_{h}$) is assumed to be a diagonal matrix.
2.2. Identification

This study combines two identification methods to identify an unconventional monetary policy shock. One is the TVP-VAR-ZLB model presented by Nakajima (2011); the other is the sign-restricted identification method that was originally developed by Uhlig (2005) and Mountford and Uhlig (2009) and was later adapted to the TVP-VAR model by Canova and Gambetti (2009) and Franta (2011).

2.2.1. TVP-VAR-ZLB model

Nakajima (2011) estimated a four-variable TVP-VAR model that included the inflation rate, the output gap, the short-term interest rate, and the medium-term interest rate. Nakajima (2011) considered the situation in which the short-term interest rate did not react to structural shocks at the zero lower bound (ZLB) of the nominal interest rate, and estimated the TVP-VAR model by imposing the restriction that the coefficients and simultaneous parameters related to the short-term interest rate were equal to zero during the ZLB period.

More precisely, we assume that the variations in the time-varying parameters (i.e., $u_{\beta_t}$ and $u_{\alpha_t}$) in the interest rate equation vanish at the ZLB. In other words, the relevant elements $\beta_t$ and $\alpha_t$ remain at their most recent values when the nominal interest rate hits the lower bound because variations in $u_{\beta_t}$ and $u_{\alpha_t}$ never occur. Based on this assumption, the values of these parameters are replaced by zero. By doing so, Nakajima (2011) incorporates the dynamic property of the short-term interest rate at the ZLB into the TVP-VAR model and calls the result the TVP-VAR-ZLB model.

However, there is one shortcoming in this study. Although the medium-term interest rate is contained in the estimation model, monetary policy shocks are only characterized by variations in the short-term interest rate. Therefore, a monetary policy that increases the monetary base, such as QE, cannot be captured explicitly.

2.2.2. Sign restrictions for unconventional monetary policy

Contrary to Nakajima (2011), the TVP-VAR model employed by Franta (2011) comprises of both the short-term interest rate and the monetary base, in addition to industrial production and the inflation rate. Furthermore, Franta (2011) uses sign restrictions to distinguish
in an intuitive way a monetary policy shock at the ZLB. Throughout the sample period, a monetary policy shock is characterized as a shock that lowers the short-term interest rate while raising the monetary base. In addition, a nonnegativity constraint is imposed on the short-term interest rate when the interest rate falls close to the ZLB. To be specific, in response to a monetary policy shock, the interest rate is assumed not to fall more than 1 basis point for the QE period, 5 basis points for a zero interest rate policy (ZIRP) period, and 50 basis points for a very low call rate period.

Although monetary policy is identified by a combination of interest rate and monetary base—thus taking QE into consideration—there yet remains the possibility that the short-term interest rate fluctuates in response to structural shocks, in spite of having fallen to the ZLB. Furthermore, the nonnegativity constraints imposed on the interest rate are not strictly adhered to because the minimum value of a call rate is 0.1 basis points during the sample period. In fact, even during the ZLB period, the time-varying volatility of the reduced-form residuals in the interest rate equation is estimated to be comparatively large, and this can make it difficult to sample a valid draw that strictly satisfies nonnegativity constraint. Therefore, besides the nonnegativity constraints, it is necessary to impose zero restrictions on the time-varying coefficients in order to correctly identify an unconventional monetary policy shock.

2.2.3. Identification strategy

This study identifies three types of structural shocks: monetary policy, unanticipated fiscal policy and anticipated fiscal policy. To do so, the TVP-VAR model in this study consists of government spending, the short-term interest rate (call rate), excess stock returns of construction industry, the monetary base, and GDP. Regarding monetary policy shock, we extend the TVP-VAR-ZLB model presented by Nakajima (2011) with sign restrictions to discern monetary policy shock under the ZLB of nominal interest rate. Moreover, anticipated fiscal policy shock is characterized by incorporating the approach using stock returns as presented in Fisher and Peters (2010) into “news shock” restrictions employed in Mountford and Uhlig (2009) for government spending. Each shock is identified as follows.
First, unanticipated fiscal policy shock is identified under the standard assumption that government spending is the most exogenous variable and thus is affected only by this shock at the impact period. This assumption is based on the fact that fiscal policy cannot react to changes in the state of the economy immediately due to the decision lag. This fact has also been accounted for by most studies in the previous literature (e.g. Blanchard and Perotti 2002, Galí et al. 2007).

Second, A monetary policy shock is defined as a shock that lowers the short-term interest rate and increases monetary base. This assumption is widely accepted in previous studies that examine the effects of monetary policy by using sign restrictions. In this study, additional restrictions are imposed in order to characterize the dynamic property of the short-term interest rate under the ZLB. As noted in Nakajima (2011), the monetary policy does not work through the interest rate channel when the interest rate falls to near zero. In other words, it seems that the short-term interest rate does not change in response to monetary policy shock during the ZLB. Following Nakajima (2011), this study introduces the restriction that the coefficients related to the short-term interest rate equals zero when the interest rate hits the ZLB, thus removing the transmission effects for the interest rate of the structural shocks. Furthermore, regarding the contemporaneous relation during the ZLB period, we calculate the impulse vector of monetary policy shock—where the interest rate does not respond to monetary policy shock—by applying ‘zero’ restriction of Mountford and Uhlig (2009). This is further explained in Section 2.3. Combining the above two restrictions, we try to capture the dynamic property of monetary policy under the ZLB of nominal interest rate in the framework of a TVP-VAR model. In addition, the nonnegativity constraints are also incorporated to rule out the possibility that the interest rate falls more than the observed rate in response to monetary policy shock, as in Franta (2011).

Third, anticipated fiscal policy shock is identified by incorporating the approach presented in Fisher and Peters (2010) into sign restriction from Mountford and Uhlig (2009). Fisher and Peters (2010) consider that fiscal news fluctuate the current stock prices of firms that are related to fiscal policy. They capture the anticipated increase in U.S. government
military spending by regarding the stock returns of military contractors as a proxy for news shock. We apply this identification strategy to the relationship between government spending and the Japanese construction industry. By regarding the innovations in stock returns of construction industry as anticipated fiscal policy shock, we attempt to identify anticipated fiscal policy shock in Japan. However, there are shortcomings in the identification strategy of Fisher and Peters (2010). As Fisher and Peters (2010) point out, not all variations in stock returns are due to fiscal policy news because firms sell not only to the public sector but also to the private sector. Moreover, stock prices are also influenced by the workings of the entire economy. Hence, all innovations occurred in stock returns cannot be regarded as fiscal news shock, and it is necessary to pick up the variations in stock returns that is related to fiscal new shock. To resolve this difficulty, we impose sign restriction that government spending only rises after fiscal news is realized but that it does not react beforehand. By doing so, we isolate the variations in stock returns that result from anticipated fiscal policy shocks involving future increases in government spending.

The sign restrictions employed in this study are provided in Table 1. Since government spending is the most exogenous variable, monetary policy shock is assumed not to affect it at the impact period. In response to anticipated fiscal policy shock, it is assumed that government spending does not react at all during the first two quarters and react positively after three quarter.

<table>
<thead>
<tr>
<th>Table 1: Sign restrictions</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td><strong>gov. spending</strong></td>
</tr>
<tr>
<td>monetary policy shock</td>
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<td></td>
</tr>
<tr>
<td>fiscal policy shock</td>
</tr>
<tr>
<td>unanticipated</td>
</tr>
<tr>
<td>anticipated</td>
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</table>

\(^2\)We do this because fiscal policy aimed at an economic stimulus in Japan is usually performed through public works, and those works are undertaken by construction industry.
2.3. Bayesian estimation

The estimation of the TVP-VAR model is carried out via a Bayesian approach using Markov-chain Monte Carlo (MCMC) method. This section briefly explains the process of estimating the TVP-VAR model.

Let us define \( \beta = \{ \beta_t \}_{t=s+1}^T, \alpha = \{ \alpha_t \}_{t=s+1}^T, h = \{ h_t \}_{t=1}^T, \omega = (\Sigma_\beta, \Sigma_\alpha, \Sigma_h), \) and \( y = \{ y_t \}_{t=s+1}^T \). Given the data \( y \) and the prior density function \( \pi(\Theta) \), where \( \Theta = \beta, \alpha, h, \omega, \) the random samples from the posterior distribution \( \pi(\Theta | y) \) are obtained as follows:

1. Set initial values of \( \beta^{(0)}, \alpha^{(0)}, h^{(0)}, \omega^{(0)}, \) and \( j = 0. \)
2. Sample \( \beta^{(j+1)} \) from \( \pi(\beta | \alpha^{(j)}, h^{(j)}, \Sigma^{(j)}_\beta, y). \)
3. Sample \( \Sigma^{(j+1)}_\beta \) from \( \pi(\Sigma_\beta | \beta^{(j+1)}). \)
4. Sample \( \alpha^{(j+1)} \) from \( \pi(\alpha | \beta^{(j+1)}, h^{(j)}, \Sigma^{(j)}_\alpha, y). \)
5. Sample \( \Sigma^{(j+1)}_\alpha \) from \( \pi(\Sigma_\alpha | \alpha^{(j+1)}). \)
6. Sample \( h^{(j+1)} \) from \( \pi(h | \beta^{(j+1)}, \alpha^{(j+1)}, \Sigma^{(j)}_h, y). \)
7. Sample \( \Sigma^{(j+1)}_h \) from \( \pi(\Sigma_h | h^{(j+1)}). \)
8. Identify the structural shock based on \( \beta^{(j+1)}, \alpha^{(j+1)} \) and \( h^{(j+1)} \) by using sign restrictions.
9. Return to step 2 until \( N \) iterations have been completed.

For the above, \( N \) is set at 20000 and the first \( N_0 = 10000 \) samples are discarded as burn-in.

The detailed implementation for identifying restrictions in step 8 is performed following the work of Mountford and Uhlig (2009). Given the random samples of \( \beta, \alpha \) and \( h \) in each iteration, we first use a \( k \times 1 \) vector \( q^{(1)} = [1, 0, \cdots, 0]' \), and calculate the impulse response vector associated to unanticipated fiscal policy shock for each period as follows:

\[
a_t^{(1)} = A_t^{-1} \Sigma_t q^{(1)}. \tag{12}
\]

From the form of \( q^{(1)} \), the elements of \( a_t^{(1)} \) are simply equal to the first column of \( A_t^{-1} \Sigma_t \). In other words, unanticipated fiscal policy shocks are identified under the recursive restriction.

Subsequently, the impulse response vector to monetary policy shock \( a_t^{(2)} \) is calculated by using \( q^{(2)} \), where the restrictions \( q^{(2)'} q^{(2)} = 1, q^{(2)'} q^{(1)} = 0 \) are imposed on \( q^{(2)} \) to satisfy the orthonormality. Furthermore, during the ZLB period the restriction that the short-term...
interest rate does not react to monetary policy shock is additionally imposed on $q^{(2)}$. This restriction can be written as

$$0 = C q^{(2)}, \quad (13)$$

where $C$ is a $1 \times k$ matrix of the form

$$C = \begin{bmatrix} c_{j1}(1) & \cdots & c_{jk}(1) \end{bmatrix}. \quad (14)$$

Here, $c_{ji}$ is the response of the $j$-th variables (which is the short-term interest rate) to the $i$-th column of $A_t^{-1} \Sigma_t$.

Likewise, anticipated fiscal policy shock is identified using $q^{(3)}$ which satisfies the orthonormality $[q^{(1)}, q^{(2)}, q^{(3)}]' \times [q^{(1)}, q^{(2)}, q^{(3)}] = [0, 0, 1]'$ and the ‘news restriction’,

$$0 = R q^{(3)}, \quad (15)$$

where $R$ is a $2 \times k$ matrix, denoted as

$$R = \begin{bmatrix} r_{11}(1) & \cdots & r_{1k}(1) \\ r_{11}(2) & \cdots & r_{k2}(2) \end{bmatrix}. \quad (16)$$

Similar to the element of $C$, $r_{li}$ is the response of the $l$-th variables (which is government spending) to the $i$-th column of $A_t^{-1} \Sigma_t$. By this restriction, the response of government spending for the first two periods is set to be zero.

In each period of each iteration, the above procedure is repeated until the impulse responses satisfy the sign restrictions, or the draws of $q$ reach 100. If the sign restrictions are satisfied at period $t$, the new contemporaneous relation calculated by $q$ is saved as a valid draw at period $t$. If a valid draw is not provided in 100 draws at period $t$, we save the result of period $t$ obtained in the previous iteration, instead.

3. Data and specification

We employ the quarterly data of government spending, the short-term interest rate, excess stock returns of the construction industry, the monetary base, and GDP for the period
1980Q1-2012Q4. The sample period is from 1990Q1 to 2012Q4, and the pre-sample period from 1980Q1-1989Q4 is used to calibrate the prior distribution for the initial state of the time-varying parameters. Government spending is defined as the sum of government consumption and public investment. The series, except for the short-term interest rate and excess stock returns, are seasonally adjusted per capita, and are logarithmically transformed. Following Fisher and Peters (2010), the excess stock returns are defined as the difference between the whole market returns and the returns of the construction industry. The uncollateralized overnight call rate which corresponds to the policy rate in Japan is used for the short-term interest rate after 1985Q3, and the collateralized overnight call rate is used before 1985Q2, instead.

The data for government spending and GDP are obtained from the System of National Accounts (SNA) database in Japan, and released by the Cabinet Office of the Government of Japan. We combine the series of Quarterly Estimates of GDP (Reference year = 2005): Jul.-Sep. 2013 (The 2nd preliminary) and Provisional Estimates of GDP for Benchmark Year 2005. The monetary data (i.e., the short-term interest rate and monetary base) are obtained from the Bank of Japan. We use Call Rates, Uncollateralized Overnight (a)/Average(b) as the short-term interest rate, and Monetary Base (Reserve Requirement Rate Change Adjusted)/Seasonally Adjusted (X-12-ARIMA)/Average Amounts Outstanding as a monetary base. The data on stock returns are used from Rate of Stock Returns 2012. By following Fisher and Peters (2010), we constructed the excess stock returns by subtracting the whole market returns from the returns of the construction industry. Moreover, except for the interest rate and stock returns, the data were converted to their per capita value using total population data from the Japanese Population Census (Ministry of Internal Affairs and Communication).

The estimated VAR model includes the first differences of government spending, monetary base, GDP, and the level of excess stock returns and the short-term interest rate as well as a constant term. The number of lags is set to be three. This is because the TVP-VAR model comprises too many parameters if a high-order lag is chosen. On the other hand, one or two
lags might not suffice to capture the dynamics of the systems.

With respect to the ZLB period, this study follows the definition adopted by Nakajima (2011). Accordingly, we define the period in which the short-term interest rate fell below 50 basis points as the ZLB period. Figure 1 shows a plot of the series of the short-term interest rate, and the shaded areas show the ZLB period. These correspond to the periods from 1999Q2 to 2000Q2 and from 2001Q2 to 2006Q2.

Following Nakajima (2011), the priors are assumed to be

$$
\omega_{\beta i}^2 \sim IG(40, 0.02), \quad \omega_{\alpha i} \sim IG(5, 0.02), \quad \omega_{\alpha i} \sim IG(5, 0.02) \quad (17)
$$

where $\omega_{ji}^2, j = \beta, \alpha, h$ indicates the $i$-th element of $\Sigma_j, j = \beta, \alpha, h$. For the initial state of the time-varying parameters, we follow Nakajima, Kasuya and Watanabe (2011), and set the prior distributions as follows:

$$
\beta_0 \sim N(\hat{\beta}_0, 4I), \quad \alpha_0 \sim N(\hat{\alpha}_0, 4I), \quad h_0 \sim N(\hat{h}_0, 4I) \quad (18)
$$

where $\hat{\beta}_0, \hat{\alpha}_0$ and $\hat{h}_0$ are the OLS estimators obtained using the pre-sample period.

4. Estimated results

4.1. Estimated parameter values

In Figure 2, we show the sample autocorrelation function, the sample paths, and the posterior densities for selected parameters. The sample paths for each parameter look stable, and the sample autocorrelation function damps stably. Furthermore, Table 2 shows the estimates for posterior means, standard deviations, the 95 percent credible intervals, the p-value of the convergence diagnostics (CD) of Geweke (1992), and inefficiency factors for selected parameters. Based on the CD statistics, the null hypothesis of the convergence to the posterior distribution is not rejected at the 5 percent significance level. These results suggest that the samples in our estimation are efficiently generated and adequately converge.
Figure 1: The short-term interest rate

Note: This figure shows the short-term interest rate (the uncollateralized overnight call rate) for the period 1990Q1-2012Q4. The shaded areas indicate the ZLB period in which the call rate falls below 50 basis points.

Table 2: parameter values

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean</th>
<th>St. dev</th>
<th>95% intervals</th>
<th>CD</th>
<th>inefficiency</th>
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<td>$\beta_{1,5}$</td>
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<td>$\alpha_{1,5}$</td>
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<td>$\omega_{\alpha,1}$</td>
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<td>0.0037</td>
<td>[0.0262 0.0405]</td>
<td>0.578</td>
<td>10.53</td>
</tr>
<tr>
<td>$\omega_{h,1}$</td>
<td>0.0725</td>
<td>0.0174</td>
<td>[0.0455 0.1137]</td>
<td>0.125</td>
<td>44.49</td>
</tr>
</tbody>
</table>

Note: This table shows the estimation result for selected parameters. CD denotes the p-value of the convergence diagnostics of Geweke (1992). Bandwidth of a Parzen window is set to be 500. The estimates of $\omega_{\beta,1}$ and $\omega_{\alpha,1}$ are multiplied by 100.
Figure 2: Estimation results for selected parameters

Note: This figure shows sample autocorrelations (top), sample paths (middle), and posterior densities (bottom).

4.2. Volatility

Figure 3 shows the data and the posterior estimates of the volatilities of the reduced-form residuals (i.e., $\sigma^2_t = \exp(h_t/2)$). The solid line and the shaded areas indicate the median of the sampled volatility and the 68% credible intervals, respectively.

The remarkable finding in Figure 3 is that the volatility of the short-term interest rate is estimated to be almost zero during the ZLB period. This stems from the zero restrictions on the coefficients and the contemporaneous relation of the interest rate equation. In fact, the estimated volatility presented by Franta (2011) does not exhibit such a small value.
Figure 3: Data and standard deviations of reduced-form residuals

Note: This figure shows the data (top) and the estimated stochastic volatilities of reduced-form residuals (bottom). In the bottom charts, blue lines indicates the median of estimated values and the shaded areas indicates 68% credible intervals.

This small estimated volatility enables us to sample valid draws even when imposing a strict nonnegativity constraint on the short-term interest rate.

On the other hand, the volatility of the monetary base rose during the period in which an unconventional monetary policy was adopted, as seen in Figure 3. This implies that the monetary policy shock played an important role in the variations of the monetary base. In addition, we observe that the volatility of government spending in the 1990s was relatively high compared with that after the 2000s. This is thought to reflect the aggressive fiscal policy implemented in the 1990s and the passive fiscal policy in the 2000s. Subsequently,
4.3. Impulse response function

The IRFs for unanticipated and anticipated fiscal policy shocks and monetary policy shocks are plotted in Figures 4, 5, and 6, respectively. The figures show time series of the IRFs during the impact period and at one- and two-year horizons. In the figures, the shaded areas indicate the ZLB period.

stock returns became more volatile after the 2000s. The volatility of GDP also gradually increase throughout the sample period.
Figure 5: Responses to anticipated fiscal policy shocks

Note: This figure shows the time-varying impulse responses to anticipated fiscal policy shocks. The impact (blue), one-year (red), and two-year (green) horizons are plotted. The shaded periods correspond to the period of the ZLB of nominal interest rate.

Figure 4 shows the responses to an unanticipated fiscal policy shock. Except for the start of our sample period, GDP responds positively to unanticipated fiscal policy shock at the impact period. Moreover, in the long-run (i.e., one year after and two year after), it is found that GDP shows positive responses throughout the whole sample period (see the bottom-right chart). From the viewpoint of the fiscal and monetary interaction, we find that, in response to an unanticipated fiscal policy shock, the response of call rate shows a negative sign and that of monetary base shows a positive sign except during the ZLB period. These reactions are very notable until the ZIRP period, which began in 1999Q2. Accordingly, this
Figure 6: Responses to monetary policy shocks

Note: This figure shows the time-varying impulse responses to monetary policy shocks. The impact (blue), one-year (red), and two-year (green) horizons are plotted. The shaded periods correspond to the period of the ZLB of nominal interest rate.

result indicates that the monetary authority takes an accommodative stance when positive fiscal policy is enacted. The response of stock returns in construction industry indicates negative sign in almost all sample period.

Figure 5 shows the responses to an anticipated fiscal policy shock. Unlike the case of the unanticipated fiscal policy shock, government spending is restricted not to respond to this shock until the third period: however, it does gradually increase. The response of GDP indicates a negative sign in the short-run throughout the sample period. After the ZIRP period, GDP decreases in response to this shock even in the long-run. In the section
of robustness check below, we estimate the TVP-VAR model in which GDP is replaced with consumption or investment, and clarify which components contribute to the negative response of GDP. Regarding monetary policy instruments, we note that the short-term interest rate barely reacts to the shock at first impact. One year after news is announced, however, call rate is falling. The monetary base also increases in the long-run, except for the recent period.

Finally, we discuss the effects of monetary policy, which are shown in Figure 6. For the short-term interest rate, we observe that the strict nonnegativity constraint worked well during the ZLB period, especially in the QE period. Furthermore, it is found that the accommodative monetary policy shock had an expansionary effect on the monetary base during the QE and the recent period. Also, we can see the persistent positive effects on GDP except for the period of the Lehman shock although the impact responses of GDP vary throughout the sample period.

4.4. Fiscal multiplier

In the figures shown above, we cannot compare the sizes of effects of the fiscal policy on GDP in each period because the size of the fiscal policy shock varies over time. Figure 7 shows the estimates of fiscal multipliers for an unanticipated fiscal policy shock. Since the endogenous variables in the VAR model are within the logarithms, the fiscal multiplier is computed as follows:

\[
\text{fiscal multiplier}_t = \frac{\text{IRF of GDP}}{\text{IRF of Gov. spending}} \times \frac{\text{GDP}_t}{\text{Gov. spending}_t}
\]

This study calculates two types of fiscal multipliers: “impact” and “cumulative”. The former uses impulse responses during the impact period, while the latter uses the sum of the impulse responses for four quarters.

One can see that both the impact and accumulated multipliers show the same historical pattern. The impact multiplier starting from a negative value gradually increases, and reaches about 1.5 at the second half of the 2000s. The cumulative one is somewhat large compared with the impact.
For the fiscal policy under the ZLB, we can observe that the values of multipliers exceed one after the second half of the 1990s in which the BOJ began to adopt the ZIRP or the QE. The cumulative multiplier has already exceed one before the ZIRP and the impact one also exceed one at the end of ZIRP period. After the BOJ adopts the QE, both multipliers are always over one up to the end of the sample period. Based on the fact that the short-term interest rate was sufficiently low after 2006Q2, this result implies that the effects of (unanticipated) fiscal policy is enhanced in the state where the short-term interest rate is extremely low. This is consistent with the theoretical prediction of Braun and Waki (2006), Christiano et al. (2011), and Eggertsson (2010).

![Figure 7: Fiscal multiplier](image)

**Figure 7: Fiscal multiplier**

Note: This figure shows the time-variations in the fiscal multipliers that are calculated based on the results of time-varying impulse responses. The shaded areas correspond to the period of the ZLB of nominal interest rate.
5. Robustness check

5.1. Components of GDP

To understand the effects of each structural shocks on GDP in detail, we estimate the model in which GDP is replaced with private consumption or private investment. Private consumption and investment are obtained from the SNA database. The aim of this section is to clarify which component contributes to the dynamic response of GDP. Figure 8 shows the IRFs of consumption and investment to each shock. As in Figure 4, 5 and 6, the plotted series indicate the IRFs during the impact period and one- and two-year horizons.

Regarding the responses to unanticipated fiscal policy shock, we can first confirm that the effects on consumption have been increasing after ZIRP period. Although the response of consumption shows a negative sign at the second half of the 1990s, it overturns after the beginning of the 2000s. On the other hand, investment seems to be basically crowding-out by unanticipated fiscal policy. Hence, it can be concluded that positive responses of GDP to unanticipated fiscal policy shock stems from positive responses of consumption. Moreover, our results imply the possibility that a rise of the effects of fiscal policy at the ZLB period is caused through consumption channel.

In contrast, the response of consumption to anticipated fiscal policy shock shows a positive sign before the ZLB period, and it has been dampened after 2000. With respect to investment, one can observe the stronger crowding-out effect. Due to this large crowding-out effects, GDP shows negative response even in the period when consumption positively responds to fiscal news shock.

The results related with monetary policy are contrary to our intuition. As long as our result is seen, monetary policy shock is considered to have stimulated not investment but consumption. In addition, the results show that unconventional monetary policy like as ZIRP and QE had exert negative effects on consumption and investment.
Figure 8: The IRFs of consumption and investment

Note: This figure shows the time-varying impulse responses of consumption and investment to each structural shock. The impact (blue), one-year (red), and two-year (green) horizons are plotted. The shaded periods correspond to the period of the ZLB of nominal interest rate.

6. Conclusion

This study has investigated the effects of fiscal and monetary policy shocks in Japan by using the TVP-VAR model and accounting for the ZLB of the nominal interest rate. In particular, we focused on the effects of the macroeconomic policies under the ZLB of the nominal interest rate. We proposed a new identification method for unconventional monetary policies, in which we combined the methods presented by Nakajima (2011) and
Franta (2011). Furthermore, we calculated the fiscal multiplier throughout the sample period to confirm whether the effects of the fiscal policy increased during the period of the ZLB, as predicted by Christiano et al. (2011) and Eggertsson (2010).

We summarize the main results as follows. First, the TVP-VAR-ZLB model can replicate the fact that the volatility of the short-term interest rate becomes quite small during the ZLB period. This plays an important role in being able to sample valid draws that satisfy non-negativity constraints on the short-term interest rate. Additionally, during the period of the QE, our estimated results capture the rise of volatility in the monetary base. Furthermore, the calculated IRFs imply that the effects of the fiscal and monetary policy shocks change over the sample period. The time-varying effects are observed in both the magnitude of the shock and the transmission mechanism. Our result shows that unanticipated fiscal policy shock has basically positive effects of GDP while anticipate fiscal policy and monetary policy shock have a negative or only quite small positive effects on GDP. Moreover, in responses to both fiscal policy shock, it turns out that consumption increases but investment is crowded out. Finally, as one of the principal findings of this study, we found there is evidence that the effects of fiscal policy increase during a ZLB period in Japan. Also, it found that an increase in fiscal multipliers corresponding to unanticipated fiscal policy during the ZLB period is stemmed from a rise in the response of consumption.

Since several developed countries have experienced quite low policy rates, the estimation methodology presented in this study will be useful and applicable for analyzing those countries. In particular, it is important to clarify and reconcile the observed and theoretically predicted effects of fiscal policies during a ZLB. Thus, it remains to be determined if our results are only specific to the particular economy of Japan.

References


