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Macroeconomic Effects of Monetary Policy in Japan: An Analysis Using Interest Rate Futures Surprises*

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Abstract

We estimate the effects of monetary policy on the aggregate economy in Japan during the last three decades when the effective lower bound (ELB) on interest rates was occasionally binding. Using monetary policy surprises from the interest rate futures market as the external instrument to identify monetary policy shocks in the VAR model, we show that monetary policy has been effective in Japan for the entire sample period but its effect was more persistent in the ELB regime. Using a New Keynesian model with forward guidance, we further show that our empirical finding is consistent with theoretical predictions.

Keywords: Unconventional monetary policy, high-frequency identification, structural vector autoregressive models, external instruments, effective lower bound

JEL Classification: E31, E32, E44, E52

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1 Introduction

In the face of the effective lower bound (ELB) of the short-term rates, the central banks have attempted to affect expectations of the future path of interest rates through forward guidance. The effectiveness of such unconventional monetary policy, however, remains to be empirically investigated. Among the advanced economies, Japan has long been constrained by the ELB, for the two decades since 1999. It would be insightful to take advantage of this unique experience and empirically investigate the effect of monetary policy in Japan with an emphasis on the channels of affecting expectations.

In this paper, we identify monetary policy shocks in a vector autoregressive (VAR) model by using external instruments and evaluate the effectiveness of monetary policy in Japan for the period between 1990 and 2020. We use as external instruments an extended series of monetary policy surprises from Kubota and Shintani (2022), which reflect changes in the expectations of the market participants on monetary policy up to one-year horizons.[1] Our sample covers the entire period of the ELB regime, along with a sufficient number of observations from the period of the non-ELB regime. For this reason, we further investigate how the effectiveness of monetary policy changes when the economy is constrained by the ELB by taking into consideration shifts in the interest rate dynamics.

Our main estimation results, which are obtained by using the market-based measure of monetary policy surprises as external instruments, show that monetary policy has

[1]The method of identifying the structural shocks in a VAR model using the external instrument has been developed by Stock and Watson (2012), Mertens and Ravn (2013), Gertler and Karadi (2015), and Stock and Watson (2018), among others.

significant effects on both the output and the price level in Japan. In addition, the decline in credit spreads in response to an expansionary monetary policy shock supports the credit channel, which is in line with the finding in Gertler and Karadi (2015) for the US. In contrast, when we employ the standard identification scheme using the Cholesky decomposition, we obtain much weaker responses for the output and the price level, as well as puzzling responses for the financial variables.

When we allow the shifts in interest rate dynamics, we find that the effects of monetary policy under the ELB regime are more persistent than those under the non-ELB regime. To explain our finding, we utilize a simple New Keynesian model with the ELB constraint. In line with Reifschneider and Williams (2000) and Katagiri (2016), our model incorporates the forward guidance rule to capture the situation where monetary policy affects not only the current level of the interest rate but also the expectations on its future path. The model of forward guidance predicts that the effects of monetary policy become more persistent under the ELB regime.

Our paper is closely related to recent studies that employ external instruments in the VAR framework in the evaluation of unconventional monetary policies. Gertler and Karadi (2015) point out that one benefit of using monetary policy surprises as instruments is that they can capture the effect of forward guidance, in addition to the effect of conventional monetary policy. In particular, these authors demonstrate the importance of forward guidance in the US by using policy surprises in futures rates with different maturities. In a similar vein, Lakdawala (2019) employs the target and path factors of Gürkaynak et al. (2005) as external instruments to estimate the effect of forward guidance. Furthermore, Altavilla et al. (2019) and Kim et al. (2020) focus on the effect of the asset purchases in the Euro area and the US, respectively, and employ the QE factor of Swanson (2021) as the external instruments.

In earlier VAR studies on conventional monetary policy in Japan, the short-term rate has been often employed as the main policy variable, including Miyao (2000, 2002), who use the standard Cholesky decomposition, and Braun and Shioji (2006), who use the sign restriction to identify monetary policy shocks. For the later studies on the ELB period, Honda et al. (2013) use the BOJ's current account balances, and Iwasaki and Sudo (2017) use the shadow rates in the VAR model to identify the monetary policy shocks. Using market-based surprises, Nakashima et al. (2019) identify the multiple types of unconventional monetary policy shocks, and Nakamura et al. (2021) evaluate the effects of monetary policy shocks on employment. Nagao et al. (2021) adopt heteroskedasticity-based identification of monetary policy shocks employed by Bu et al. (2021). Identification of unconventional monetary policy shocks in nonlinear VAR models has also been conducted in several papers, which include Kimura and Nakajima (2016) and Hayashi and Koeda (2019), who use the regime-switching VAR model; Miyao and Okimoto (2020), who use the smooth transition VAR model; and Ikeda et al. (2022), who use a censored and kinked VAR model. Unlike these studies based on sophisticated nonlinear models, this paper takes into account the regime shift in some parameters in a simple linear VAR framework.

The remainder of the paper proceeds as follows. In Section 2, we first examine the overall effectiveness of monetary policy on the aggregate economy using the VAR model.

We then employ the specification that allows for the shift in the interest rate dynamics in the ELB regime. In Section 3, we use a simple New Keynesian model incorporating the ELB and forward guidance to investigate the mechanism behind the estimation result. Concluding remarks are made in Section 4.

2 Empirical Analysis

2.1 Methodology

In this section, we identify monetary policy shocks using the external instruments and evaluate the dynamic responses of aggregate variables in the VAR model. While Gertler and Karadi (2015) employ the original series of monetary policy surprises in federal fund futures rates as the external instrument, we also consider the factors as candidates for the instruments, as in the analysis of Lakdawala (2019). By using either the original surprise series or factors as external instruments, we can extract the monthly monetary policy shocks from the error term of the interest rate equation in the reduced-form VAR model. Unlike the identification using Cholesky decomposition, the external instruments approach does not need to impose a recursive structure of structural shocks.

First, we briefly review how the external instruments method can be applied in identifying the monetary policy shock. A valid scalar instrument Z_t to monetary policy shocks ε_t^p in an n-dimensional VAR model must satisfy both the relevance and the exogeneity:

$$\mathrm{E}\left[Z_t \varepsilon_t^p\right] = \phi, \quad \mathrm{E}\left[Z_t \boldsymbol{\varepsilon}_t^q\right] = 0$$

where $\boldsymbol{\varepsilon}_t^q$ denotes an $(n-1)\times 1$ vector of other structural shocks and $\phi \neq 0$. For the instrument, Gertler and Karadi (2015) use the high-frequency monetary policy surprise, which denotes a change in futures rates within a thirty-minute window around the monetary policy announcements. Since such a surprise measure is expected to reflect the revisions of the market's expectations attributable only to the announcements, the above conditions are presumably satisfied.

The identification with the external instrument proceeds as follows. Let u_t^p denote the reduced-form shock to the policy indicator and $\boldsymbol{u}_t^q$ denote an $(n-1)\times 1$ vector of the reduced-form shocks to the other variables. The relationship between the reduced-form shock in the VAR model and the structural shocks are given by

$$\begin{pmatrix} u_t^p \\ \boldsymbol{u}_t^q \end{pmatrix} = \begin{pmatrix} s^p & \boldsymbol{s}_{12} \\ \boldsymbol{s}^q & \boldsymbol{s}_{22} \end{pmatrix} \begin{pmatrix} \varepsilon_t^p \\ \boldsymbol{\varepsilon}_t^q \end{pmatrix}. \tag{1}$$

Since s^p and $\boldsymbol{s}^q$ represent the contemporaneous effects of monetary policy shocks ε_t^p on the reduced-form shock u_t^p and $\boldsymbol{u}_t^q$, monetary policy shocks can be identified by obtaining s^p and $\boldsymbol{s}^q$. From (1), we obtain the following expression.

$$u_t^p = s^p \varepsilon_t^p + \boldsymbol{s}_{12}\boldsymbol{\varepsilon}_t^q \tag{2}$$

$$\boldsymbol{u}_t^q = \frac{\boldsymbol{s}^q}{s^p} u_t^p + \left(\boldsymbol{s}_{22} - \frac{\boldsymbol{s}^q}{s^p}\boldsymbol{s}_{12}\right)\boldsymbol{\varepsilon}_t^q \tag{3}$$

We cannot directly estimate $\boldsymbol{s}^q/s^p$ in (3) by running a regression of $\boldsymbol{u}_t^q$ on u_t^p because (2) implies that the regressor u_t^p is correlated with the error term $(\boldsymbol{s}_{22} - (\boldsymbol{s}^q/s^p)\boldsymbol{s}_{12})\boldsymbol{\varepsilon}_t^q$. If

Z_t is available, we can isolate monetary policy shocks ε_t^p from the reduced-form shock u_t^p and estimate $\boldsymbol{s}^q/s^p$. Since the reduced-form shocks u_t^p and $\boldsymbol{u}_t^q$ are unobservable, we use the reduced-form VAR residuals and the instrument Z_t to run an instrumental variable regression. Finally, using the estimated value of $\boldsymbol{s}^q/s^p$ and the sample covariance matrix of the reduced-form residuals, we obtain the estimates of $\boldsymbol{s}^q$ and s^p.[2]

2.2 Data

We estimate the VAR model of order twelve as in Gertler and Karadi (2015), using the sample period from January 1990 to January 2020. Our sample covers the whole period of unconventional monetary policies that have been adopted by the Bank of Japan over two decades. The model includes five monthly variables: (i) the industrial production (IP); (ii) the consumer price index (CPI, tax-adjusted); (iii) the one-year Japanese government bond (JGB) yield; (iv) the stock price index; and (v) the credit spread. To incorporate the credit channel considered by Gertler and Karadi (2015), we include the credit spread based on the difference between the medium-term corporate bond yield and the five-year JGB yield. We also include the stock price following Miyao (2002) and other VAR studies in Japan.[3]

[Table 1 about here.]

Our instruments are based on monetary policy surprises measured with the three-month Euroyen futures (EYF) rates with maturities of three, six, nine, and twelve months.

[2] For the derivation in detail, see Gertler and Karadi (2015).

[3] The corporate bond yield is approximated using the Nikkei Bond Index (medium term with maturities of 3 to 7 years), which is the yield index for public and corporate bonds with the majority being corporate bonds. For the stock price index, we use the Tokyo Stock Price Index (TOPIX). We also take monthly averages for the interest rates, the stock price index, and the corporate bond yield.

In essence, EYF rates reflect the current expectation on the three-month interest rate up to one-year horizons. For the period starting in October 1999, we use the high-frequency surprises constructed by Kubota and Shintani (2022), which are measured around every Monetary Policy Meeting (MPM) by the Bank of Japan. Since high-frequency data of the EYF rates are not available before October 1999, we extend the series by using daily surprises. In particular, for the period from 1998 to September 1999, we measure the daily surprises around the MPM dates. As the MPMs were not held until 1997, we measure the daily surprises based on the policy change dates specified in Honda and Kuroki (2006) for the period from 1992 to 1997. Table 1 summarizes the number of events in each subsample.

We consider multiple candidates for the instruments from monetary policy surprises in Japan. First, we consider using only the three-month ahead EYF surprises (EYF3 surprises). Gertler and Karadi (2015) also employ the original series of monetary policy surprises in federal fund futures rates as the instrument. Second, we also consider the target and path factors of the EYF surprises, as in Kubota and Shintani (2022). These factors summarize the information contained in surprise series from futures rates with different maturities, and thus the factors reflect both the shorter-term and longer-term expectations. This approach is similar to that of Lakdawala (2019), who identifies monetary policy shocks by concurrently using the target and path factors of Gürkaynak et al. (2005).

[Table 2 about here.]

Stock et al. (2002) suggest the possibility of weak instruments when the F-statistic in the first-stage regression is below 10. To check the strength of the instruments, the results of the first-stage regressions for all candidate instruments, including the robust F-statistics, are reported in Table 2.[4] Each column represents the results for a particular choice of the instrument set. Reported F-statistics are above 10 in the case of the EYF3 surprise and the case of the target factor, but are below 10 in the case of the path factor and the case of both the target and path factors. Therefore, we conclude that both EYF3 surprises and the target factor are strong instruments. It should be noted, however, that the target factor summarizes expectations up to one-year horizons, and thus contains information on the expectations on longer horizons compared to the EYF3 surprise. For this reason, meanwhile, we proceed with the analysis by using the target factor as the external instrument.

2.3 Baseline Estimates

Figure 1 shows the impulse response of each variable to an expansionary monetary policy shock identified by using the target factor as the instrument. The policy shock is normalized to induce a one percentage point decline in the one-year rate on impact. For each response, 68 percent and 90 percent confidence bands are indicated with the darker and lighter shaded areas, respectively. We compute the confidence bands using the asymptotic formula of Montiel Olea et al. (2021), along with a HAC covariance matrix estimator.

[Figure 1 about here.]

[4] We convert all the surprise measures into the monthly frequency using the method explained in Gertler and Karadi (2015, footnote 11). Accordingly, our instrument set spans the time period from July 1992 through January 2020.

On the whole, our impulse responses identified by using external instruments are consistent with predictions from standard macroeconomic theory. First, we observe that both the IP and the CPI significantly increase in response to a monetary policy shock that induces a one percent decline in the one-year rate. The rise in the IP reaches a 4 percent within a year, and then reverts to the original level. The response of the CPI is persistent; it increases by 0.6 percent after one year and gradually reverts to the original level. Second, the two financial market variables also significantly respond to a monetary policy shock. The stock price rises by more than 30 percent, and the credit spread gradually decreases by nearly 30 basis points after a year. Our results imply that monetary policy has been effective over the last three decades in Japan. In addition, the negative response of the credit spread presents evidence of the credit channel in Japan, as discussed by Gertler and Karadi (2015) for the US.

[Figure 2 about here.]

For comparison, we also report the impulse responses computed using the Cholesky decomposition in Figure 2.[5] Unlike the external instrument approach, the traditional identification using the Cholesky decomposition exhibits puzzling responses for some variables. In particular, the two financial variables initially respond in the direction inconsistent with the theory: the stock price declines and the credit spread increases. These anomalies with the Cholesky decomposition are also observed in the US by Gertler and Karadi (2015), who argue that imposing zero restrictions on the impact matrix fails to capture the simultaneous relationship between the monetary policy and the financial

[5]The variables are ordered as the IP, the CPI, the one-year rate, the stock price, and the credit spread.

variables. We also observe that the responses of the IP and CPI are not statistically significant, which can be a consequence of the identifying assumption.

2.4 The ELB Regime and the Non-ELB Regime

We now investigate whether the dynamic pattern of monetary policy transmissions changes due to the ELB. For example, Ikeda et al. (2022) employ the censored and kinked VAR model to incorporate the change in the dynamics of the interest rate when the economy hits the ELB. In a similar spirit, we adopt a simple extension of our baseline VAR model to allow for a structural change in the dynamics of the interest rate equation. Specifically, the interest rate equation in the reduced-form VAR model is now replaced by:

$$r_t = \sum_{j=1}^{12} \left(\alpha_j + \beta_j \mathbb{1}_{\{r_t \leq \overline{r}\}}\right)' X_{t-j} + u_{r,t}, \tag{4}$$

where r_t denotes an interest rate; X_t denotes a 5×1 vector of the variables in the VAR model; $\mathbb{1}_{\{r_t \leq \overline{r}\}}$ is an indicator function, which takes value one if $r_t \leq \overline{r}$ holds (the ELB regime); $\overline{r}$ denotes the threshold between the two regimes; α_j's and $(\alpha_j + \beta_j)$'s represent the 5×1 vectors of coefficients under the non-ELB and ELB regimes, respectively; and $u_{r,t}$ denotes the error term. Instead of estimating the threshold, we simply set $\overline{r}$ at 0.05 percent. With this choice of the threshold value, our classification of the non-ELB and ELB regimes is shown in Figure 3. In particular, we have four ELB episodes: May 2001 to July 2001, September 2001 to September 2005, March 2013, and September 2014 to the January 2020. We note that the Bank of Japan has implemented the unconventional monetary policies throughout these periods.

[Figure 3 about here.]

To incorporate unconventional monetary policies by the Bank of Japan in the ELB regimes, we employ an alternative instrument in this analysis, which we refer to as the combined factor. As discussed in Section 2.2, the target and path factors reflect surprises on the market expectation on shorter and longer horizons, respectively. The fact that the central bank tends to affect longer horizon expectations through forward guidance in the ELB regime motivates us to regard the target and path factors as the main measurement of policy surprises for the non-ELB and ELB regimes, respectively. Since the central bank tends to affect longer horizon expectations through forward guidance in the ELB regime, it seems more natural to use the path factor as the main measurement of policy surprises for the ELB regime, while keeping the target factor as the instrument for the non-ELB regime. For this reason, we define the combined factor by $Z_t = \mathbb{1}_{\{r_t \leq \bar{r}\}} Z_{\text{Target},t} + (1 - \mathbb{1}_{\{r_t \leq \bar{r}\}}) Z_{\text{Path},t}$, where $Z_{\text{Target},t}$ and $Z_{\text{Path},t}$ denote the target and path factors, respectively.

The result of the first-stage regression of the VAR residual $\widetilde{u}_{r,t}$ in the interest rate equation (4) on the combined factor is given by

$$\widehat{\widetilde{u}}_{r,t} = \underset{(0.004)}{0.002} + \underset{(0.309)}{1.068} \; Z_t$$

$$F\text{-statistic: } 11.95; \quad \text{Adjusted } R^2\text{: } 0.102,$$

where $\widehat{\widetilde{u}}_{r,t}$ is the fitted value, and the numbers in parentheses are heteroskedasticity-robust standard errors. Since the robust F-statistic is 11.95, the possibility of weak instruments can be ruled out.

[Figure 4 about here.]

The estimated impulse responses to an expansionary monetary policy shock in the two regimes are reported in Figure 4. The solid and dashed lines correspond to the impulse responses under the non-ELB and ELB regimes, respectively. Overall, the shapes of responses in the ELB regime and those in the non-ELB regime are similar to each other in terms of the direction of the response. However, a closer comparison suggests some difference between the two regarding the persistence of a monetary policy shock. In particular, we observe that the effects under the ELB regime seem stronger for longer horizons in comparison to the non-ELB regime. This observation implies that unconventional monetary policies operated under the ELB regime have had more persistent effects on the aggregate economy. Our findings are in line with the empirical results of Ikeda et al. (2022), who estimate the censored and kinked VAR model and find that monetary policy has had delayed effects on inflation and the output gap under the ELB regime in Japan. In the next section, we investigate whether such increased persistence in the responses of the IP, the CPI, and the interest rate under the ELB regime can be theoretically explained by a simple New Keynesian model that incorporates forward guidance.

3 A Model of Forward Guidance

To investigate the mechanism behind the persistent responses in the ELB regime, we conduct a simulation using a standard New Keynesian model and compare the responses of the economy to a monetary policy shock to those in the non-ELB regime. In addition to the ELB constraint, the model incorporates the forward guidance rule, which can generate a persistent effect of monetary policy by keeping interest rates lower for a longer period. Our formulation of forward guidance closely follows the ones proposed by Reifschneider and Williams (2000) and Katagiri (2016).[6] The remaining parts of the model follow a canonical New Keynesian model, which consists of a representative household, firms, and a central bank.

3.1 Household

The representative household maximizes the lifetime utility by choosing the consumption level C_t and the labor supply L_t. The lifetime utility is given by

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\frac{\left(C_t - h\overline{C}_{t-1}\right)^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\omega}}{1+\omega} \right) \right],$$

where $\overline{C}_{t-1}$ denotes lagged aggregate consumption; β denotes the discount factor; σ denotes the inverse of the intertemporal elasticity of substitution of consumption; h measures the degree of consumption habit formation; and ω denotes the inverse of the Frisch

[6] Here we implicitly assume that the central bank never deviates from the commitment by the central bank through forward guidance and the agents in the economy understand there is no time-inconsistency problem. Nakata and Sunakawa (2022) show that the central bank, which would face a risk of reputational loss by deviating from the commitment, can still credibly keep the policy rate at the ELB for an extended period.

labor supply elasticity. The budget constraint is given by

$$P_t C_t + B_t = W_t L_t + R_{t-1} B_{t-1} + T_t,$$

where W_t denotes the nominal wage, B_t denotes the purchases of government bonds, R_t denotes the risk-free nominal interest rate on government bonds, P_t denotes the final goods price, T_t denotes the lump-sum transfer.

As a result of the household's optimization, the consumption Euler equation is given by

$$1 = \beta \mathbb{E}_t \left[\frac{R_t}{\pi_{t+1}} \frac{\Lambda_{t+1}}{\Lambda_t} \right], \tag{5}$$

where $\Lambda_t = \left(C_t - h\overline{C}_{t-1} \right)^{-\sigma}$. The labor supply function is given by

$$L_t^{\omega} = \frac{W_t}{P_t} \Lambda_t. \tag{6}$$

3.2 Firms

The final goods firm purchases the intermediate goods $Y_{f,t}$ ($f \in [0,1]$) and produces the final goods Y_t according to the CES technology:

$$Y_t = \left(\int_0^1 Y_{f,t}^{\frac{\varepsilon-1}{\varepsilon}} df \right)^{\frac{\varepsilon}{\varepsilon-1}},$$

where ε denotes the substitution elasticity of intermediate goods. The final goods firm maximizes its profit under perfect competition.

The intermediate goods firms $f \in [0, 1]$ produce with linear production technology:

$$Y_{f,t} = L_{f,t} \tag{7}$$

where $L_{f,t}$ denotes labor input. Under monopolistic competition, the intermediate goods firms maximize their profits by choosing the intermediate goods prices $P_{f,t}$, given the demand function. In price settings, the firms faces a Rotemberg-style price adjustment cost function:

$$\Phi\left(\pi_{f,t}\right) = \frac{\phi_p}{2}\left(\pi_{f,t} - \pi\right)^2,$$

where $\pi_{f,t} \equiv P_{f,t}/P_{f,t-1}$ and π denotes the steady-state inflation rate. As a result, at the symmetric equilibrium, the New Keynesian Phillips curve is given by

$$0 = \frac{W_t}{P_t} - \Phi'\left(\pi_t\right)\pi_t + \left(1 - \varepsilon\right)\left(1 - \Phi\left(\pi_t\right)\right) + \beta\mathbb{E}_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\frac{Y_{t+1}}{Y_t}\Phi'\left(\pi_{t+1}\right)\pi_{t+1}\right]. \tag{8}$$

3.3 Monetary Policy

Monetary policy is governed by the Taylor rule combined with the ELB constraint and forward guidance. Without forward guidance, the nominal interest rate R_t corresponds to the notional rate when the latter is larger than the ELB. In the model with forward guidance, the notional rate becomes lower than the rate predicted by the Taylor rule. In particular, following Reifschneider and Williams (2000) and Katagiri (2016), we introduce the forward guidance term γ_t so that the central bank commits to keep the notional rate lower than the rate suggested by the Taylor rule as long as γ_t is nonzero.

Typically, the notional interest rate follows

$$R_t^* = \left(R_{t-1}^*\right)^{\rho_R} \left(R \left(\frac{\pi_t}{\pi}\right)^{\psi_\pi} \left(\frac{Y_t}{Y_{t-1}}\right)^{\psi_Y} \right)^{1-\rho_r} e^{\varepsilon_{R,t}}, \tag{9}$$

where ρ_R, ψ_π, ψ_Y, and $\varepsilon_{R,t}$ denote the degree of interest rate smoothing, sensitivity to inflation, sensitivity to the output growth, and a monetary policy shock, respectively. This specification is in line with Gust et al. (2017), Plante et al. (2018), and Iiboshi et al. (2022), where the nominal interest rate is observed as $R_t = \max\{R_t^*, 1\}$ in the face of ELB.

With forward guidance, the notional interest rate becomes lower by the amount γ_{t-1} so that the nominal interest rate is given by

$$R_t = \max\{R_t^* - \gamma_{t-1}, 1\}, \tag{10}$$

where $R_t^* - \gamma_{t-1}$ can be viewed as the new notional interest rate adjusted by the forward guidance. The forward guidance term follows a nonlinear process:

$$\gamma_t = \begin{cases} \gamma_{t-1} + \zeta\left(1 - R_t^*\right) & \text{if } R_t^* < 1; \text{ and} \\ \gamma_{t-1} - \left(R_t^* - R_t\right) & \text{otherwise,} \end{cases} \tag{11}$$

where the coefficient $\zeta(> 0)$ determines the degree of forward guidance. The forward guidance term γ_t is always zero as long as the economy does not hit the ELB but becomes positive once the ELB binds. Once the economy hits the ELB, the forward guidance term γ_t accumulates as long as $R_t^* < 1$ holds. As R_t^* reverts to its steady state $R(> 1)$ and becomes greater than one, γ_t begin to decrease but positive γ_t keeps the (forward-guidance-adjusted) notional rate $R_t^* - \gamma_{t-1}$ lower than R_t^*, which is implied by the Taylor rule. Finally, γ_t becomes zero once the ELB constraint is not binding.

3.4 Closing the Model

The aggregate resource constraint of this economy is given by:

$$Y_t = C_t + \Phi(\pi_t) Y_t. \tag{12}$$

The model dynamics is described by (5), (6), (7), (8), (9), (10), (11), and (12).

3.5 Simulation Results

To compute the impulse responses to a monetary policy shock in this model, we log-linearize the model equations, except for the two occasionally binding constraints: the ELB constraint (10) and the forward guidance rule (11). The OccBin algorithm developed by Guerrieri and Iacoviello (2015) is employed to obtain the piecewise linear solution of a perfect foresight equilibrium. The parameter values used in the simulation are summarized in Table 3, which closely follow the prior means in Iiboshi et al. (2022), except for the forward guidance coefficient ζ. We set ζ at 0.9, based on the Japanese estimate obtained by Katagiri (2016). Under this parameterization, the steady-state nominal interest rate $R = \pi/\beta$ is 0.38 percent at a quarterly rate. Here, the adjustment cost parameter ϕ_p is reparameterized in terms of the slope of the Phillips curve given by $\kappa = (\varepsilon - 1)(\omega + \sigma/(1 - h))/(\pi\phi_p)$.

[Table 3 about here.]

We compute the impulse responses to an expansionary monetary policy shock based on the piecewise-linear solution when the ELB is not binding in the initial period. In Figure 5, the solid lines and the dashed lines represent the responses of five selected variables in the non-ELB regime and the ELB regime, respectively. Five variables are (i) the output; (ii) the price level; (iii) the one-year nominal rate; (iv) the (forward-guidance-adjusted) notional rate; and (v) the forward guidance term. We calculate the response of the one-year rate by the average expectations on the short-term nominal rates for a one-year horizon. The unit of the vertical axes for the output and the forward guidance term is a percentage deviation from their steady state levels, that for the price level is a percentage deviation from its original level, and that for the one-year rate and the notional rate is a percentage point deviation. The size of the policy shock is chosen so that the one-year rate will decrease by one percentage point in the non-ELB regime, which turns out to be large enough for the short term interest rate to hit the ELB for a few initial periods.

[Figure 5 about here.]

Two features stand out in this simulation exercise. First, because of forward guidance, the one-year rate exhibits more persistent movement under the ELB regime compared to the non-ELB regime. Under the ELB regime, the forward-guidance-adjusted notional interest rate hits the ELB so that the forward guidance term remains positive for several periods. The positive forward guidance terms reduce the forward-guidance-adjusted notional rate more than the notional rate under non-ELB regime. As a result, under the ELB regime, it takes more time for the notional rate to cross the ELB level (the horizontal dotted line) and to revert to its steady state. For this reason, the reduction of the one-year rate persists more under the ELB regime. The model well describes how the central bank commits to keeping the short-term rate lower for an extended period through forward guidance.

Second, the lower-for-longer policy through forward guidance implies the lagged effects on the economy under the ELB regime. Reflecting the persistent response of the interest rate, the output exhibits a more delayed response. Regarding the response of the price level, the model predicts a permanent effect under both regimes. However, a price increase lasts for a longer time under the ELB regime than the non-ELB regime, reflecting more persistent movements in the interest rate. This outcome suggests that a positive response of the inflation rate is more persistent in the ELB regime, and it takes more time for the inflation rate to return to its steady state.

Clearly, these two features are consistent with the shape of estimated impulse responses identified through the use of external instruments in Section 2.4. Our theoretical model suggests that the observed persistence in the responses of the economy during the

ELB periods can be explained by the persistent nature of forward guidance.

4 Conclusion

We estimate the macroeconomic effects of monetary policy in Japan and investigate how its effects change because of the ELB. To this end, we follow Gertler and Karadi (2015) and use the monetary policy surprise for Japan based on Kubota and Shintani (2022) as an external instrument to identify monetary policy shocks in the VAR framework. Our estimation results imply the following two points. First, over the last three decades, monetary policy shocks had significant effects on the aggregate economy in Japan. The effects on the financial variables imply that the credit channel is present in Japan as in the case of the US. In addition, the use of the external instrument resolves the puzzling responses identified through the Cholesky decomposition. Second, in the analysis where we take into account a shift in the interest rate dynamics caused by the ELB, we find that the monetary policy under the ELB regime has more persistent effects on the aggregate economy.

To explain the latter result, we further conduct a simulation exercise using a New Keynesian model incorporating the ELB and forward guidance. We show that the model with forward guidance along the line of Reifschneider and Williams (2000) and Katagiri (2016) can describe the persistent movement of the interest rates. Our simulation exercise implies that the effect of monetary policy on the interest rate, output, and prices tends to be more persistent in the ELB regime through forward guidance, which is consistent with the empirical result in our VAR analysis.

There are several directions in which this study could be extended. To investigate the monetary policy effect on longer-horizon expectations, it is possible to make use of the longer-term interest rate futures data, such as the ten-year JGB futures. However, the event study analysis by Kubota and Shintani (2022) suggests that the long-term interest rate futures surprises are affected by the information effect. Thus, further analysis should be conducted by taking into account the presence of information effects using approaches introduced by Jarociński and Karadi (2020) and Miranda-Agrippino and Ricco (2021), among others. Another line of extension would be to apply the natural language processing technology to monetary policy announcements, news articles, and other types of text information to identify the policy shocks as adopted by Handlan (2022) and Aruoba and Drechsel (2023). These extensions remain for future work.

References

Altavilla, C., L. Brugnolini, R. S. Gürkaynak, R. Motto, and G. Ragusa (2019). Measuring Euro Area Monetary Policy. *Journal of Monetary Economics 108*, 162–179.

Aruoba, S. B. and T. Drechsel (2023). Identifying Monetary Policy Shocks: A Natural Language Approach. *Working Paper*.

Braun, R. A. and E. Shioji (2006). Monetary Policy and the Term Structure of Interest Rates in Japan. *Journal of Money, Credit, and Banking 38*(1), 141–162.

Bu, C., J. Rogers, and W. Wu (2021). A Unified Measure of Fed Monetary Policy Shocks. *Journal of Monetary Economics 118*, 331–349.

Gertler, M. and P. Karadi (2015). Monetary Policy Surprises, Credit Costs, and Economic Activity. *American Economic Journal: Macroeconomics 7*(1), 44–76.

Guerrieri, L. and M. Iacoviello (2015). OccBin: A Toolkit for Solving Dynamic Models with Occasionally Binding Constraints Easily. *Journal of Monetary Economics 70*, 22–38.

Gürkaynak, R. S., B. Sack, and E. T. Swanson (2005). Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements. *International Journal of Central Banking 1*(1), 55–93.

Gust, C., E. Herbst, D. López-Salido, and M. E. Smith (2017). The Empirical Implications of the Interest-Rate Lower Bound. *American Economic Review 107*(7), 1971–2006.

Handlan, A. (2022). Text Shocks and Monetary Surprises: Text Analysis of FOMC Statements with Machine Learning. *Working Paper*.

Hayashi, F. and J. Koeda (2019). Exiting from Quantitative Easing. *Quantitative Economics 10*(3), 1069–1107.

Honda, Y. and Y. Kuroki (2006). Financial and Capital Markets' Responses to Changes in the Central Bank's Target Interest Rate: The Case of Japan. *The Economic Journal 116*(513), 812–842.

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

Iiboshi, H., M. Shintani, and K. Ueda (2022). Estimating a Nonlinear New Keynesian Model with the Zero Lower Bound for Japan. *Journal of Money, Credit and Banking 54*(6), 1637–1671.

Ikeda, D., S. Li, S. Mavroeidis, and F. Zanetti (2022). Testing the Effectiveness of Unconventional Monetary Policy in Japan and the United States. *London School of Economics CFM Discussion Paper CFM-DP2022-18.*

Iwasaki, Y. and N. Sudo (2017). Myths and Observations on Unconventional Monetary Policy: Takeaways from Post-Bubble Japan. *Bank of Japan Discussion Paper No. 17-E-11.*

Jarociński, M. and P. Karadi (2020). Deconstructing Monetary Policy Surprises—the Role of Information Shocks. *American Economic Journal: Macroeconomics 12*(2), 1–43.

Katagiri, M. (2016). Forward Guidance as a Monetary Policy Rule. *Bank of Japan Discussion Paper No. 16-E-6*.

Kim, K., T. Laubach, and M. Wei (2020). Macroeconomic Effects of Large-Scale Asset Purchases: New Evidence. *Finance and Economics Discussion Series 2020-047*.

Kimura, T. and J. Nakajima (2016). Identifying Conventional and Unconventional Monetary Policy Shocks: A Latent Threshold Approach. *The B.E. Journal of Macroeconomics 16*(1), 277–300.

Kubota, H. and M. Shintani (2022). High-Frequency Identification of Monetary Policy Shocks in Japan. *The Japanese Economic Review 73*(3), 483–513.

Lakdawala, A. (2019). Decomposing the Effects of Monetary Policy Using an External Instruments SVAR. *Journal of Applied Econometrics 34*(6), 934–950.

Mertens, K. and M. O. Ravn (2013). The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States. *American Economic Review 103*(4), 1212–47.

Miranda-Agrippino, S. and G. Ricco (2021). The Transmission of Monetary Policy Shocks. *American Economic Journal: Macroeconomics 13*(3), 74–107.

Miyao, R. (2000). The Role of Monetary Policy in Japan: A Break in the 1990s? *Journal of the Japanese and International Economies 14*(4), 366–384.

Miyao, R. (2002). The Effects of Monetary Policy in Japan. *Journal of Money, Credit, and Banking 34*(2), 376–392.

Miyao, R. and T. Okimoto (2020). Regime Shifts in the Effects of Japan's Unconventional Monetary Policies. *The Manchester School 88*(6), 749–772.

Montiel Olea, J. L., J. H. Stock, and M. W. Watson (2021). Inference in Structural Vector Autoregressions Identified with an External Instrument. *Journal of Econometrics 225*(1), 74–87.

Nagao, R., Y. Kondo, and Y. Nakazono (2021). The Macroeconomic Effects of Monetary Policy: Evidence from Japan. *Journal of the Japanese and International Economies 61*, 101149.

Nakamura, F., N. Sudo, and Y. Sugisaki (2021). Monetary Policy Shocks and the Employment of Young, Middle-Aged, and Old Workers. *Bank of Japan IMES Discussion Paper No. 2021-E-6*.

Nakashima, K., M. Shibamoto, and K. Takahashi (2019). Identifying Quantitative and Qualitative Monetary Policy Shocks. *Kobe University Discussion Paper Series No. 2019-09*.

Nakata, T. and T. Sunakawa (2022). Credible Forward Guidance. *Bank of Japan IMES Discussion Paper No. 2022-E-6.*

Plante, M., A. W. Richter, and N. A. Throckmorton (2018). The Zero Lower Bound and Endogenous Uncertainty. *The Economic Journal 128*(611), 1730–1757.

Reifschneider, D. and J. C. Williams (2000). Three Lessons for Monetary Policy in a Low-Inflation Era. *Journal of Money, Credit and Banking 32*(4), 936–966.

Stock, J. H. and M. W. Watson (2012). Disentangling the Channels of the 2007–09 Recession. *Brookings Papers on Economic Activity 43*, 81–156.

Stock, J. H. and M. W. Watson (2018). Identification and Estimation of Dynamic Causal Effects in Macroeconomics Using External Instruments. *The Economic Journal 128*(610), 917–948.

Stock, J. H., J. H. Wright, and M. Yogo (2002). A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments. *Journal of Business & Economic Statistics 20*(4), 518–529.

Swanson, E. T. (2021). Measuring the Effects of Federal Reserve Forward Guidance and Asset Purchases on Financial Markets. *Journal of Monetary Economics 118*, 32–53.

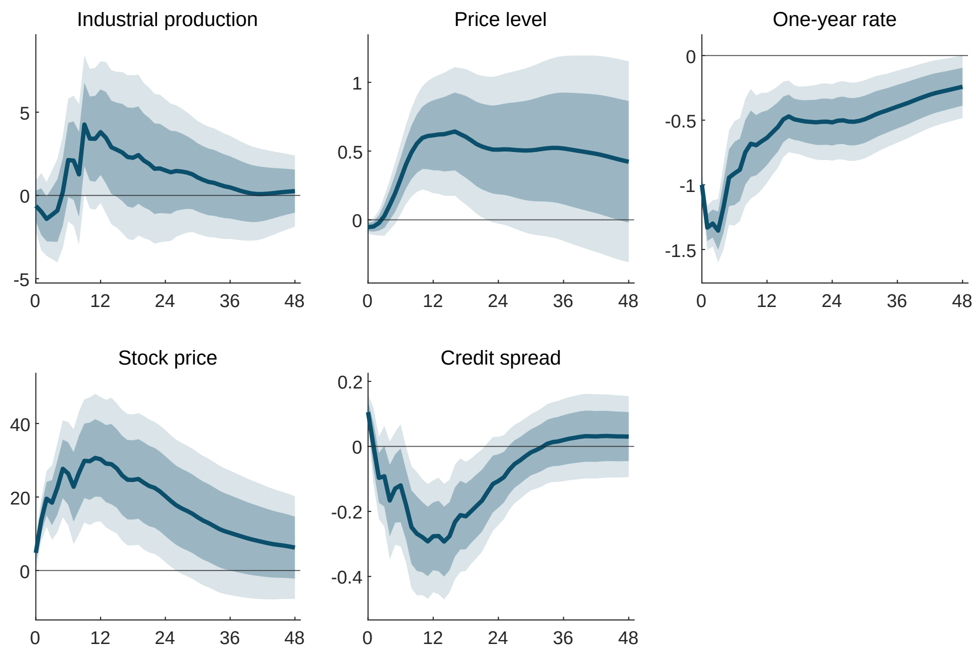

Figure 1. Responses to an Expansionary Monetary Policy Shock: External Instrument

Note: The darker and lighter shaded areas indicate the 68 percent and 90 percent confidence bands, respectively. The unit of the horizontal axes is a month.

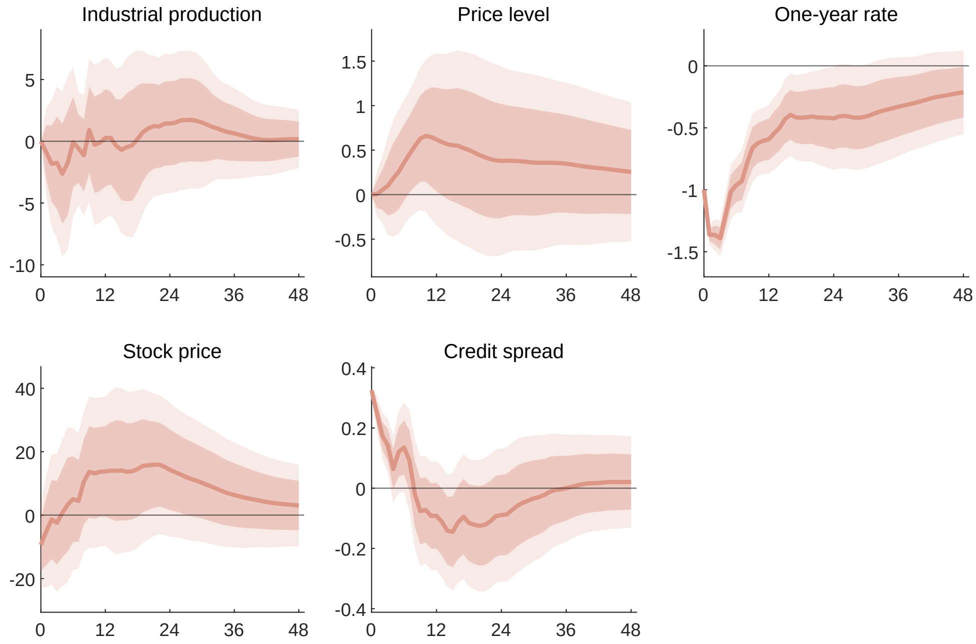

Figure 2. Responses to an Expansionary Monetary Policy Shock: Cholesky Decomposition

Note: The darker and lighter shaded areas indicate the 68 percent and 90 percent confidence bands, respectively. The unit of the horizontal axes is a month.

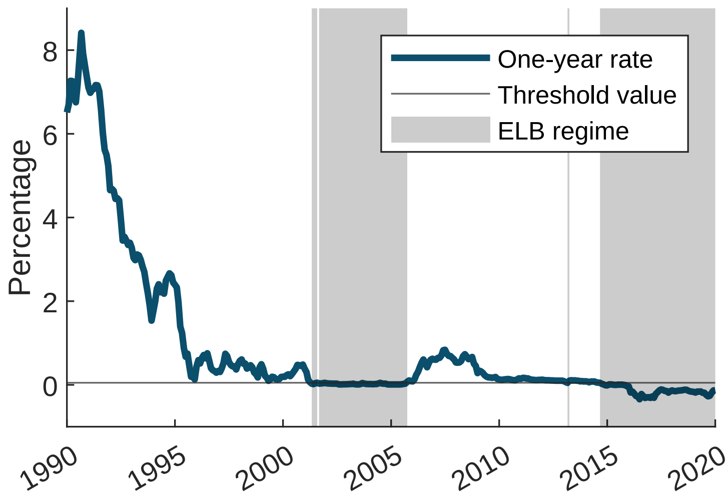

Figure 3. The One-Year Rate and the ELB Regime

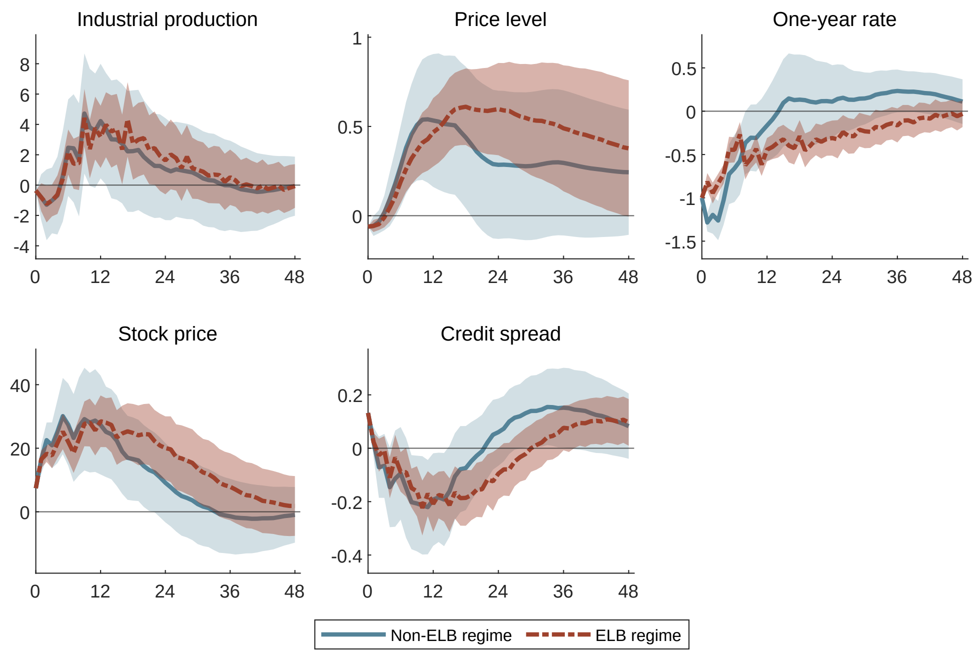

Figure 4. Responses to an Expansionary Monetary Policy Shock: Comparison of the Two Regimes

Note: The shaded areas indicate the 90 percent confidence bands. The unit of the horizontal axes is a month.

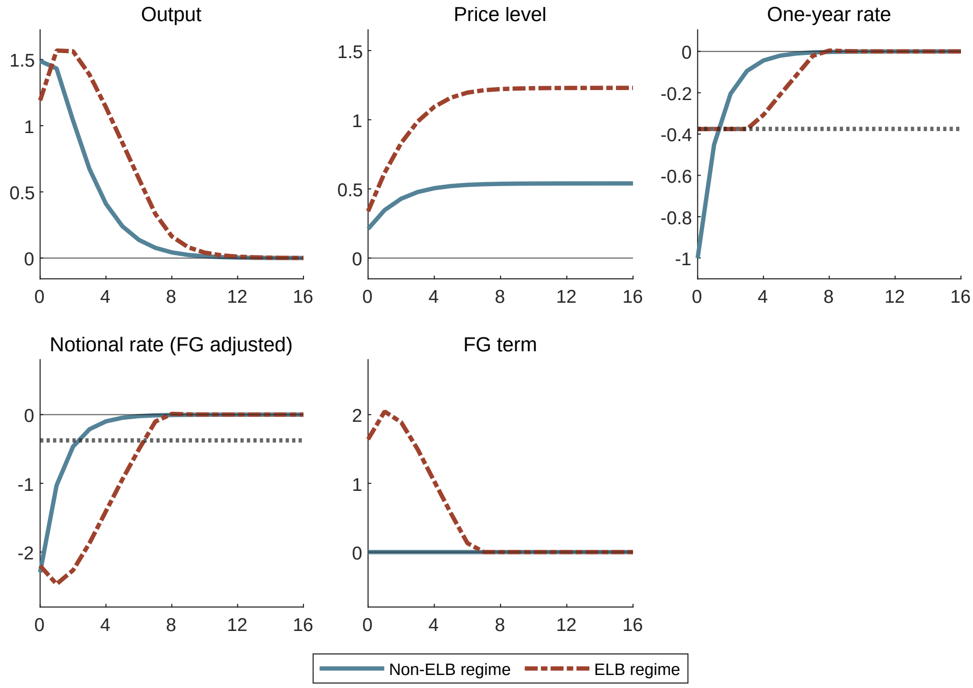

Figure 5. Responses to an Expansionary Monetary Policy Shock: Model

Note: The horizontal dotted lines in panels for the interest rates represent the ELB level. The unit of the horizontal axes is a quarter. FG stands for forward guidance.

Period		Frequency	Event	Obs
(i)	October 13, 1999 to January 21, 2020	High frequency	MPM	280
(ii)	January 16, 1998 to September 21, 1999	Daily	MPM	34
(iii)	July 3, 1992 to November 28, 1997	Daily	Policy change	29

Table 1. Monetary Policy Surprise Series in Japan

Instrument	(1)	(2)	(3)	(4)
EYF3	1.213***			
	(0.300)			
Target factor		1.234***		1.236***
		(0.318)		(0.315)
Path factor			−0.190	−0.211
			(0.491)	(0.394)
F-statistic	16.37	15.08	0.149	7.723
Adjusted R^2	0.123	0.126	−0.001	0.126

Table 2. The First-Stage Regression of VAR Residuals on Instruments

Note: Heteroskedasticity-consistent standard errors are reported in parentheses. *, **, and *** denote significance at 10 percent, 5 percent, and 1 percent, respectively. An intercept is included in regressions but the estimates are not reported.

Parameters		Value
Discount factor	β	0.99875
Substitution elasticity of intermediate goods	ε	6
Inverse of intertemporal elasticity of substitution	σ	1.5
Consumption habit	h	0.5
Inverse of labor supply elasticity	ω	3
Slope of the Phillips curve	κ	0.05
Steady-state inflation	π	1.0025
Interest rate smoothing	ρ_R	0.5
Sensitivity to inflation	ψ_π	1.8
Sensitivity to output gap	ψ_Y	0.125
Forward guidance coefficient	ζ	0.9

Table 3. Parameter Values