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Optimal Monetary Policy in a Liquidity Trap: Evaluations for Japan's Monetary Policy *

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Abstract

This paper shows that the Bank of Japan's monetary policy shares several common points with optimal monetary policy in a liquidity trap to large negative shocks by the recent pandemic. The zero interest rate policy continues even after inflation rates sufficiently exceed the 2 percent and hit the peak. Optimal monetary policy keeps the zero interest rate policy until the second quarter of 2024 and the Bank of Japan continues the zero interest rate at least until the second quarter of 2024. Recent high inflation rates can be explained by a prolonged zero interest rate policy. Average inflation rates from 2021 to 2023 years are 2.2 percent and 2.1 percent in the data and the simulation, respectively.

According to scenarios for anchored inflation expectations and long-run natural interest rates, the optimal timing to terminate the zero interest rate policy and a speed of the monetary tightening after the zero interest rate policy change. As anchored inflation expectations and natural interest rates decline, the zero interest rate policy continues longer.

JEL Classification: E31; E52; E58; E61
Keywords: liquidity trap; optimal monetary policy; inflation persistence; forward guidance

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1 Introduction

In Japan, the Bank of Japan (BOJ) virtually introduces the zero interest rate policy from September 1995 by cutting the policy rate to about 0.5 percent. During the zero interest rate policy, a policy commitment, recently so called as the forward-guidance policy, is a key for monetary policy. For example, the BOJ Governor, Masaru Hayami, announces at a press conference in April 1999 that the BOJ continues the zero interest rate policy until the deflationary concerns are dispelled to lower long-term interest rates. This is the first case of the commitment policy in a liquidity trap. Moreover, in September 2016, the BOJ introduces the inflation-overshooting commitment. Under this policy, the BOJ commits to continue the monetary easing until the year-on-year CPI inflation rate stably exceeds the 2 percent target rate. This commitment policy works as optimal monetary policy to increase an inflation rate and its expectation and to lower the real interest rate as discussed below. Now, the BOJ faces an exit policy from a liquidity trap under the commitment and we would like to evaluate whether the BOJ conducts optimal monetary policy.

In this paper, we first analytically show optimal commitment monetary policy in a liquidity trap for a hybrid new Keynesian model including inflation persistence. Then, we apply our model to Japan's monetary policy and show that optimal monetary policy replicates the BOJ's monetary policy and economy during and after the pandemic period. The BOJ's monetary policy shares several common points with optimal monetary policy in a liquidity trap. The zero interest rate policy continues even after inflation rates sufficiently exceed the 2 percent and hit a peak. The inflation rate reaches its peak in the fourth quarter of 2022 in the data and in the third quarter of 2023 in the simulation. Optimal monetary policy keeps the zero interest rate policy until the second quarter of 2024. The BOJ continues the zero interest rate policy at least until the second quarter of 2024. Recent high inflation rates can be explained by a prolonged zero interest rate policy. Average inflation rates from 2021 to 2023 years are 2.2 percent and 2.1 percent in the data and the simulation, respectively.

Our paper is not the first paper for optimal monetary policy in a liquidity trap.

Eggertsson and Woodford (2003b,a) and Jung et al. (2001, 2005) show that the optimal commitment policy is history dependent and a central bank continues a zero interest rate policy even after the natural interest rate turns positive. Adam and Billi (2006, 2007) and Nakov (2008) introduce stochastic shocks into the zero interest rate policy analyses under the optimal commitment policy as well as the discretionary policy. Werning (2011) shows that the future consumption boom as well as the future high inflation play important roles in mitigating a liquidity trap. Evans et al. (2015) show an exit strategy from a liquidity trap under optimal discretionary policy by using a purely forward-looking model and a purely backward-looking model. As an independent work for a deterministic shock, Michau (2019) shows optimal monetary and fiscal policy in a liquidity trap for a new Keynesian Phillips curve including a lagged inflation rate. He shows that a central bank terminates the zero interest rate policy earlier under a higher inflation persistence.[1] All these papers are the foundation for our paper and our contribution is to show optimal monetary policy in Japan after the last pandemic.

The remainder of the paper proceeds as follows. Section 2 presents a model of the economy with inflation persistence. Section 3 derives an optimal monetary policy in a liquidity trap. In Section 4, we show optimal monetary policy for Japan after the pandemic. Section 5 concludes.

2 The Model

We use a new Keynesian model following Woodford (2003) and Eggertsson and Woodford (2006) and skip detailed explanations for the model. The macroeconomic structure is expressed by the two equations:

$$x_t = \mathrm{E}_t x_{t+1} - \chi \left(i_t - \mathrm{E}_t \pi_{t+1} - r_t^n \right), \tag{1}$$

$$\pi_t - \gamma \pi_{t-1} = \kappa x_t + \beta \left(\mathrm{E}_t \pi_{t+1} - \gamma \pi_t \right) + \mu_t, \tag{2}$$

[1]Our companion paper Hasui et al. (2024) show that the Fed's exit policy from a liquidity trap is optimal monetary policy by using a new Keynesian model.

where χ is the intertemporal elasticity of substitution of expenditure, β is a discount factor, γ $(0 \leq \gamma \leq 1)$ is the degree of inflation persistence, and

$$\kappa = \frac{(1-\alpha)(1-\beta\alpha)}{\alpha}\frac{\omega+\chi^{-1}}{1+\omega\theta},$$

where ω is the elasticity of firm's real marginal cost and θ is an elasticity of substitution across goods. It should be noted that a slope of the Phillips curve κ depends on price stickiness α. x_t, i_t and π_t denote the output gap, the nominal interest rate (or policy rate), and the rate of inflation in period t, respectively. The expectations operator E_t covers information available in period t. r_t^n is the natural rate of interest and works as the shock. μ_t is the cost-push shock.

Equation (1) is the forward-looking IS curve as shown in Clarida et al. (1999) and Woodford (2003). The IS curve states that the current output gap is determined by the expected value of the output gap and the deviation of the current real interest rate, defined as $i_t - \mathrm{E}_t\pi_{t+1}$, from the natural interest rate.

Equation (2) is the hybrid Phillips curve. When $\gamma = 0$, the hybrid Phillips curve turns into a purely forward-looking Phillips curve, where current inflation is dependent on expected inflation and the current output gap. When $0 < \gamma \leq 1$, the Phillips curve is both forward-looking and backward-looking, and the current inflation rate depends on the lagged inflation rate, as well as the expected inflation and the current output gap. When γ is closer to 1, the coefficient on the lagged inflation rate is closer to 0.5. Following the indexation rule in Woodford (2003), some firms that cannot reoptimize their own goods prices adjust current prices based on the past inflation rate.

Next, we show the central bank's intertemporal optimization problem. The central bank sets the nominal interest rate i_t so as to minimize the approximated welfare loss $\mathcal{L}_t$ defined as

$$\mathcal{L}_t = \mathrm{E}_t \sum_{i=0}^{\infty} \beta^i \mathrm{L}_{t+i}, \tag{3}$$

where L_t is the period loss function obtained by second-order approximation of the household utility function. In an economy with inflation inertia, Woodford (2003) shows that L_t is given by

$$\mathrm{L}_t = (\pi_t - \gamma\pi_{t-1})^2 + \lambda_x x_t^2, \tag{4}$$

where $\lambda_x = \frac{\kappa}{\theta}$ is a weight for the output gap and a non-negative parameter. A central bank needs to stabilize $\pi_t - \gamma\pi_{t-1}$ in approximation rather than the inflation rate itself from the target rate when inflation exhibits persistence. In an economy with indexation on inflation rates, price dispersion comes from an environment where some firms not reoptimizing their prices follow the past inflation rate with a certain degree γ and other firms reoptimize prices. Therefore, to minimize price dispersion, a central bank needs to set the current inflation rate so as to be close to the lagged inflation rate with adjustment by γ. This is eventually consistent with the BOJ's inflation-overshooting commitment to allow inflation rates to flexibly exceed a target level of inflation rate. However, it notes that we show optimal monetary policy that maximizes the household's utility regardless of the approximation.

Finally, we give a nonnegativity constraint on the nominal interest rate:

$$i_t \geq 0. \tag{5}$$

The central bank maximizes equation (3) subject to equations (1), (2), and (5).

3 Optimal Monetary Policy in a Liquidity Trap

We follow Hasui et al. (2024) and analytically show optimal commitment monetary policy in a liquidity trap and clarify the optimal exit strategy. To analyze features of optimal monetary policy, we denote the degree of inflation persistence in the hybrid Phillips curve as γ_{pc} and that in the period loss function as γ_{loss}. This setup is just to clarify the mechanism of inflation persistence and we set $\gamma_{pc} = \gamma_{loss} = \gamma$ in the model. The optimization problem is represented by the following Lagrangian form:

$$\mathcal{L} = \mathrm{E}_t \sum_{i=0}^{\infty} \beta^i \left\{ \begin{array}{c} \left(\pi_{t+i} - \gamma_{loss}\pi_{t+i-1}\right)^2 + \lambda_x x_{t+i}^2 \\ -2\phi_{1t+i}\left[x_{t+i+1} - \chi\left(i_{t+i} - \pi_{t+i+1} - r_{t+i}^n\right) - x_{t+i}\right] \\ -2\phi_{2t+i}\left[\kappa x_{t+i} + \beta\left(\pi_{t+i+1} - \gamma_{pc}\pi_{t+i}\right) - \pi_{t+i} + \gamma_{pc}\pi_{t+i-1}\right] \end{array} \right\},$$

where ϕ_1 and ϕ_2 are the Lagrange multipliers associated with the IS constraint and the Phillips curve constraint, respectively. We differentiate the Lagrangian with respect to π_t, x_t, and i_t under the nonnegativity constraint on nominal interest rates to obtain the first-order conditions:

$$-\beta\gamma_{loss}\left(\mathrm{E}_t\pi_{t+1}-\gamma_{loss}\pi_t\right)+\pi_t-\gamma_{loss}\pi_{t-1}-\beta^{-1}\chi\phi_{1t-1}-\beta\gamma_{pc}\mathrm{E}_t\phi_{2t+1}+\left(\beta\gamma_{pc}+1\right)\phi_{2t}-\phi_{2t-1}=0, \tag{6}$$

$$\lambda_x x_t+\phi_{1t}-\beta^{-1}\phi_{1t-1}-\kappa\phi_{2t}=0, \tag{7}$$

$$i_t\phi_{1t}=0, \tag{8}$$

$$\phi_{1t}\geq 0, \tag{9}$$

$$i_t\geq 0. \tag{10}$$

Equations (8), (9), and (10) are conditions for the nonnegativity constraint on nominal interest rates. The above five conditions, together with the IS curve of equation (1) and the hybrid Phillips curve of equation (2), determine the loss minimization. The optimal interest rate is set by these conditions each period. We also need initial conditions for all variables being zero except the nominal interest rate, which takes a positive value in the steady-state. When the nonnegativity constraint is not binding, i.e., $i_t > 0$, the Lagrange multiplier ϕ_{1t} becomes zero by the Kuhn-Tucker condition in equation (8), and the interest rate is determined by the conditions given by equations (1), (2), (6), and (7) with $\phi_{1t} = 0$. When the nonnegativity constraint is binding, i.e., $i_t = 0$, the interest rate is simply set to zero. The interest rate remains zero at least until the Lagrange multiplier ϕ_{1t} becomes zero.

To obtain the path of variables under optimal monetary policy in a liquidity trap, we need numerical simulations because of the nonnegativity constraint on nominal interest rates. Equations (6) and (7) define the qualitative characteristics of optimal monetary policy in a liquidity trap and an economy with persistent inflation.

The first feature is that, due to the central bank's objective to minimize the change in inflation rates $\pi_t - \gamma\pi_{t-1}$, the optimality condition includes terms to smooth inflation rates as shown in equation (6). A strong commitment to inflation smoothing is motivated by both the expected and current changes in inflation rates. In an economy with inflation persistence, less weight is imposed on the deviation of inflation rates from a target level than in an economy without inflation persistence. Thus, agents expect more accommodative stance of the central bank against inflation and a high inflation rate accelerates along with a high expected inflation rate.

The second feature of optimal monetary policy is forward-looking terms associated with introducing inflation persistence into the model. The central bank's monetary policy is determined by the forecast of future inflation rates and the output gap. There are two channels to make optimal monetary policy forward-looking. The first channel is given by the parameter γ_{loss} on the future inflation rate in equation (6). Optimal monetary policy in a model with inflation persistence should respond to the expected inflation rate. The second channel is given by the parameter γ_{pc} in equation (6) on the Lagrange multiplier ϕ_{2t+1} that is related to the future output gap and a future zero interest rate condition. Note that the optimality condition includes the backward-looking variables, which induces history dependent policy as in the standard new Keynesian model. Theoretically, both forward-looking and backward-looking elements determine the optimal path of the nominal interest rates, including the optimal exit from a liquidity trap.

4 Optimal Monetary Policy for Japan

4.1 Calibration for Japanese Economy

For some parameters, we simply borrow these from a representative paper for a liquidity trap analysis, Eggertsson and Woodford (2003b) and Eggertsson and Woodford (2006), and set $\chi = 0.5$, $\theta = 10$, $\omega = 0.47$ as shown in Table 1. Then, we have $\kappa = 0.0079$, and $\lambda_x = 0.0008$.

For a price stickiness parameter, we use the value $\alpha = 0.875$ in Sugo and Ueda (2008). Mukoyama et al. (2021) also estimate high price stickiness as $\alpha = 0.82$. These papers imply that a price stickiness is high and it could characterize the exit policy from a liquidity trap in Japan. Inflation persistence is also high. For example, Kawamoto et al. (2021) show that a coefficient on the lagged inflation rate is 0.85 in the BOJ's economic projection model. It implies that $\gamma = 1$ is still conservative to describe inflation persistence. Sugo and Ueda (2008) estimates γ as high as 0.862. As emphasized in Bank of Japan (2024), inflation expectation itself is largely adaptive in Japan and it implies that a coefficient on the lagged inflation rate can be further larger. We assume a full indexation $\gamma = 1$ in the simulations.

Evaluating a long-run (steady-state) nominal interest rate is not an easy work since it is time-varying but fundamentally determines the monetary policy. The long-run nominal interest rate in the model is given by a sum of an anchored inflation expectation and the natural rate of interest. Osada and Nakazawa (2024) estimate the principal component-based composite index of inflation expectations for different forecast horizons and show that these expectations are about 1.5 percent at the end of 2023. Bank of Japan (2024) shows that the break-even inflation rate, which is the yield spread between fixed-rate coupon-bearing JGBs and inflation-indexed JGBs and captures inflation expectation in financial markets, is about 1.5 percent in the April 2024. Thus, we set the anchored inflation expectation at 1.5.[2]

For the natural interest rate in a long-run, Bank of Japan (2024) shows a variety of the estimates because it is difficult to specify an exact natural interest rate. The BOJ shows that the latest estimates of the natural interest rate are between about 0.5 percent and about -1 percent in 2023. Thus, we set the natural interest rate in simulations as a mid-point of -0.25 as a baseline case. Therefore, we set a nominal interest rate at

[2]Woodford (2004) shows that the model and all conditions eventually do not change when we set $\gamma = 1$ even for a non-zero inflation target due to $\pi_t - \gamma\pi_{t-1}$ terms in the model.

1.25 percent annually in the steady-state and a discount factor is given by $\beta = 0.99688$ as the baseline case. We show alternative scenarios for the natural interest rate and an anchored inflation expectation for robust analyses.

In simulations, we interpret the second quarter of 2020 as the starting point since we observe the largest negative shocks for the output gap and an inflation rate by the pandemic. The output gap is -6.3 and the inflation rate is -2.8 in the second quarter of 2020.[3] The pandemic induces a very large size, but a very short-term shock. We interpret that the BOJ focuses on the exit policy to these large negative shocks. Regarding shocks for the simulation, we give one-time negative natural rate shock and one-time negative cost-push shock without shock persistence as Eggertsson and Woodford (2003b) to match simulations to the data for an inflation rate and the output gap at the second quarter of 2020, as shown in Figure 1.[4] The simulations are deterministic and we use Dynare to run simulations.[5]

4.2 Optimal Monetary Policy for Japan

Figure 1 shows inflation rates, the output gap, and policy rates under optimal monetary policy and these Japanese data from the second quarter of 2020 to the fourth quarter of 2024. The data ends in the first quarter of 2024. We observe that the BOJ's monetary policy shares several common points with optimal monetary policy in a liquidity

[3]We use the Real Gross Domestic Product (Expenditure), Quarterly, Seasonally Adjusted Annual Rate for the output gap. We make trend series of one year moving average and calculate a gap from the trend series to real GDP. For inflation rates, we use the Consumer Price Index for all items, less fresh food, seasonally adjusted. We calculate an annual inflation rate by a growth rate from a previous period. For the BOJ's policy rate, we use the call rate, uncollateralized overnight, average, annually.

[4]We assume -18.4 percent of the natural rate shock and -1 percent of cost-push shock at a time zero as a quarterly base. In simulations, we use the inflation rate data at the first quarter of 2020 to an inflation lag in the model in a period 0. Before shocks occur, other variables are set to zero.

[5]We extend a code by Johannes Pfeifer for optimal monetary policy in a liquidity trap, JohannesPfeifer/DSGE_mod/blob/master/Gali_2015/Gali_2015_chapter_5_commitment_ZLB.mod. Our code is available upon your request.

trap. The zero interest rate policy continues after inflation rates sufficiently exceed the 2 percent. This is consistent with the inflation-overshooting commitment that allows inflation rates to stably exceed the 2 percent target. Moreover, the zero interest rate policy continues even after the peak of inflation rates. An inflation rate hits a peak in the fourth quarter of 2022 in the data and in the third quarter of 2023 in the simulation. Optimal monetary policy keeps the zero interest rate policy until the second quarter of 2024. The BOJ continues the zero interest rate at least until the second quarter of 2024. Recent high inflation rates can be explained by a prolonged zero interest rate policy. Average inflation rates from 2021 to 2023 years are 2.2 percent and 2.1 percent in the data and the simulation, respectively.

4.3 Alternative Scenarios for Natural Rates, Anchored Inflation Expectations, and Demand Elasticity

High State Economy: 2.5 Percent Nominal Interest Rate

We assume that an inflation expectation is anchored at the 2 percent target level and the natural interest rate is given by the upper bound of the estimation as 0.5 percent. In this case, the nominal interest rate in the steady-state for simulation is 2.5 percent and we set $\beta = 0.9938$.

Figure 2 shows a simulation result in the case of the 2.5 percent nominal interest rate in the steady-state.[6] A clear difference from the baseline case is two quarters earlier termination of the zero interest rate policy. A reason for it is that the monetary easing becomes stronger for the same zero interest rate policy as the nominal interest rate in a long-run becomes higher by a higher anchored inflation expectation and a higher natural interest rate, as described in equation (1). Thus, the zero interest rate policy becomes shorter for a high state economy for the anchored inflation expectation and the natural interest rate.

[6] We assume -20.4 percent of the natural rate shock and -1.08 percent of cost-push shock at a time zero as a quarterly base.

Low State Economy: 0.5 Percent Nominal Interest Rate

We assume that an inflation expectation is anchored at the 1.5 percent target level and the natural interest rate is given by the lower bound of estimation as -1 percent. In this case, the nominal interest rate in the steady-state is given 0.5 percent and we set $\beta = 0.9987$.

Figure 3 shows a simulation result in the case of the 0.5 percent nominal interest rate in a long-run.[7] A clear difference from the baseline case is one quarter later termination in the zero interest rate policy and the policy rate is about 2 percent annually in the fourth quarter of 2024.

Low Elasticity of Demand to Real Interest Rate

A response of the output gap to the real interest rate is a key parameter for optimal monetary policy in a liquidity trap. In Japan, deflation and low growth continue for a few decades under the zero interest rate policy. This is a peculiar phenomenon in Japan and one reason for it is a weak demand even under a low interest rate environment. In this section, we assume a low intertemporal elasticity of substitution of expenditure, i.e., a low elasticity of the output gap to the real interest rate. In particular, we set $\chi = 0.1$ to depict a weak output gap after the shocks in the simulation and follow the baseline case for other settings.

Figure 4 shows a simulation result.[8] Under a low elasticity of the output gap to the real interest rate, the zero interest rate policy continues beyond the fourth quarter of 2024.

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[7] We assume -17.5 percent of the natural rate shock and -1 percent of cost-push shock at a time zero as a quarterly base.

[8] We assume -73 percent of the natural rate shock and -0.92 percent of cost-push shock at a time zero as a quarterly base.

5 Concluding Remarks

After the zero interest rate policy for a few decades, the BOJ now faces the exit policy from a liquidity trap. We evaluate whether the BOJ's monetary policy is optimal monetary policy or not by using the conventional new Keynesian model.

We show that optimal monetary policy in a liquidity trap well replicates the BOJ's monetary policy and economy during and after the pandemic period. The BOJ's monetary policy shares several common points with optimal monetary policy. The zero interest rate policy continues even after inflation rates sufficiently exceed the 2 percent and hit a peak. Optimal monetary policy continues the zero interest rate policy until the second quarter of 2024. The BOJ continues the zero interest rate policy at least until the second quarter of 2024. Recent high inflation rates can be explained by a prolonged zero interest rate policy.

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Table 1: Calibration for Japan

Parameters	Values	Explanation
β	0.99688	Discount Factor
χ	0.5	Intertemporal Elasticity of Substitution of Expenditure
ω	0.47	Elasticity of Firm's Real Marginal Cost
θ	10	Elasticity of Substitution across Goods
κ	0.0079	Elasticity of Inflation to Output Gap
α	0.875	Price Stickiness
γ	1	Degree of inflation persistence
λ_x	0.0008	Weight for Output Gap
i^*	1.25	Steady-state Nominal Interest Rate (Annual)

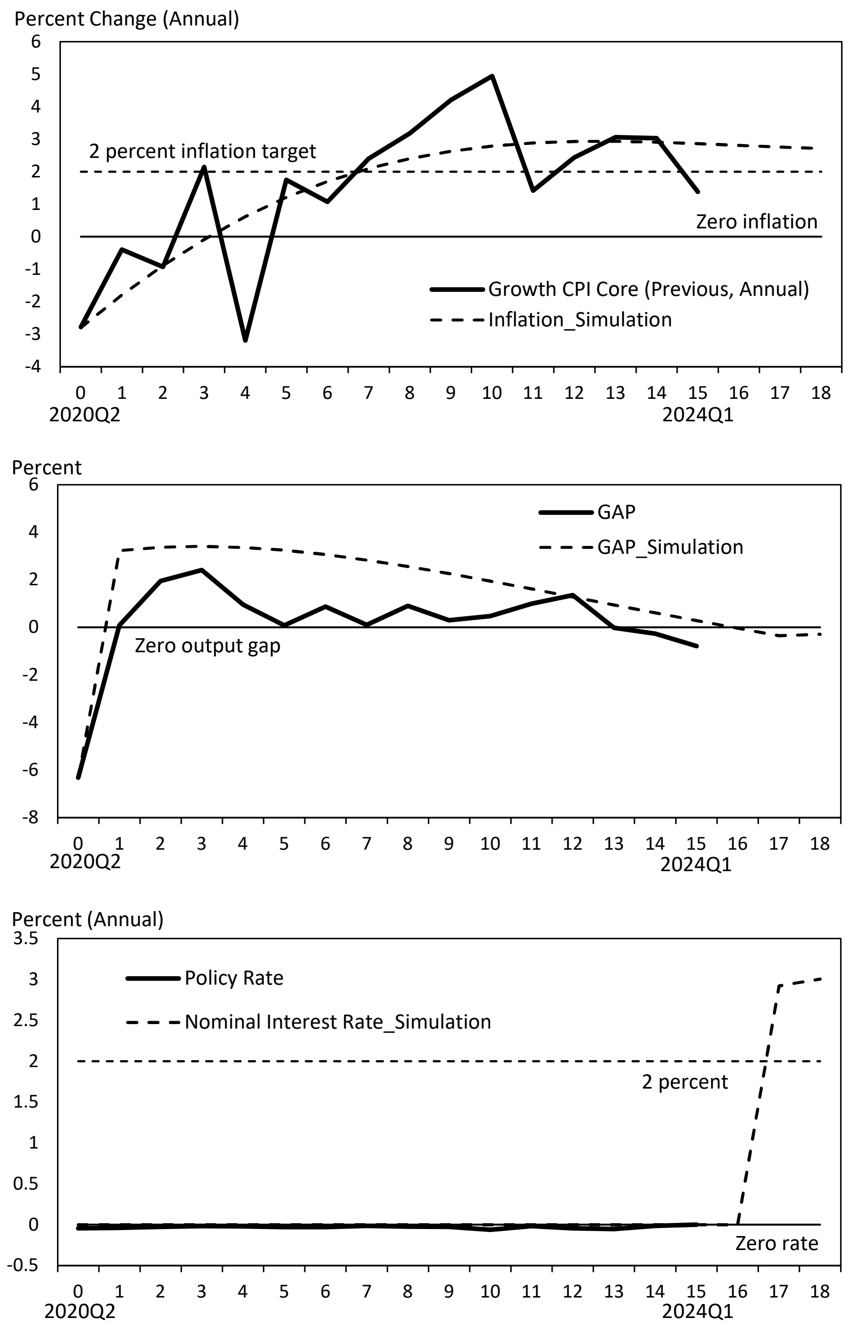

Figure 1: Simulation for Japanese Monetary Policy

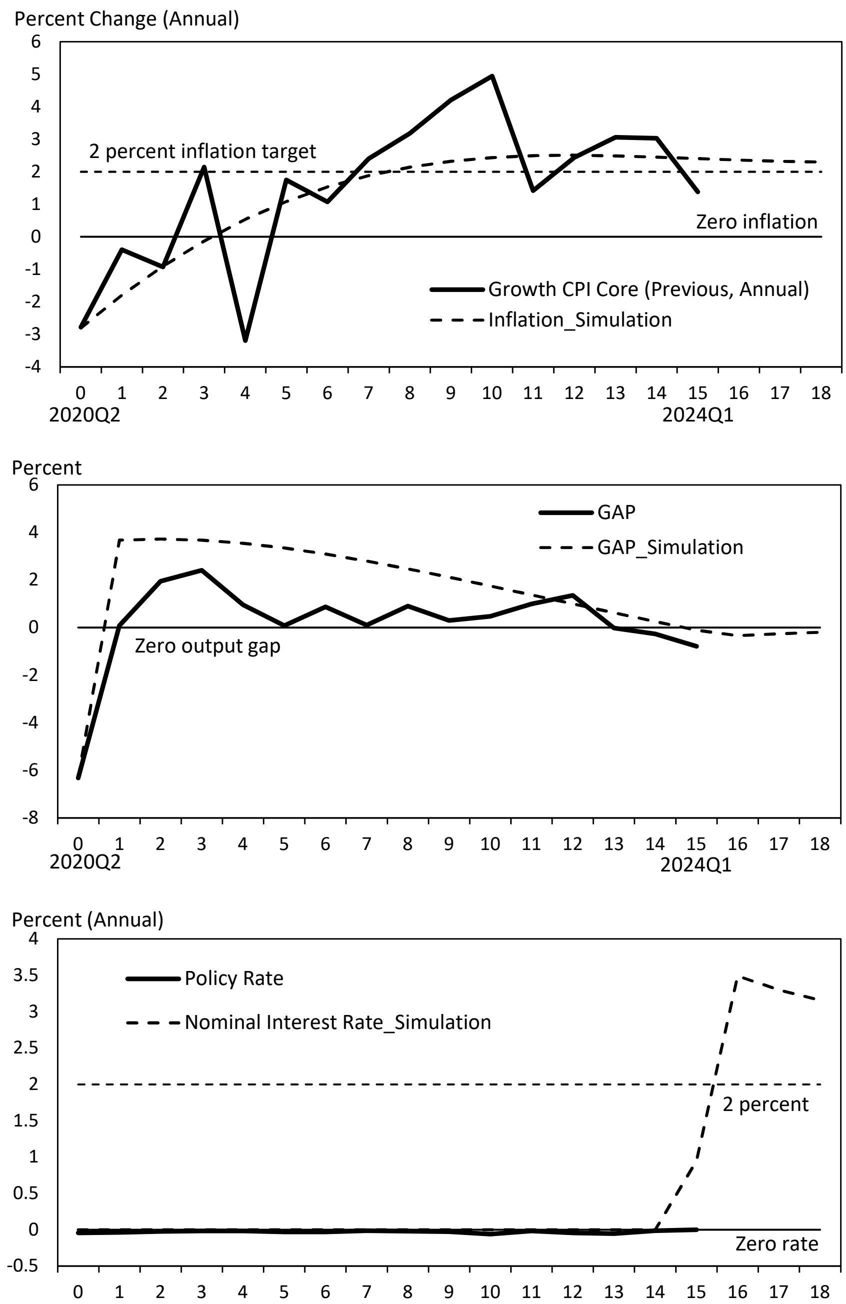

Figure 2: Simulation for Japanese Monetary Policy: High State Economy

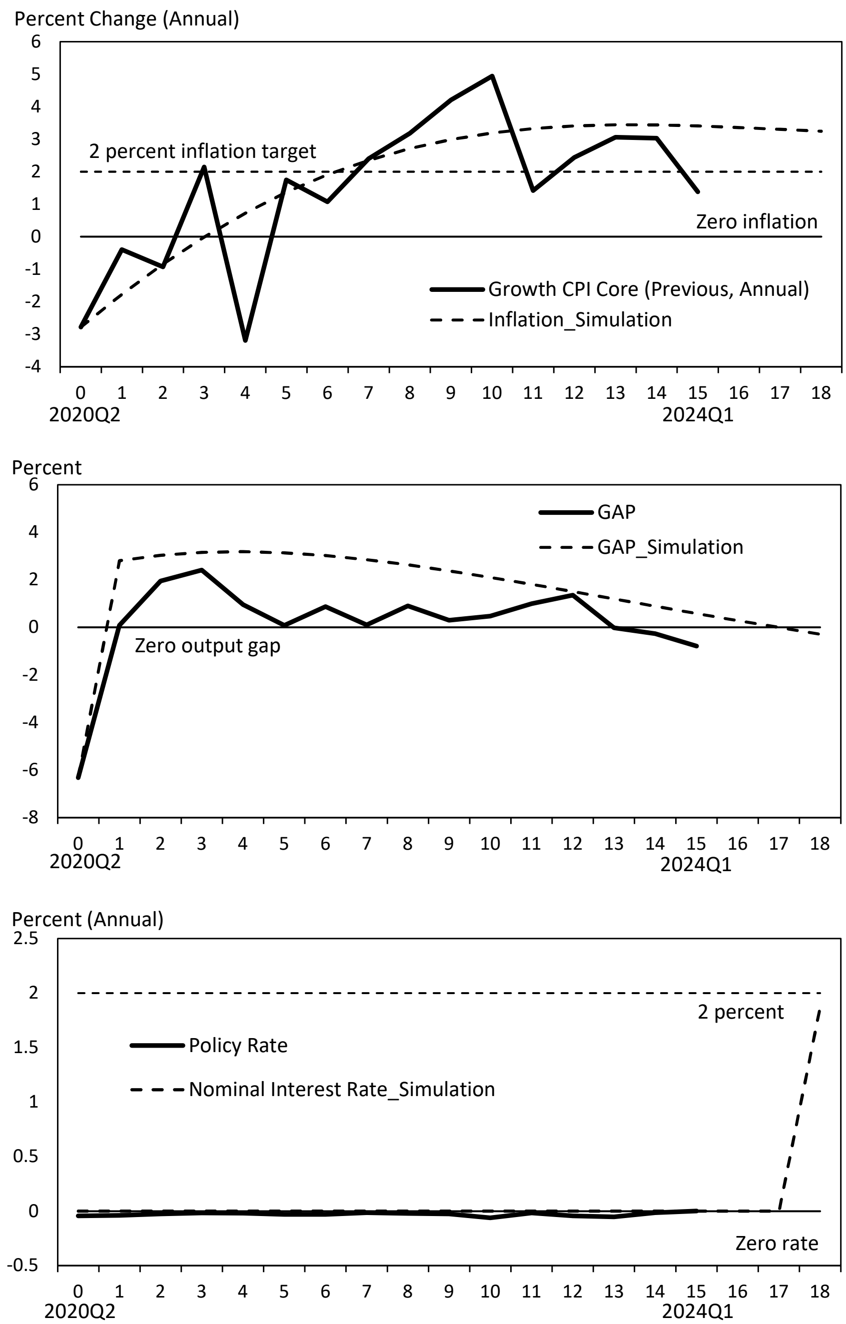

Figure 3: Simulation for Japanese Monetary Policy: Low State Economy

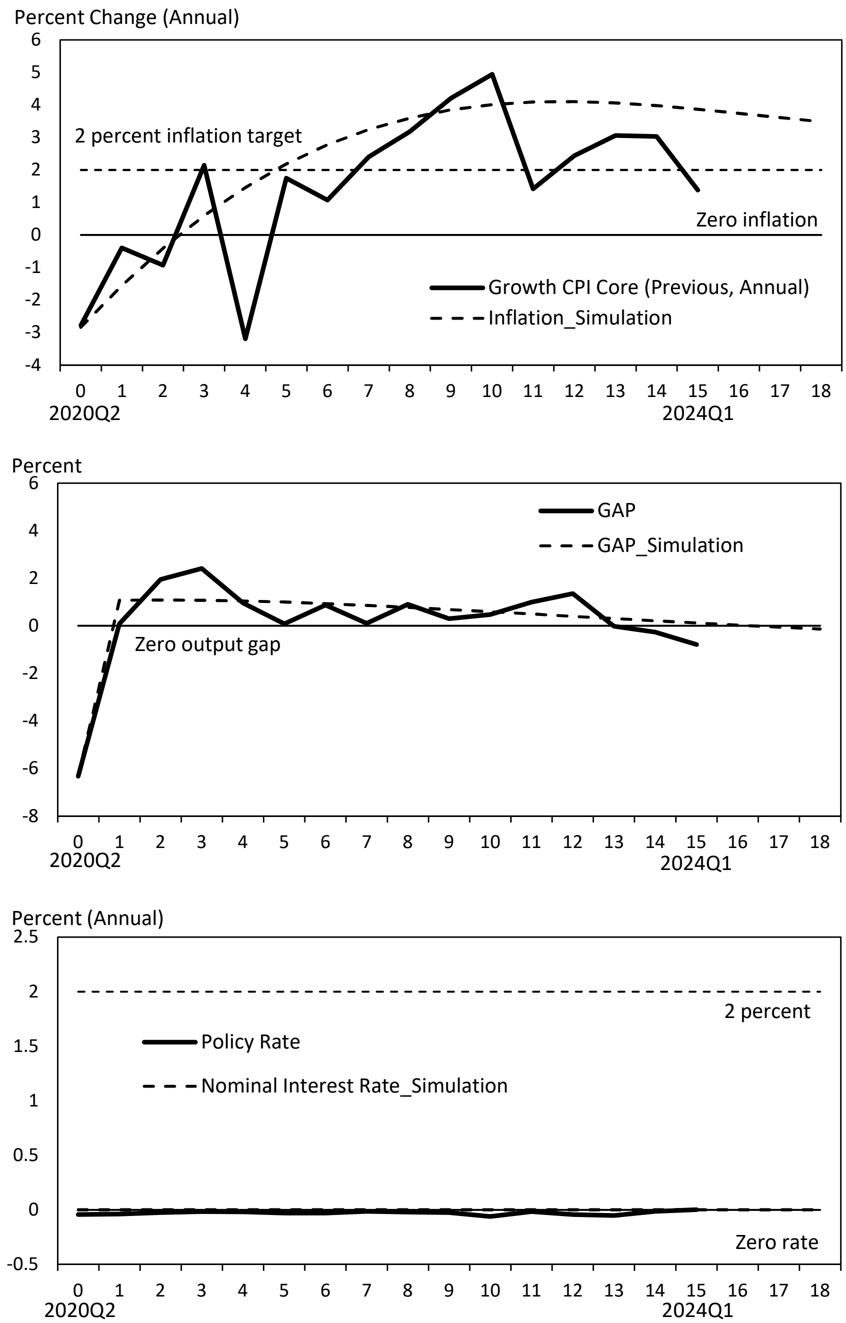

Figure 4: Simulation for Japanese Monetary Policy: Low Elasticity of Demand to Real Interest Rate