Stock prices and monetary policy in Japan: An analysis of a Bayesian DSGE model

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Stock prices and monetary policy in Japan: An analysis of a Bayesian DSGE model

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Abstract

This paper reevaluates the role of asset price stabilization in Japan during the 1980s through a Bayesian estimation of the dynamic stochastic general equilibrium model. Our results show the presence of the wealth channel from increased stock prices in Japan. In addition, we argue the possibility that the Bank of Japan (BOJ) may have conducted its monetary policy by targeting the stock price stability in addition to inflation and the output gap. The BOJ's response to stock price movements as a matter of policy, however, is subject to considerable uncertainty. Our results indicate that while the BOJ may have reacted to stock prices deviated from their fundamental values, it could not prevent a stock price bubble simply by implementing a contractionary monetary policy shock. Therefore, we conclude that the BOJ's monetary policy stance aimed at stabilizing stock price fluctuations and minimizing macroeconomic volatility, whereas endogenous volatility was caused by bad shocks.

JEL codes: E52; E58;

Keywords : Monetary policy; Bayesian estimation; DSGE model; Stock prices; Wealth effect

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1 Introduction

The objective of this paper is to reassess whether the Bank of Japan (BOJ) considered stock price stabilization in its monetary actions during Japan's 1980s asset bubble. Researchers have disagreed on whether the BOJ should have reacted more aggressively to fluctuations in asset prices during the latter half of the 1980s, when the Japanese economy experienced a boom and burst in stock prices. Indeed, the boom in stock prices led to an economic boom via the wealth effect brought about by rapidly increasing asset prices. Unfortunately, the bubble in stock prices also caused irrational behavior on the part of firms and banks. Consequently, the Japanese economy became trapped in secular stagnation when the bubble burst and asset prices collapsed in 1990 (Ogawa, 2003).

As mentioned above, evaluation of the stock price boom of the 1980s has been generated a debate about whether the BOJ should have raised its policy rates in response to the boom in the stock market. This evaluation is separated by dichotomous viewpoints about raising the interest rate: the view of the Federal Reserve System (FED) and that of the Bank of International Settlement (BIS). Some economists support the view that the BOJ would have had difficulty raising the policy rate in response to a sudden increase in stock prices because the inflation rate remained stable during the period. This evaluation is considered as the FED view (Bernanke and Gertler, 2000). In contrast, other economists assert that what the BOJ's failure to increase the interest rate to moderate the extraordinary boom in stock prices caused the secular stagnation that followed. That group argued that even though inflation was stable, the BOJ might have prevented the stock price bubble if the central bank responded correctly to it. This assertion is regarded as the BIS view (Cecchetti et al., 2002). There seems to be no consensuses on whether the BOJ should have attempted to stabilize the fluctuating stock prices that occurred during the 1980s.

This paper reevaluates the performance of the BOJ's monetary policy from the 1980s to 1990s using a Bayesian estimation of the dynamic stochastic general equilibrium (DSGE) model.[1] In the DSGE model, stock price movements are characterized by both a demand and a supply side. On the one hand, the demand side of stock prices is based on the role of the wealth effects of stock prices, which implies that an increase in stock prices leads to increased

[1] See also Kaihatsu and Kurozumi (2014), Hirakata et al. (2016), Hirose (2008), Iiboshi et al. (2006), Muto et al. (2016), and Sugo and Ueda (2008) for Bayesian estimation of the DSGE using Japanese time series data.

consumption spending in the private sector (Castelnuovo and Nistico, 2010). On the other hand, the supply-side channel of stock prices implies that an increase in stock prices induces a decline in real marginal costs that reduces inflation (Carlstrom and Fuerst, 2007). Our study contributes to previous studies because none of previous studies directly incorporated stock price stabilization into the monetary policy rules of DSGE models.

While we acknowledge the importance of both channels in the Japanese economy, this paper focuses on identifying of the deep parameter that captures the demand channel of stock prices because we want to know whether that channel had a substantial effect on movements in stock prices. In addition, since our objective is to evaluate whether the BOJ attempted to stabilize the stock price boom of the late 1980s, we consider whether one can appropriately identify the BOJ's intention to stabilize stock prices using a model with an wealth effect. More precisely, our research question is to evaluate whether the BOJ responded to stock prices in addition to its standard policy goals, such as inflation and output stabilization. To do this, we add a monetary policy rule to incorporate the role of stock price stabilization with the standard policy objectives and identify the coefficient for stock price stabilization in the policy rule.

To examine the role of asset price stabilization in the Japanese economy, we estimate the DSGE model developed by Castelnuovo and Nistico (2010), who incorporated the Blanchard-Yaari type perpetual youth model into the standard new Keynesian (NK) model to consider the wealth channel of stock prices. They found that the FED may have responded systematically to fluctuations in asset prices. We evaluate the BOJ's monetary policy stances during 1980s using the theoretical framework that those researchers developed. We use the model developed by Castelnuovo and Nistico (2010) so we can consider both the demand and the supply channel of stock prices in a single DSGE model. As we mentioned earlier, while the demand side of the wealth channel can be directly identified by Bayesian estimation, the supply side of the channel is theoretically considered in the model. Therefore, Castelnuovo and Nistico (2010)'s model is quite suitable for our purpose.

Our results identify the presence of the wealth channel resulting from increased stock prices in Japan. In addition, we point out the possibility that the BOJ's monetary policy decisions at the time gave weight to stock price stabilization in addition to more traditional policy goals such as inflation and the output gap. However, our results indicate that while the BOJ might have reacted to stock prices deviated from their fundamental values, it could not have prevent a stock price bubble by implementing only a contractionary monetary policy shock. Therefore, our study emphasizes that the BOJ's monetary policy stance aimed to stabilize fluctuations in stock prices and minimize the macroeconomic volatility, whereas endogenous volatility was caused by bad shocks.

The contribution of our paper is as follows. Our paper is related to the arguments by Bernanke and Gertler (2000) and Jinushi et al. (2000). Their studies argue that the BOJ was unable to sufficiently raise the policy rate, which caused both the boom and the crash in stock prices in the late 1980s. However, their evaluations are derived from the simulation results using the estimated simple Taylor rule. Furthermore, while Okina et al. (2001) discuss whether the BOJ should have responded to the drastic increase in stock prices, that discussion was not based on a structural macroeconomic model. While Miyao (2002) found that BOJ monetary policy was characterized by active policy stances in the late 1980s, his finding is based on the estimation results suggested by the structural vector autoregressive (VAR) model. In that sense, our study addresses the challenge to evaluating reactions to stock prices using monetary policy rules based on the Bayesian DSGE model. Therefore, our study complements their discussions based on evaluation using a Bayesian DSGE model. To the best of our knowledge, ours is the first study that evaluates whether the BOJ should have directly reacted to stock price fluctuations in that we evaluate that issue by using an estimated DSGE model.

Our study is closely related to the work of Hirose (2008). He estimated a medium-scale DSGE model with a sunspot shock as well as a financial accelerator effect.[2] He showed that the BOJ's estimated reaction function was close to the performance suggested by the optimal monetary policy rule that minimizes the central bank's loss function. He concluded that based on the simulation result, BOJ monetary policy could have minimized the macroeconomic volatility during the period. However, Hirose (2008) did not explore how the BOJ reacted to stock prices in the latter of 1980s. In contrast to Hirose (2008), this study identifies the BOJ's attitude toward stock price fluctuations during the period by incorporating stock price stabilization into the Taylor rule. Our result implies the possibility that BOJ responses considered stock price fluctuations during the late 1980s. In our analysis, this possibility is characterized by the coefficient of stock price stabilization in the estimated BOJ reaction function.

[2] Muto et al. (2016) also build a DSGE model with a financial accelerator and evaluate the effect of the financial accelerator on the Japanese economy by Bayesian estimation.

The structure of this paper is as follows. Section 2 provides facts about the Japanese economy from the 1980s to the 1990s and shows how a change in stock prices affects the Japanese economy. We briefly review the literature related to our study and address the contribution of our paper. In Section 3, we briefly explain the DSGE model and describe the Bayesian estimation methods. Section 4 provides detailed explanations about Bayesian estimation of the DSGE model, and Section 5 reports the main results of this paper. In Section 6, we discuss whether the BOJ should have responded to the stock price gap based on the estimation results obtained in the previous section. Section 7 concludes. Appendix A provides a detailed model description of Castelnuovo and Nistico (2010).

2 Stock prices and monetary policy in Japan

2.1 A brief review of the Japanese economy in the 1980s

This section briefly explains the Japanese economy during the 1980s. The Japanese economy experienced both boom and burst during this period. Figure 1 shows several time-series data that capture the story of the Japanese economy during the 1980s and 1990s. Following the Plaza Accord in 1985, the Japanese economy faced the risk of deflation from sharp appreciation in the exchange rate. In fact, the yen appreciated sharply against the dollar in response to the Plaza Accord, from approximately 250 yen in 1985 to around 120 yen in the subsequent year. As shown in Figure 1, after the Plaza Accord, the inflation rate was near zero in accordance with sharp appreciation in the nominal exchange rate. Accordingly, the GDP gap was also negative in 1986-1987 following the Plaza Accord.

[Figure 1 around here]

To combat this risk, the BOJ aggressively cut the official discount rate that represented its monetary policy stance during the 1980s. Indeed, as shown in the left lower panel of Figure 1, the official discount rate dropped sharply from 6.5 % in 1985 to 2.5% in 1987, and this monetary easing continued until April, 1989. The left upper panel of Figure 1 shows that as noted earlier, while the GDP gap was negative in response to the Plaza Accord, the gap was improved by monetary easing. Several studies point out that the continuation of monetary easing from 1987 to 1989 induced the asset price bubble, whereas the sharp increase in the official discount rate generated the collapse of the bubble. The BOJ decided to raise the policy rate in April, 1989, and it raised its policy rate sharply. Indeed, the official discount rate reached 6.25% in 1990. As argued in several previous studies, while extended monetary easing created that stock price bubble, a sharp increase in the official discount rate caused it to collapse. As pointed out in Miyao (2002), this fact would reveal that the BOJ's monetary policy stance was active in a sense that the BOJ's monetary policy was easing during 1986-1987 and contractionary during 1989-1990.

We calculate the stock price gap, which is defined as the deviation of actual stock prices from detrended ones. It may be one proxy for the deviation of stock prices from their fundamental values. The right lower panel of Figure 1 shows that the stock price gap significantly increased with monetary easing during these periods. Bernanke and Gertler (2000) and Jinushi et al. (2000) argue that the BOJ could have prevented the asset price bubble if it had raised its policy rate in accordance with an increase in stock prices.

Why did the BOJ not aggressively raise the official discount rate in response to asset price movements? According to Okina et al. (2001), there are several reasons. One is related to a change in the inflation rate during the late of 1980s. Based on the FED view, as long as the inflation rate is stable, the central bank has difficulty raising the policy rate even if movements in asset prices are fluctuating because of nonfundamental components (Bernanke and Gertler, 2000). Thus, the FED view supports the policy stance that the central bank has an incentive to conduct monetary tightening only if such a boom in asset prices leads to inflation risk. In fact, inflation risk did not emerge in this period. Therefore, as pointed out by Okina et al. (2001), it is possible that the BOJ lost the chance to increase the official discount rate for this reason.

Our study is motivated to answer the question of whether the central bank actually contemplated responding to an increase in stock prices even if low inflation was maintained.

2.2 Stock prices and monetary policy: Literature review

This section briefly reviews the literature related to our study and clarifies how this study is related to previous studies in terms of examining the role of asset price stabilization.[3] Indeed, several papers investigate whether the central bank should have considered the effect of asset prices on the real economy. As noted earlier, it has been debated whether central banks should

[3]See also Shibamoto et al. (2020) for a detailed discussion about BOJ's monetary policy during the 1980s.

react to fluctuations in asset prices. Bernanke and Gertler (2000) asserted that, based on the framework developed by Bernanke and Gertler (2000), the central bank should not stabilize asset prices unless they affect an increase in future inflation expectations. Conversely, Cecchetti et al. (2002) argued that the central bank should respond to asset prices as a precaution, because the bursting of asset price bubbles can cause severe economic stagnation. In addition, according to Chadha et al. (2004) and Haugh (2018), the central bank might consider the effect of stock price misalignment that causes asset prices to deviate from their fundamental values on the real economy.

No consensus has been reached in terms of the theoretical aspects of the NK model. For instance, several studies support the assertion of Bernanke and Gertler (2000). They argue that the central bank can stabilize the economy if it reacts strongly to inflation. Thus, the response to asset prices in the policy rule is redundant when the central bank aggressively raises the policy rate in response to inflation. Several studies support this view (Carlstrom and Fuerst, 2007; Gilchrist and Leahy, 2002; Faia and Monacelli, 2007; Iacoviello, 2005).

On the other hand, some previous studies assert that the central bank can obtain gains from asset price stabilization (Airaudo, 2013; Gambacorta and Signoretti, 2014; Kannan et al., 2012; Pfajfar and Santoro, 2014). For instance, Airaudo et al. (2013) showed that a mild response to asset prices in a monetary policy rule can achieve a unique REE and rule out nonfundamental volatility in an NK model with financial market imperfections. As suggested by Kannan et al. (2012), when the model contains heterogeneities of households, the central bank can obtain gains by implementing an augmented monetary policy rule that contains both asset price stabilization and a macro-prudential tool such as a credit growth rate.

Our study is related to the work of Castelnuovo and Nistico (2010) in terms of asset price stabilization. They argued that including a stock-price gap in the monetary policy rule is consistent with post-WWII stock market boom and bust cycles by using a DSGE model with Bayesian techniques. We use the same framework as Castelnuovo and Nistico (2010) and find that using Japanese time-series data, positive and significant responses to stock prices are ambiguous. Thus, we conclude that while the BOJ might have reacted to fluctuations in stock prices, the response was affected by a great amount of uncertainty. This is in stark contrast to the findings in the work of Castelnuovo and Nistico (2010).

In summary, it seems that there is no consensus about whether the central bank should react aggressively to asset price fluctuations in terms of the DSGE model. Note that in this paper we do not provide the normative answer of whether the central bank should react to stock prices aggressively; rather, we simply evaluate the BOJ's monetary policy stance during the 1980s by focusing on stock price stabilization in the monetary policy rule.

3 Model description

This paper focuses on the wealth channel of stock prices to evaluate the BOJ's monetary policy stance. To do so, we adopt the framework of Castelnuovo and Nistico (2010), who incorporate a discrete-time perpetual youth model developed by Blanchard (1985) and Yaari (1965) into a standard NK model. We briefly explain the framework of the perpetual–youth NK model. Readers who want to know detailed derivations of the model are referred to Nisticò (2012) and Castelnuovo and Nistico (2010). Readers familiar with this model can skip to Section 4, which provides explanations of the model estimation.

3.1 Model summary

The model is based on a canonical DSGE model with the wealth channel of stock prices. The wealth channel is captured by the parameter ξ, which represents the probability of being replaced the next period begins. Carlstrom and Fuerst (2007) model the NK model with stock price dynamics, which focuses on the supply side of stock price that the dividend is negatively affected by the real marginal cost. In contrast to Carlstrom and Fuerst (2007), Castelnuovo and Nistico (2010)'s framework can consider both demand and supply channels of stock prices. Therefore, the model that we employ is based on Castelnuovo and Nistico (2010) and Nisticò (2012). As in Castelnuovo and Nistico (2010), we consider a stochastic trend in productivity to estimate the DSGE model. This enables us to estimate the model without implementing in data prefiltering. The model description is explained as follows.

The economy consists of an indefinite number of cohorts that are subject to the constraint of a constant probability ξ of being replaced when the next period begins. Following the terminologies established by Castelnuovo and Nistico (2010), the interaction between "newcomers" owning zero financial assets and "old traders" that accumulates their wealth causes the wedge between the stochastic discount factor pricing all securities and the average marginal rate of substitution in consumption that is equalized in a representative agent (RA) model. In this case, individual consumption smoothing that is optimal in an RA model does not carry over in aggregate terms because agents in the financial markets change over time and have different wealth and different consumption levels. The case for $\xi = 0$ corresponds to the RA model.

Each household obtains utility from consumption and disutility from labor supply. More precisely, following Nisticò (2012), each household has Cobb-Douglas preferences over consumption and labor supply. Household consumption is captured by habit formation. As in a standard NK model, nominal price rigidity is introduced by the assumption of staggered price contracts.

The production sector consists of two types of firms: retailers and intermediate goods firms. Retailers use intermediate goods to produce final goods under a perfectly competitive market. Following Calvo (1983), intermediate goods firms set their nominal prices based on a staggered manner. Thus, a fraction $1-\theta_p$ of all firms optimally adjusts their price, whereas the remaining fraction θ_p of firms that do not optimally change their prices follows the indexation rule associated with past inflation as well as steady state inflation. In addition, following Castelnuovo and Nistico (2010), households specialize in supplying a different type of labor and each cohort spans all labor types. For each labor type there exists a an infinitely lived monopoly labor union that determine the nominal wage. Each union faces Calvo's (1983) nominal wage rigidity. Following Erceg et al. (2000), a fraction of $1-\theta_w$ can change nominal wages in its union, whereas remaining fraction θ_w cannot optimally choose their wages follows the indexation rule associated with past price inflation as well as productivity growth and steady state inflation.

3.2 Log-linearized model

We briefly explain the log-linearized equations.[4] Following Castelnuovo and Nistico (2010), we express log-deviations from the detrended steady state with lower case letters. In this section we focus on the equations expressed by a gap term, which implies the deviation of the level value from its detrended steady state. The output gap is expressed by $\hat{x}_{y,t} = \hat{y}_t - \hat{y}_t^*$. Similarly, we also define the real wage gap as $\hat{x}_{w,t} = \hat{w}_t - \hat{w}_t^*$ and the stock price gap as $\hat{x}_{s,t} = \hat{q}_t - \hat{q}_t^*$. Here, the variables with a hat denote the log-deviation from the detrended steady state. The variables with an asterisk denotes the counterparts under frictionless equilibrium. Following

[4]See the Appendix A or Castelnuovo and Nistico (2010) for a detailed derivation of the structural model.

Castelnuovo and Nistico (2010), frictionless equilibrium is defined as flexible prices and wages in addition to nonstochastic markup on prices and wages and no financial shocks. Variables under frictionless equilibrium are defined in Appendix A.

The log-linearized equations are summarized as follows:

$$
\begin{aligned}
\hat{x}_{y,t} = & \frac{1-h/\gamma}{1-h/\gamma+\psi}\left(E_t\hat{x}_{y,t+1} - \frac{h}{\gamma}\hat{x}_{y,t}\right) + \frac{(1-h/\gamma)(1-g/y)}{1-h/\gamma+\psi}\psi\hat{x}_{s,t} \\
& + \frac{h}{\gamma}\hat{x}_{y,t-1} - \frac{(1-h/\gamma)^2(1-g/y)}{1-h/\gamma+\psi}\left(\hat{R}^n_t - E_t\hat{\pi}_{t+1} - \hat{R}^*_t\right), \qquad (1)
\end{aligned}
$$

$$
\begin{aligned}
\hat{x}_{s,t} = & \tilde{\beta}E_t\hat{x}_{s,t+1} + \frac{\mu^p(1-\tilde{\beta})}{\alpha+\mu^p}E_t\hat{x}_{y,t+1} - \frac{(1-\tilde{\beta})(1-\alpha)}{\alpha+\mu^p}E_t\hat{x}_{w,t+1} \\
& - \left(\hat{R}^n_t - E_t\hat{\pi}_{t+1} - \hat{R}^*_t\right) + z^{\nu}_t, \qquad (2)
\end{aligned}
$$

$$
\hat{\pi}_t = \tilde{\beta}\left(E_t\hat{\pi}_{t+1} - \iota_p\hat{\pi}_t\right) + \iota_p\hat{\pi}_{t-1} + \lambda_p\hat{x}_{w,t} + \frac{\alpha\lambda_p}{1-\alpha}\hat{x}_{y,t} + z^p_t, \qquad (3)
$$

$$
\begin{aligned}
\hat{w}_t = & \tilde{\beta}\left(E_t\hat{w}_{t+1} - \hat{w}_t + E_t\hat{\pi}_{t+1} - \iota_w\hat{\pi}_t + E_t z^{\gamma}_{t+1} - \iota_w z^{\gamma}_t\right) + \hat{w}_{t-1} \\
& - \hat{\pi}_t + \iota_w\hat{\pi}_{t-1} - z^{\gamma}_t + \iota_w z^{\gamma}_{t-1} + \lambda_w\left(\frac{1}{(1-h/\gamma)(1-g/y)} + \frac{\varphi}{1-\alpha}\right)\hat{x}_{y,t} \\
& - \frac{\lambda_w h/\gamma}{(1-h/\gamma)(1-g/y)}\hat{x}_{y,t-1} - \lambda_w\hat{x}_{w,t} + z^w_t. \qquad (4)
\end{aligned}
$$

Here, $\hat{\pi}_t$ denotes the inflation rate, and $\hat{R}^n_t$ denotes the nominal interest rate. $\hat{w}_t$ is the real wage rate and $\hat{R}^*_t$ is the natural rate of interest, which is defined as the real interest rate under frictionless equilibrium. As we explain below, z^j_t (for $j = a, g, v, r, b, p, w$) denotes structural shocks that follow the autoregressive (AR)(1) process. The deep parameters in the above structural equations are defined as follows:

$$
\begin{aligned}
\tilde{\beta} = \frac{\beta(1-h/\gamma)}{1-h/\gamma+\psi},\ \lambda_p = \frac{\mu^p(1-\theta_p)(1-\theta_p\tilde{\beta})(1-\alpha)}{\theta_p(\mu_p+\alpha)}, \\
\lambda_w = \frac{\mu^w(1-\theta_w)(1-\theta_w\tilde{\beta})}{\theta_w(\mu_w+\varphi(1+\mu_w))},\ \psi = \xi\frac{1-\beta(1-\xi)}{1-\xi}\frac{\omega}{c}.
\end{aligned}
$$

In addition, h is the degree of habit formation in consumption, g/y is the ratio of demand for consumption goods relative to output excluding household consumption, and γ is the productivity growth in the steady state. μ_p is the price markup and μ_w is the wage markup. ι_p is the degree of indexation of past prices in the price index and ι_w is the degree of indexation of past wages in the wage index. α is the degree of diminishing return to scale in production function. ω/c denotes the ratio of the aggregate wealth to aggregate consumption in the steady state.

Equation (1) is the dynamic IS curve with the wealth effect of stock prices. Equation (2) represents stock price dynamics. Equation (3) is the price new Keynesian Phillips curve and Equation (4) is the wage new Keynesian Phillips curve.

To close the model, we specify the monetary policy rules. This study employs the standard monetary policy rule suggested by Taylor (1993). In particular, we consider whether each central bank should react to the stock price gap. More specifically, we specify a log-linearized monetary policy rule as follows:

$$\hat{R}_t^n = \phi_r \hat{R}_{t-1}^n + (1-\phi_r)\left(\phi_\pi \hat{\pi}_t + \phi_{x.y}\hat{x}_{y,t} + \phi_{x.s}\hat{x}_{s,t}\right) + z_t^r, \tag{5}$$

where ϕ_π is the coefficient of the rate of inflation, $\phi_{x.y}$ is the coefficient of the output gap, and $\phi_{x,s}$ denotes the coefficient of the stabilization weight on the stock price gap.

The seven structural shocks are considered as follows:

$$\begin{aligned}
z_t^\gamma &= \rho_\gamma z_{t-1}^\gamma + \varepsilon_t^\gamma, \\
z_t^p &= \rho_p z_{t-1}^p + \varepsilon_t^p, \\
z_t^w &= \rho_w z_{t-1}^w + \varepsilon_t^w, \\
z_t^g &= \rho_g z_{t-1}^g + \varepsilon_t^g, \\
z_t^b &= \rho_b z_{t-1}^b + \varepsilon_t^b, \\
z_t^\nu &= \rho_\nu z_{t-1}^\nu + \varepsilon_t^\nu, \\
z_t^r &= \rho_r z_{t-1}^r + \varepsilon_t^r.
\end{aligned}$$

where ε_t^j follows $N(0, \sigma_j^2)$ for all $j = a, g, v, r, b, p, w$. As we will argue, the measurement error shock of the growth rate of stock prices are defined in Section 4.

4 Asset price stabilization in Japan: A Bayesian estimation

This section represents the estimation strategy. Since our model includes the trend due to the production technology, we must rewrite it to the detrended equilibrium conditions. The lower-case variables denote detrended macrovariables. We introduce the detrended macro variables as follows: $y_t = Y_t/A_t$, $c_t = C_t/A_t$, $d_t = D_t/A_t$, $w_t = W_t/A_t$, $q_t = Q_t/A_t$, $\omega_t = \Omega_t/A$, and

$mrs_t = MRS_t/A_t$. Here A_t is the level of the technology, C_t is consumption, D_t denotes the dividend, and Ω_t is financial wealth, respectively.

Then, we estimate the DSGE model with the wealth channel of asset prices by Bayesian methods.[5] To evaluate the likelihood function, we apply the Kalman filter to the system consisting of log-linearized equilibrium and observation equations. Then, 1000,000 draw from the posterior distribution of parameters to be estimated is obtained by the Metropolis-Hastings (MH) algorithms to approximate the moments. The scale parameter in the MH algorithms is set so that the acceptance ratio is maintained around 25%. The first half draws are discarded and the remaining half draws are used for our analysis.

We estimate the key structural parameters using seven quarterly Japanese time-series data.[6] Y_t is real per capita GDP, C_t is real per capita consumption, and SP_t is real per capita Nikkei stock average (NIKKEI 225). As for these real series, we divide these nominal series with the GDP deflator. Regarding the per capita terms, each series is divided by population over 15 years old. W_t is the real wage, l_t is hours worked, DEF_t is the GDP deflator, and R_t^n is the call rate. Like previous studies that examine the Japanese economy in the DSGE frameworks, we select the sample period from 1981:Q1 to 1998:Q4 to avoid the problems from the nonnegativity constraints on nominal interest rates.

The observation equations are given by

$$\begin{bmatrix} 100\Delta \ln Y_t \\ 100\Delta \ln C_t \\ 100\Delta \ln SP_t \\ 100\Delta \ln W_t \\ 100\Delta \ln l_t \\ 100\Delta \ln DEF_t \\ R_t^n \end{bmatrix} = \begin{bmatrix} \overline{\gamma} \\ \overline{\gamma} \\ \overline{\gamma} \\ \overline{\gamma} \\ 0 \\ \overline{\pi} \\ \overline{R}^n \end{bmatrix} + \begin{bmatrix} z_t^\gamma + \hat{y}_t - \hat{y}_{t-1} \\ z_t^\gamma + \hat{c}_t - \hat{c}_{t-1} \\ z_t^\gamma + \hat{q}_t - \hat{q}_{t-1} \\ z_t^\gamma + \hat{w}_t - \hat{w}_{t-1} \\ 1/(1-\alpha)\,(\hat{y}_t - \hat{y}_{t-1}) \\ \hat{\pi}_t \\ \hat{R}_t^n \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ me_t \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

where $\overline{\gamma} = 100 \ln \gamma$, $\overline{\pi} = 100 \ln \pi$, and $\overline{R}^n = 100 \ln R^n$.[7] me_t is the measurement error for the

[5] Our estimation is conducted by Dynare (Adjemian et al., 2011).

[6] We explain detailed explanation of data descriptions in the Appendix B.

[7] We use the growth rate of hours worked in the observation equation to maintain the specification of the Castelnuovo and Nistico (2010)'s model.

stock price growth rate, which is given by

$$me_t = \rho_{mq} me_{t-1} + \varepsilon_t^{mq},\ \varepsilon_t^{mq} \sim \text{i.i.d.} N(0, \sigma_{mq}^2),$$

where $\rho_{mq} \in [0, 1)$ represents the autoregressive coefficient and σ_{mq}^2 is the white noise. The measurement error follows the first order autoregressive process used by Matsumae et al. (2011).[8]

Following previous studies, we assume that some parameters in the model are fixed. For example, we set the capital share, $\alpha = 0.37$, the discount factor, $\beta = 0.995$, and price and wage markup, $\mu^p = \mu^w = 0.2$, following Sugo and Ueda (2008), and the steady state exogenous demand factors to output ratio $g/y = 0.3$ follows the sample mean.

Following previous studies, we set the prior distributions of estimated parameters that we estimate below. Table 1 reports the priors of each parameter. The priors of the turnover rate ξ, leisure weight in the household's utility χ and monetary policy response to stock price gap $\phi_{x.s}$ follow those of Castelnuovo and Nistico (2010). More precisely, ξ, χ, and $\phi_{x.s}$ follow the uniform distribution from 0 to 1.0, the gamma distribution with a mean of 1.4 and the standard deviation of 1.0, and the normal distribution with mean of 0 and standard deviation of 0.025, respectively. Regarding the priors of the almost structural parameters $\{h, \theta_p, \theta_w, \iota_p, \iota_w\}$, we follow those of Sugo and Ueda (2008). As argued in previous studies that focus on the Japanese economy using a Bayesian DSGE model, except for $\phi_{x.s}$, the parameters of the monetary policy rule are the same distributions of Iiboshi et al. (2006).

Regarding the priors of seven structural shocks, the persistence of each shock $\rho_x, x \in \{\gamma, p, w, g, b, \nu, r\}$ are the beta distribution with the mean of 0.5 and the standard deviation of 0.2 and the standard deviation of shocks $\sigma_x, x \in \{\gamma, p, w, g, b, \nu, r\}$ are the inverse gamma with the mean of 0.5 and the standard deviation of infinity. Finally, While previous studies used the DSGE models for the Japanese economy that did not incorporated the nonfundamental financial shock z_t^ν, we assume that the prior distribution of the financial shock also has same distribution as other shock to ensure the same conditions.

[8] As argued by Castelnuovo and Nistico (2010), the measurement error is also introduced for the stock prices, but it is the white noise. In contrast, the measurement error in our model is the AR(1) process because the contamination from the errors would continue to carry over from the previous period.

5 Results

This section provides the main results of the paper. Section 5.1 provides the posterior estimates of the structural model. Section 5.2 explores whether the BOJ reacted to the stock market. In Section 5.3 we examine dynamic and cyclical properties of the estimated model by using the impulse response function and the variance and historical decomposition.

5.1 Posterior estimates

Table 1 summarizes the values of estimated parameter and those 90% posterior interval.[9] To confirm the importance of stock prices in the model, we focus firstly on the turnover rate ξ, which is characterized by wealth effect of stock prices through the household's demand side. The posterior mean $\xi = 0.046$ and its 90% interval is $[0.026, 0.066]$ which suggests the presence of the wealth effects. Thus, we identify the effect of the stock prices on real activities through the variation in the household's consumption. In the US economy, Castelnuovo and Nistico (2010) estimated ξ to be about 0.13. This results suggest that the wealth effects in the Japanese economy is smaller than that in US economy. We will discuss the importance of the reaction to stock prices $\phi_{x,s}$ in Section 5.2.

The posterior mean of most structural parameters is similar to that obtained in the DSGE model for Japan, but some differ from previous studies. The wage stickiness $\theta_w = 0.216$ is lower than Hirose and Kurozumi (2012) and Kaihatsu and Kurozumi (2014). The former estimated value is 0.522 and the latter one is 0.503. Our estimated value of the price indexation ι_p is 0.041, which is smaller than that reported in Hirose and Kurozumi (2012) and Kaihatsu and Kurozumi (2014). The former and the latter estimated values are 0.631 and 0.408, respectively. These differences may be caused by the selection of the data on prices. More precisely, although Hirose and Kurozumi (2012) and Kaihatsu and Kurozumi (2014) incorporate the CPI into the observation equation, our analysis use the GDP deflator as the data on prices. Indeed, Hirakata et al. (2016) used the GDP deflator, and we confirmed that their estimated value of the price indexation was the similar result as the value estimated in our study.[10]

[9] We have confirmed that the estimated parameters are correctly identified in our model. Additional results on this identification problem are available upon request. See also footnote 10.

[10] Although Hirakata et al. (2016) select the sample period from 1981Q1 to 2013Q4, the sample period in our analysis is from 1981Q1 to 1998Q4.

The leisure weight in the utility, $\chi = 0.031$, is quite low compared with that estimated by Castelnuovo and Nistico (2010), who analyzed the US economy using the estimated DSGE model ($\chi = 1.4456$). The difference might have been caused by the inclusion of the period before *Jitan*, which means the reduction in the hours worked in a week due to the 1987 amendments to the Labor Standards Act in Japan. Therefore, the leisure weight might be underestimated by including the periods of long working hours.

Next, we examine the parameters of the financial shock, which directly effects stock prices and is the specific shock in our analysis. Although the financial shock is relatively persistent, it does not fluctuate so much (i.e., $\rho_\nu = 0.958$ and $\sigma_\nu = 0.561$). This is because in the observation equation the measurement error for the stock prices absorbs its volatility. The standard deviation of the financial shock would be estimated to be relatively the low value. Indeed, the standard deviation of the measurement error for the stock prices is an extremely high value ($\sigma_{mq} = 6.986$).

5.2 The Bank of Japan's response to the stock market

Following Table 1, we have found that a positive value of ξ significantly accounts for the wealth effect of stock prices in Japan. Dose this wealth effect also justify the BOJ's stock price stabilization? Table 1 reports the estimated value of stock price stabilization, $\phi_{x,s}$. Since the estimated value of $\phi_{x,s}$ is 0.164, this might indicate that the BOJ responded to movements in stock prices. However, the result also shows that the estimated value might be an insignificant response of the BOJ to fluctuations in stock prices because the credible interval $[-0.096, 0.423]$ contains zero. Therefore, while the BOJ reacted to an increase in stock prices in the 1980s, this result indicates that there is great uncertainty about the stabilization of stock prices.

Next, we compare several models with the benchmark model. Table 2 reports the comparison of Bayesian estimation results restricted by several key parameters with the benchmark result. "Baseline" implies the estimation results without any parameter restrictions. The second column of the table shows the estimation result with the restriction to ξ. Thus, this model corresponds to the model without wealth effect of stock prices. Note that it still contains the stabilization of stock prices in this restricted model. The third column implies the alternative model with the restriction of no stock price stabilization. The final column represents the restricted model, where wealth effect and stock price stabilization are absent. The last row of the table reports the log-marginal likelihood for each model.

[Table 2 around here]

The likelihood of the model with $\phi_{x,s} = 0$ leads to the smallest log-marginal likelihood of other specifications. Accordingly, the model with $\xi = 0$ and $\phi_{x,s} > 0$ outperforms other models. This result might indicate that the BOJ responded to fluctuations in stock prices during the 1980s. In addition, comparing the model $\xi = 0$ with that with $\xi = \phi_{x,s} = 0$ implies that the former model outperforms the latter one. Put differently, the model in which both wealth effect and stock price stabilization are absent results in worse performance than that with $\xi = 0$.[11] This result also indicates that the BOJ contemplated the stabilization of stock prices during the period.

Finally, we attempt to investigate whether the BOJ could have reacted more aggressively to the sharp increase in stock prices in the late 1980s. To do this, we consider the counterfactual estimations as if the BOJ has responded strongly to asset prices during the period. Table 3 reports the estimation results of the case as if the BOJ has adopted the stronger response to stock prices. The second column of the table shows that the BOJ's reaction to stock prices is stronger than the baseline case, namely, $\phi_{x,s} = 0.164$. The comparison of the model with $\phi_{x,s} = 0.25$ with the models that include the value of $\phi_{x,s}$ above 0.25 shows that a more aggressive response to stock prices cannot improve the performance of the model. However, even in this case, the model with a stronger response to stock prices outperforms the baseline model. Further discussion is provided in the next section.

[Table 3 around here]

[11] We confirmed the problem of parameter identification under these constraints. However, this confirmation suggests that the case of $\xi = 0$ or $\xi = \phi_{x,s} = 0$ may be weakly identified due to measurement errors in stock prices. Our model that takes such measurement error into account is based on Castelnuovo and Nistico (2010). We re-estimated the model without taking into account the measurement error of stock prices, but we confirmed that excluding this measurement error does not affect the results obtained in this paper. Detailed estimation results of the DSGE model excluding the measurement error of stock prices are available upon request. In few restricted models, a few parameters did not meet the convergence diagnostic criteria. We confirmed, however, that this problem can be mostly solved by increasing the sampling of the MH algorithm. Therefore, we can say that our main message is unaffected by these issues.

Therefore, we can say that these results imply that the BOJ contemplated the greater uncertainty that could result from the effect of stock price fluctuations on the Japanese economy. This result is stark contrast with the assertion of Bernanke and Gertler (2000) who point out the possibility that the BOJ could have prevented a sharp increase in stock prices if it implemented precautionary monetary tightening.

5.3 Variance and historical decomposition

In this subsection, we evaluate the contribution of the shocks to the business cycle fluctuations in the Japanese economy, and discuss variance and historical decomposition of the several key variables. Table 4 represents the variance decomposition of the key macrovariables that we pick up at the quarterly forecast horizons of $T = 8$ and $T = 32$. Table 4 shows for the variance decomposition of the nominal interest rate, the monetary policy shock account for its almost variation at both the short and the medium term. However, the financial shock also generates the fluctuations in the interest rate and the contribution increases, especially in the medium term. The financial shock leads to the nonfundamental disturbances in stock prices. Thus, the central bank manipulates the interest rate in response to the variation in the stock prices generated by the financial shock. These findings support the result that monetary policy responds to the asset prices as stated in the previous discussion.

[Table 4 around here]

As mentioned above, the financial shock effects the nonfundamental component of the stock prices. This is supported by the results of the variance decomposition of the stock price gap. However, the fluctuations in the stock price gap is mainly caused by the exogenous demand shock. Since we do not incorporate real investment as the observation data and endogenous variable into our analysis, the estimation results would overestimate the effects of the exogenous demand shock in the demand side of the economy. For the variance decomposition of the stock price growth, the structural shocks do not explain much of the variations because of introducing the measurement error to the observation equation. The fluctuations in the output growth are primarily generated by the neutral technology shock. This result is consistent with Hirose and Kurozumi (2012) and Kaihatsu and Kurozumi (2014).

Figure 2 illustrates the historical decomposition of the nominal interest rate and shows that the monetary policy shock plays the most vital role in its fluctuations over the periods. The historical decomposition shows the significant effect of the financial shock on the policy rate. We can see that this shock creates the downward pressure on the policy rate in the late 1980s. This result may be interpreted as the scenario that the BOJ combated a sharp increase in stock prices, but it could not substantially raise the nominal interest rate due to bad shocks associated with financial frictions during 1987-1990. By contrast, it follows from Figure 2 that precautionary monetary easing during 1992-1993 can be explained by the negative contributions of the financial shocks. This implies that the BOJ's precautionary monetary easing policy rate results in an active reduction in its policy rate down by reacting to the recession associated with the collapse of the asset price bubble.

[Figure 2 around here]

5.4 Dynamic and cyclical properties of the estimated model

This subsection investigates the quantitative properties of the estimated model. Figures 3-6 summarize impulse responses of the nominal interest rate, stock price gap, inflation, stock price growth, and output growth to the shock to monetary policy, preference, financial conditions, and neutral technology. "Baseline" represents the impulse responses of the model variables to the shocks under the estimated parameters in the benchmark model. We firstly focus on the impulse responses in the benchmark model.

Figure 3 shows the impulse response to a monetary policy shock in an estimated DSGE model. The contractionary monetary policy shock increases the nominal interest rate, the stock price gap, and growth and decreases the inflation and output growth. The increase in the nominal interest rate causes the increases in dividends and consequently the stock price gap and growth. This is because the contractionary monetary policy decreases the payments for labor compensation more than the decrease in the output. Moreover, the impulse responses illustrates that this shock generates the trade-off between stabilization of the inflation and the stock price gap. These results suggest that the central bank must sacrifice the price stability to prevent fluctuations in stock prices as long as a monetary policy rule contains the stabilization term that responds to the stock price gap. As the results show, inflation and the stock price gap are characterized by persistent responses, compared to the case for other shocks.

[Figure 3 around here]

As shown in Figure 4, the preference shock leads to stock price fluctuations though a change in the discount factor. Except for the stock price growth, the positive preference shock increases macrovariables. However, the impulse responses of stock price gap and growth appear to be inconsistent with the ones that we expect. Figure 5 shows the financial shock, which induces the nonfundamental disturbances for the stock prices. This shock results in increases in stock prices, inflation, and the output gap through the wealth effects of stock prices, which increase the demand for output. In response to both shocks, although the central bank increases its nominal interest rate, the policy reaction is more persistent in the case of the financial shock than that of other shocks. Put differently, the financial shock is the more persistent effects on the interest rate than any other structural shock.

[Figure 4 around here]

[Figure 5 around here]

As shown in Figure 6, the positive neutral technology shock increases output growth and stock prices via an increase in the dividend, whereas it declines the inflation. Thus, the central bank also faces a policy trade-off between inflation and stock price stabilization in the case of the technology shock. In contrast to the monetary policy shock, since the neutral technology shock is less persistent than other shocks, inflation and the stock price gap promptly converge to stationary steady states.[12]

Figures 3-6 also reveal whether monetary policy stabilizes the real economy by reacting to stock prices. These figures summarize the impulse responses under the different values of $\phi_{x.s}$: Baseline ($\phi_{x.s} = 0.164$), $\phi_{x.s} = 0.25$, and $\phi_{x.s} = 0.5$. As the value of $\phi_{x.s}$ increases, it indicates that monetary policy reacts more strongly to the stock market conditions.[13]

[Figure 6 around here]

These impulse responses reveal that as the central bank respond strongly to the fluctuations in the stock price gap, the nominal interest rate tends to react more strongly and are more persistent, whereas the growth rate of stock price and output are no significant changes relative

[12]While the persistence of the monetary policy shock is 0.325, it of the neutral technology shock is 0.079.

[13]In this simulation, while we change only the value of $\phi_{x.s}$ in the baseline model, we do not consider the re-estimation of the model under the different value of $\phi_{x.s}$.

to that of the baseline model. These results suggest that even if the monetary policy reacts strongly to the fluctuations of stock price gap, it is difficult for the central bank to stabilize sufficiently the stock price and output volatility in the periods.

5.5 Role of measurement error for stock prices

In the previous section, we estimated a DSGE model that takes into account the measurement error of stock prices. The specification of the baseline model is based on Castelnuovo and Nistico (2010). The estimation results appear to show that the BOJ's response to stock prices is positive, whereas there is a large uncertainty about its statistical significance. This is because the result also shows that the estimated standard deviation of the measurement error of stock prices is quite large. We conjecture that the estimation results may be strongly affected by this measurement error. Therefore, to check for robustness, we estimate the DSGE model without the measurement error of stock prices.

Table 5 shows the estimation results of the DSGE model excluding the measurement error of stock prices.[14] There are several caveats to this robustness check. First, the performance of the model obtained in Table 3 is better than that of the model excluding the measurement error. Second, all log marginal likelihoods are worse than the ones obtained in Table 3, however. Thus, the performance of the model excluding the measurement error of stock prices is worse than that of the benchmark. Third, the estimates of the stabilization coefficients of stock prices are much smaller than those in Table 1. For example, in the baseline specification excluding the measurement error of stock prices, $\phi_{x,s}$ is 0.008, which is much smaller than 0.164 in Table 1. This robustness check indicates that the main message of this paper remains unaffected by the exclusion of the measurement error for stock prices.

[Table 5 around here]

[14]In this robustness analysis, the posterior distribution of the MH algorithm was drawn 500,000 times and the second half of the distribution was used for the analysis. The results showed that most of the parameters met the diagnostic criteria for convergence of the distribution, but some did not. However, we would like to mention that this robustness check does not affect the main conclusion of this paper.

6 Policy reevaluation: Bad policy or bad luck?

In this section, we discuss the role of stock price stabilization during the 1980s based on the simulation results obtained in the previous section. The main purpose of this section is to reevaluate the BOJ's monetary policy during the 1980s based on the implication of these results. As discussed in Bernanke and Gertler (2000), Jinushi et al. (2000), and Okina et al. (2001), it has been discussed the possibility that both the delay and the shortage of monetary tightening policies from 1985 to 1987 led to the stock price bubble. In addition, sharp increases in the official discount rate in subsequent periods resulted in the bursting of the bubble in 1990. The problem is whether the BOJ could have prevented the stock price bubble in the late 1980s, had it decided to pursue aggressive increases in the policy rate in response to stock prices during the period.

For instance, Bernanke and Gertler (2000) argued that the BOJ should have reacted to the stock price boom in the latter of the 1980s using the estimation result of the BOJ's reaction function suggested by the Taylor rule.[15] They asserted that the BOJ should have aggressively raised its interest rate in the late 1980s.[16] Miyao (2002) found that the BOJ's monetary policy was characterized by active policy stances in the late 1980s by estimating the VAR model. He pointed out that the BOJ's monetary policy was easing in 1986-1987 and it was tightening in 1989-1990. Summing up, these results seem to stress the importance of the BOJ's active policy stance in these periods.

On the other hand, Hirose (2008) estimated the financial accelerator effects in a DSGE model with a sunspot shock and found that the estimated monetary policy rule during 1980s was similar performance the optimal monetary policy rule that minimizes the welfare loss. Therefore, he concluded that the since the monetary policy could reduce the macroeconomic fluctuations in Japan, the endogenous volatility during the period were associated with the exogenous shocks that was induced by "bad luck" rather than "bad policy".

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[15] In their estimation, they introduced the exchange rate into the reaction function because the exchange rate plays a significant role in the Japanese economy during the latter of the 1980s.

[16] However, Bernanke and Gertler (2000) also pointed out that an increase in the policy rate should be justified if the BOJ combats the inflationary risk induced by stock price boom. Thus, they claimed that the central bank should not react to a fluctuation in asset prices as long as asset price fluctuations do not connect to the inflationary risk (namely, the FED view).

As shown in Figure 3, our model suggests that the BOJ could not prevent stock price bubble even if it put a larger weight on stock price stabilization in its reaction function. Figure 3 showed that a reaction function with a larger weight on stock prices leads to a persistent decline in the inflation rate, whereas it creates a more increased response of the stock price gap. This result might imply that even if the BOJ decided active monetary tightening in 1987, such a policy prescription could not prevent a drastic increase in stock prices that deviate from their fundamental values.

Figure 7 illustrates the impulse response to monetary policy shock under several parameter restrictions.[17] The first case corresponds to the case for no asset price channel. In this case, monetary tightening with stock price stabilization causes a decline in the stock price gap. A contractionary policy shock prevents a stock price boom in the case of $\xi = \phi_{x,s} = 0$. $\xi = 0$ implies that the model reduces to the RA model. This case corresponds to Carlstrom and Fuerst (2007). However, in the presence of stock price channel (i.e., $\xi > 0$), even a positive weight on stock prices in the reaction function cannot prevent a positive response of the stock price gap regardless of monetary tightening. Okina et al. (2001) argued the possibility that the BOJ could not have prevented the stock price bubble even if it decided to raise the official discount rate gradually in response to a sharp increase in stock prices. They asserted, instead, that a sharp increase in the policy rate might have been required to restrain the stock price bubble. Our result has shown that the BOJ might not have prevented the stock price bubble even if it decided to raise the policy rate sharply. In that sense, we might say that our result supports the assertion of Okina et al. (2001) in terms of a Bayesian DSGE investigation.

[Figure 7 around here]

How come the positive weight on stock prices did not prevent a stock price boom? In our model, it is possible that monetary tightening policy leads to a positive response of the stock price gap. A contractionary monetary policy causes a decline in output and inflation. The decline in the inflation rate reduces the real marginal cost. In our model, stock price dynamics proportionally change with the dividend, which is related positively to output and negatively to the real marginal cost.[18] Since monetary tightening induces a decline in the real

[17] In this simulation, we reestimate the model under each restriction.

[18] The log-linearized dividends are rewritten as follows $\hat{d}_t = \hat{y}_t - \frac{1-\alpha}{\alpha + \mu^p}(\hat{w}_t + \alpha \hat{l}_t)$. The dividend is the remaining of the income net of the cost in the production.

marginal cost, which increases the dividend. When the effect of a decline in the real marginal cost dominates that of decreased output, therefore, stock prices may increase in response to monetary tightening. Figure 8 plots the historical decomposition of the dividend. This figure shows that the dividend increases regardless of monetary tightening during 1989-1990. It follows from Figure 8 that the fluctuations in financial shocks during this period contributed significantly to this increase in dividends. This empirical finding is consistent with the model prediction and the assertion of Okina et al. (2001).

[Figure 8 around here]

7 Concluding remarks

This study reexamined the role of stock price stabilization in Japan. To do this, we adopted a DSGE model that included the wealth channel through stock prices. Our results showed the presence of the wealth channel through an increase in stock prices in Japan. In addition, we argued for the possibility that the BOJ conducted its monetary policy by giving weight to stock price stabilization as a policy objective in addition to controlling inflation and the output gap. However, our results indicate that while the BOJ might have reacted to stock prices that deviated from their fundamental values, it could not prevent a stock price bubble purely by implementing a contractionary monetary policy shock. Therefore, we conclude that the BOJ's monetary policy stance aimed to stabilize fluctuations in stock prices and minimize the macroeconomic volatility, whereas endogenous volatility was caused by bad shocks.

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A Appendix A: Castelnuovo and Nistico (2010) model

In this appendix, we provide a detailed explanation of the framework of the perpetual-youth NK model developed by Castelnuovo and Nistico (2010).

A.1 Households

The representative household obtains utility from consuming final goods and spending leisure. Thus, the household's preference is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t (1-\xi)^t e^{z_t^b} \left[\log\left(C_t(j,k) - hC_{t-1}\right) + \chi \log\left(1 - l_t(k)\right)\right],$$

where β is subjective discount factor, ξ is turnover rate, z_t^b is a shock to preference, $C_t(j,k)$ is individual consumption, C_t is aggregate consumption, h is a parameter of habit persistence, χ is the weight of leisure, $l_t(k)$ is hours worked.

The household's budget constraint is given by

$$C_t(j,k) + E_t f_{t,t+1} \frac{P_{t+1} B_{t+1}}{P_t} + \int_0^1 Q_t(i) Z_{t+1}(j,k,i) di = W_t(k) l_t(k) - T_t + \frac{1}{1-\xi} \Omega_t(j,k),$$

where $f_{t,t+1}$ is stochastic discount factor, P_t is price level, B_t is the household's nominal bond holdings, $Q_t(i)$ is real stock price, $Z_t(j,k,i)$ is equity share issued by intermediate good firms, $W_t(k)$ is real wage, T_t is a lump sum transfer and profit, and $\Omega_t(j,k)$ is financial wealth and defined as follows

$$\Omega_t(j,k) \equiv B_t(j,k) + \int_0^1 \left(Q_t(i) + D_t(i)\right) Z_t(j,k,i) di.$$

No-arbitrage condition is given by

$$E_t f_{t,t+1} = \frac{1}{R_t^n},$$

where R_t^n is the gross nominal interest rate.

The first-order conditions are summarized as follows

$$P_t Q_t = E_t f_{t,t+1} P_{t+1} \left(Q_{t+1}(i) + D_{t+1}(i)\right),$$

$$E_t f_{t,t+1} = \beta E_t \frac{P_t \tilde{C}_t(j,k)}{P_{t+1} \tilde{C}_{t+1}(j,k)} e^{z_{t+1}^b - z_t^b},$$

where $\tilde{C}_t(j,k) \equiv C_t(j,k) - hC_{t-1}$.

A.2 Retailers

Retailers produce final goods Y_t using intermediate goods $Y_t(i)$ to maximize their profit under the perfect competitive market. Their profit is given by $P_tY_t - \int_0^1 P_t(i)Y_t(i)di$. Here, Y_t is production function of retailers which is given by $Y_t = \left[\int_0^1 Y_t(i)^{1/(1+\mu_t^p)}di\right]^{(1+\mu_t^p)}$, where μ_t^p is the time varying price markup. The first-order condition for retailers is given by

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-(1+\mu_t^p)/\mu_t^p} Y_t, \tag{A.1}$$

which denotes the demand for intermediate goods. Given the perfect competitive market, the price level is given

$$P_t = \left(\int_0^1 P_t(i)^{-1/\mu_t^p}\right)^{-\mu_t^p}. \tag{A.2}$$

A.3 Intermediate good firms

Intermediate goods firm i produce output $Y_t(i)$ by using labor service $l_t(i)$. The production function of the intermediate goods firms is

$$Y_t(i) = A_t l_t(i)^{1-\alpha},$$

where $\alpha \in (0,1)$, $Y_t(i)$ is an intermediate good and A_t is a neutral technology level and the logarithm of it is given by

$$\ln A_t = \ln \gamma + \ln A_{t-1} + z_t^\gamma,$$

where γ is the growth rate of technology and z_t^γ is the stochastic term of technology.

The intermediate good firms set their prices to maximize their discount future profit in the monopolistically competitive market as given the demand for intermediate goods (A.1). Their price setting follows Calvo (1983). Specifically, while a fraction $1-\theta_p$ of all firms reoptimize their price, the remaining fraction θ_p firms that do not optimally set their price follows the indexation rule associated with past inflation and the steady state inflation rate. Regarding the firms that reoptimize their price, the first-order condition for P_t^o is given by

$$E_t \sum_{s=0}^{\infty} \theta_p^s f_{t,t+1} \frac{P_{t+s}Y_{t+s|t}}{\mu_{t+s}^p}\left[\frac{P_t^o}{P_{t+s}}\left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{\iota_p} \pi^{s(1-\iota_p)} - (1+\mu_{t+s}^p)mc_{t+s|t}\right] = 0,$$

where P_t^o is the reoptimized price, ι_p is the degree of price indexation and $mc_{t+s|t}$ is the economy wide marginal cost and expressed as follows

$$mc_{t+s|t} = mc_{t+s}\left\{\frac{P_t^o}{P_{t+s}}\left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{\iota_p}\pi^{s(1-\iota_p)}\right\}^{-\alpha/(1-\alpha)(1+\mu_t^p)/\mu_t^p}.$$

Here, mc_t is average marginal cost and given by

$$mc_t = \frac{W_t}{(1-\alpha)A_t}\left(\frac{Y_t}{A_t}\right)^{\alpha/(1-\alpha)}.$$

Given staggered price manner, the price level (A.2) is transformed as follows

$$P_t = \left\{\theta_p(P_{t-1}\pi_{t-1}^{\iota_p}\pi^{1-\iota_p})^{-1/\mu_t^p} + (1-\theta_p)(P_t^o)^{-1/\mu_t^p}\right\}^{-\mu_t^p}.$$

A.4 Labor unions

Labor unions negotiate with intermediate goods firms with respect to wage setting and set nominal wages in order to maximize the discount future income in the monopolistically competitive market as given the demand for the labor service $l_t(k) = (W_t(k)/W_t)^{-(1+\mu_t^w)/\mu_t^w} l_t$. Here, $l_t = \left[\int_0^1 l_t(k)^{1/(1+\mu_t^w)}dk\right]^{(1+\mu_t^w)}$ is the aggregate labor hours and $W_t = \left[\int_0^1 W_t(k)^{-1/\mu_t^w}dk\right]^{-\mu_t^w}$ is the aggregate real wage. Note that they are not always free to change the wage and their wage setting follows the price setting manner of Calvo (1983). While a fraction $1-\theta_w$ of all firms reoptimizes their wage, the remaining fraction θ_w unions that do not optimally change their wage follows the indexation rule related with the past inflation and the productivity growth. As for the labor unions that reoptimize their wage, the first-order condition for W_t^o is given by

$$E_t\sum_{s=0}^{\infty}\theta_w^s f_{t,t+s}\frac{l_{t+s|t}}{\mu_{t+s}^w}\left[P_tW_t^o\left(\frac{P_{t+s-1}}{P_{t-1}}\frac{A_{t+s-1}}{A_{t-1}}\right)^{\iota_w}(\pi\gamma)^{s(1-\iota_w)} - (1+\mu_{t+s}^w)P_{t+s}MRS_{t+s|t}\right] = 0,$$

where W_t^o denotes the optimized real wage, μ_{t+s}^w is the time varying wage markup, ι_w is the degree of the wage indexation, and $MRS_{t+s|t}$ is the average marginal rate of substitution between consumption and labor hours. The relationship between average and economy-wide real marginal costs MRS_t is characterized as follows:

$$MRS_{t+s|t} = MRS_{t+s}\frac{1-l_{t+s}}{1-l_{t+s}\left\{\frac{P_tW_t^o}{P_{t+s}W_{t+s}}\left(\frac{P_{t+s-1}}{P_{t-1}}\frac{A_{t+s-1}}{A_{t-1}}\right)^{\iota_w}(\pi\gamma)^{s(1-\iota_w)}\right\}^{-(1+\mu_{t+s}^w)/\mu_{t+s}^w}},$$

where $MRS_{t+s|t}$ is the average MRS and MRS_{t+s} is the economy-wide MRS and defined as follows

$$MRS_{t+s} \equiv \chi\frac{\tilde{C}_{t+s}}{1-l_{t+s}}.$$

Given staggered wage setting, the aggregate wage index is transformed as follows

$$P_t W_t = \left[\theta_w \left\{P_{t-1}W_{t-1}\left(\pi_{t-1}\gamma e^{z_{t-1}}\right)^{\iota_w}(\pi\gamma)^{1-\iota_w}\right\}^{-1/\mu_t^w} + (1-\theta_w)(P_t W_t^o)^{-1/\mu_t^w}\right]^{-\mu_t^w}.$$

A.5 Market clearing condition

The market clearing condition for the final goods is given[19]

$$Y_t = C_t + g e^{z_t^g} A_t.$$

A.6 Log-linearized model

A.6.1 Key equations

$$\hat{y}_t = \frac{c}{y}\hat{c}_t + \frac{g}{y}z_t^g, \tag{A.3}$$

$$\begin{aligned}\hat{c}_t - \frac{h}{\gamma}\left(\hat{c}_{t-1} - z_t^\gamma\right) = &\frac{1-h/\gamma}{1-h/\gamma+\psi}\psi\hat{q}_t - \frac{(1-h/\gamma)^2}{1-h/\gamma+\psi}\left(\hat{R}_t^n - E_t\hat{\pi}_{t+1}\right)\\ &+ \frac{1-h/\gamma}{1-h/\gamma+\psi}\left(E_t\hat{c}_{t+1} - \frac{h}{\gamma}\hat{c}_t + E_t z_{t+1}^\gamma\right)\\ &- (1-h/\gamma)(1+\psi_b)\,E_t\left(z_{t+1}^b - z_t^b\right),\end{aligned} \tag{A.4}$$

$$\hat{q}_t = \tilde{\beta}E_t\hat{q}_{t+1} + (1-\tilde{\beta})E_t\hat{d}_{t+1} - \left(\hat{R}_t^n - E_t\hat{\pi}_{t+1}\right) + E_t z_{t+1}^\gamma + z_t^\nu, \tag{A.5}$$

$$\hat{d}_t = \hat{y}_t - \frac{1-\alpha}{\alpha+\mu^p}\hat{mc}_t, \tag{A.6}$$

$$\hat{l}_t = \frac{1}{1-\alpha}\hat{y}_t, \tag{A.7}$$

$$\hat{mw}_t = \varphi\hat{l}_t + \frac{1}{1-h/\gamma}\hat{c}_t - \frac{h/\gamma}{1-h/\gamma}\left(\hat{c}_{t-1} - z_t^\gamma\right) - \hat{w}_t, \tag{A.8}$$

$$\hat{mc}_t = \hat{w}_t + \frac{\alpha}{1-\alpha}\hat{y}_t. \tag{A.9}$$

[19]Unlike Castelnuovo and Nistico (2010), our analysis assume that a public sector does not consume the fraction of total output and its consumption is stochastically decided.

A.6.2 Frictionless equilibrium

$$\hat{y}_t^* = \frac{h/\gamma(1-\alpha)}{1-\alpha+(\alpha+\varphi)(1-h/\gamma)(1-g/y)}\hat{y}_{t-1}^* + \frac{(1-\alpha)(1-g/y)}{1-\alpha+(\alpha+\varphi)(1-h/\gamma)(1-g/y)}\left\{\frac{g/y}{1-g/y}\left(z_t^g - \frac{h}{\gamma}z_{t-1}^g\right) + \frac{h}{\gamma}z_t^\gamma\right\}, \tag{A.10}$$

$$\hat{w}_t^* = \frac{h/\gamma(1-\alpha)}{1-\alpha+(\alpha+\varphi)(1-h/\gamma)(1-g/y)}\hat{w}_{t-1}^* - \frac{\alpha(1-g/y)}{1-\alpha+(\alpha+\varphi)(1-h/\gamma)(1-g/y)}\left\{\frac{g/y}{1-g/y}\left(z_t^g - \frac{h}{\gamma}z_{t-1}^g\right) + \frac{h}{\gamma}z_t^\gamma\right\}, \tag{A.11}$$

$$\begin{aligned}\hat{R}_t^* = &\frac{1}{1-h/\gamma}\left\{\frac{1}{1-g/y}\left(E_t\hat{y}_{t+1}^* - \frac{g}{y}E_t z_{t+1}^g\right) + E_t z_{t+1}^\gamma\right\} \\ &- \frac{h/\gamma}{(1-h/\gamma)(1-g/y)}\left(\hat{y}_t^* - \frac{g}{y}z_t^g\right) \\ &- \frac{1-h/\gamma+\psi}{(1-h/\gamma)^2(1-g/y)}\left(\hat{y}_t^* - \frac{g}{y}z_t^g\right) \\ &+ \frac{(1-h/\gamma+\psi)h/\gamma}{(1-h/\gamma)^2}\left\{\frac{1}{1-g/y}\left(\hat{y}_{t-1}^* - \frac{g}{y}z_{t-1}^g\right) - z_t^\gamma\right\} \\ &- \frac{(1-h/\gamma+\psi)(1+\psi_b)}{1-h/\gamma}\left(E_t z_{t+1}^b - z_t^b\right),\end{aligned} \tag{A.12}$$

$$\hat{q}_t^* = \tilde{\beta}E_t\hat{q}_{t+1}^* + (1-\tilde{\beta})E_t\hat{y}_{t+1}^* - \hat{R}_t^* + E_t z_{t+1}^\gamma. \tag{A.13}$$

A.6.3 Steady states

The steady states in the log-linearized equilibrium conditions are as follows.

$$
\begin{aligned}
\frac{c}{y} &= 1 - \frac{g}{y}, \\
\frac{\omega}{c} &= \frac{R^n(\mu^p + \alpha)}{(R^n - \gamma\pi)(1 + \mu^p)c/y}, \\
\psi &= \frac{\xi\{1 - \beta(1 - \xi)\}}{1 - \xi} \frac{\omega}{c}, \\
\tilde{\beta} &= \frac{\beta(1 - h/\gamma)}{1 - h/\gamma + \psi}, \\
\varphi &= \frac{1 - \alpha}{\chi(1 - h/\gamma)(1 + \mu^w)(1 + \mu^p)c/y}, \\
\psi_b &= \frac{\psi\beta(1 - \xi)\rho_b}{(1 + \psi - h/\gamma)\{1 - \beta(1 - \xi)\rho_b\}}, \\
\lambda_p &= \frac{\mu^p(1 - \theta_p)(1 - \tilde{\beta}\theta_p)(1 - \alpha)}{\theta_p(\alpha + \mu^p)}, \\
\lambda_w &= \frac{\mu^w(1 - \theta_w\tilde{\beta})(1 - \theta_w)}{\theta_w\{\mu^w + \varphi(1 + \mu^w)\}}.
\end{aligned}
$$

B Appendix B: Data sources

We provide the detailed explanation how to make a data set to estimate the DSGE model. The data series we use in this paper are as follows:[20]

- Gross Domestic Product (Source: Cabinet Office, "National Account.")
- GDP deflator (Source: Cabinet Office, "National Account.")
- Call rate (Source: Bank of Japan)
- Nikkei 225 (Source: Federal Reserve Bank of St. Louis)
- Nominal consumption (Source: Cabinet Office, "National Account.")
- Nominal wage (Source: Ministry of Health, Labor and Welfare, "Monthly Labour Survey.")
- Labor hour (Source: Ministry of Health, Labor and Welfare, "Monthly Labour Survey.")

[20]For time series data of real GDP, GDP deflator, and nominal consumption, simple retrospective series up to 1993Q4 are used for estimation to maintain consistency in the base year.

- Population over 15 years old (Source: Statistics Bureau, Ministry of Internal Affairs and Communications, "Labor Force Survey.")

References

Adjemian, S., Bastani, H., Juillard, M., Mihoubi, F., Perendia, G., Ratto, M., Villemot, S., 2011. Dynare: Reference manual, version 4 .

Airaudo, M., 2013. Monetary policy and stock price dynamics with limited asset market participation. Journal of Macroeconomics 36, 1–22.

Airaudo, M., Cardani, R., Lansing, K.J., 2013. Monetary policy and asset prices with belief-driven fluctuations. Journal of Economic Dynamics and Control 37, 1453–1478.

Bernanke, B., Gertler, M., 2000. Monetary policy and asset price volatility. Technical Report. National bureau of economic research.

Blanchard, O.J., 1985. Debt, deficits, and finite horizons. Journal of political economy 93, 223–247.

Calvo, G.A., 1983. Staggered prices in a utility-maximizing framework. Journal of monetary Economics 12, 383–398.

Carlstrom, C.T., Fuerst, T.S., 2007. Asset prices, nominal rigidities, and monetary policy. Review of Economic Dynamics 10, 256–275.

Castelnuovo, E., Nistico, S., 2010. Stock market conditions and monetary policy in a dsge model for the us. Journal of Economic Dynamics and Control 34, 1700–1731.

Cecchetti, S.G., Genberg, H., Wadhwani, S., 2002. Asset prices in a flexible inflation targeting framework. Technical Report. National Bureau of Economic Research.

Chadha, J.S., Sarno, L., Valente, G., 2004. Monetary policy rules, asset prices, and exchange rates. IMF Staff Papers 51, 529–552.

Erceg, C.J., Henderson, D.W., Levin, A.T., 2000. Optimal monetary policy with staggered wage and price contracts. Journal of monetary Economics 46, 281–313.

Faia, E., Monacelli, T., 2007. Optimal interest rate rules, asset prices, and credit frictions. Journal of Economic Dynamics and control 31, 3228–3254.

Gambacorta, L., Signoretti, F.M., 2014. Should monetary policy lean against the wind?: An analysis based on a dsge model with banking. Journal of Economic Dynamics and Control 43, 146–174.

Gilchrist, S., Leahy, J.V., 2002. Monetary policy and asset prices. Journal of monetary Economics 49, 75–97.

Haugh, D.L., 2018. Monetary policy under uncertainty about the nature of asset-price shocks. Fourteenth issue (September 2008) of the International Journal of Central Banking .

Hirakata, N., Sudo, N., Takei, I., Ueda, K., 2016. Japan's financial crises and lost decades. Japan and the World Economy 40, 31–46.

Hirose, Y., 2008. Equilibrium indeterminacy and asset price fluctuation in japan: A bayesian investigation. Journal of Money, Credit and Banking 40, 967–999.

Hirose, Y., Kurozumi, T., 2012. Do investment-specific technological changes matter for business fluctuations? evidence from japan. Pacific Economic Review 17, 208–230.

Iacoviello, M., 2005. House prices, borrowing constraints, and monetary policy in the business cycle. American economic review 95, 739–764.

Iiboshi, H., Nishiyama, S.I., Watanabe, T., 2006. An estimated dynamic stochastic general equilibrium model of the japanese economy: A bayesian analysis .

Jinushi, T., Kuroki, Y., Miyao, R., 2000. Monetary policy in japan since the late 1980s: delayed policy actions and some explanations. Japan's financial crisis and its parallels to US experience , 115–48.

Kaihatsu, S., Kurozumi, T., 2014. Sources of business fluctuations: Financial or technology shocks? Review of Economic Dynamics 17, 224–242.

Kannan, P., Rabanal, P., Scott, A.M., 2012. Monetary and macroprudential policy rules in a model with house price booms. The BE Journal of Macroeconomics 12.

Matsumae, T., Iiboshi, H., Namba, R., Nishiyama, S., 2011. An application of hybrid mcmc and simulation smoother in estimating a dsge model with measurement errors. J. Japan Statist. Soc. Japanese Issue 41, 83–121.

Miyao, R., 2002. The effects of monetary policy in japan. Journal of Money, Credit and Banking , 376–392.

Muto, I., Sudo, N., Yoneyama, S., et al., 2016. Productivity Slowdown in Japan's Lost Decades: How Much of It Can Be Attributed to Damaged Balance Sheets? Technical Report. Bank of Japan.

Nisticò, S., 2012. Monetary policy and stock-price dynamics in a dsge framework. Journal of Macroeconomics 34, 126–146.

Ogawa, K., 2003. Daifukyo no keizai bunseki. Nihon Keizai Shinbun Sha.

Okina, K., Shirakawa, M., Shiratsuka, S., 2001. The asset price bubble and monetary policy: Japan's experience in the late 1980s and the lessons. Monetary and Economic Studies (special edition) 19, 395–450.

Pfajfar, D., Santoro, E., 2014. Credit market distortions, asset prices and monetary policy. Macroeconomic Dynamics 18, 631–650.

Shibamoto, M., Takahashi, W., Kamihigashi, T., et al., 2020. Japan's Monetary Policy: A Literature Review and An Empirical Assessment. Research Institute for Economics and Business Administration, Kobe University.

Sugo, T., Ueda, K., 2008. Estimating a dynamic stochastic general equilibrium model for japan. Journal of the Japanese and International Economies 22, 476–502.

Taylor, J.B., 1993. Discretion versus policy rules in practice, in: Carnegie-Rochester conference series on public policy, Elsevier. pp. 195–214.

Yaari, M.E., 1965. Uncertain lifetime, life insurance, and the theory of the consumer. The Review of Economic Studies 32, 137–150.

Table 1: Priors and posteriors

Parameters		Type	Prior		Posterior	
			Mean	SD	Mean	90% interval
ξ	Turnover rate	Uniform	$[0,1]$		0.046	[0.026, 0.066]
h	Habit persistence	Beta	0.700	0.150	0.174	[0.076, 0.266]
χ	Leisure weight	Gamma	1.400	1.000	0.031	[0.001, 0.061]
θ_p	Intermediate good price stickiness	Beta	0.375	0.100	0.883	[0.855, 0.914]
θ_w	Wage stickiness	Beta	0.375	0.100	0.216	[0.110, 0.320]
ι_p	Intermediate good price indexation	Beta	0.500	0.250	0.041	[0.000, 0.084]
ι_w	Wage indexation	Beta	0.500	0.250	0.057	[0.001, 0.110]
ϕ_r	Monetary policy rate smoothing	Beta	0.800	0.100	0.958	[0.931, 0.987]
ϕ_π	Monetary policy response to inflation	Gamma	1.700	0.100	1.671	[1.507, 1.832]
$\phi_{x.y}$	Monetary policy response to output gap	Gamma	0.125	0.050	0.137	[0.049, 0.220]
$\phi_{x.s}$	Monetary response to stock price gap	Normal	0.000	0.025	0.164	[-0.096, 0.423]
$\overline{\gamma}$	Steady state rate of balanced growth	Gamma	0.480	0.100	0.468	[0.344, 0.591]
$\overline{\pi}$	Steady state inflation rate	Gamma	0.240	0.100	0.256	[0.125, 0.385]
$\overline{R}^n$	Steady state interest rate	Gamma	1.090	0.100	1.101	[0.940, 1.258]
ρ_γ	Persistence in z_t^γ	Beta	0.500	0.200	0.079	[0.015, 0.141]
ρ_p	Persistence in z_t^p	Beta	0.500	0.200	0.109	[0.022, 0.191]
ρ_w	Persistence in z_t^w	Beta	0.500	0.200	0.555	[0.320, 0.784]
ρ_g	Persistence in z_t^g	Beta	0.500	0.200	0.958	[0.926, 0.993]
ρ_b	Persistence in z_t^b	Beta	0.500	0.200	0.361	[0.049, 0.665]
ρ_ν	Persistence in z_t^ν	Beta	0.500	0.200	0.958	[0.928, 0.989]
ρ_r	Persistence in z_t^r	Beta	0.500	0.200	0.325	[0.129, 0.519]
ρ_{mq}	Persistence in me_t	Beta	0.500	0.200	0.367	[0.203, 0.530]
σ_γ	Standard deviation of z_t^γ	Inverse gamma	0.500	inf	1.010	[0.870, 1.145]
σ_p	Standard deviation of z_t^p	Inverse gamma	0.500	inf	0.431	[0.363, 0.495]
σ_w	Standard deviation of z_t^w	Inverse gamma	0.500	inf	0.504	[0.368, 0.638]
σ_g	Standard deviation of z_t^g	Inverse gamma	0.500	inf	1.770	[1.529, 2.006]
σ_b	Standard deviation of z_t^b	Inverse gamma	0.500	inf	0.447	[0.159, 0.715]
σ_ν	Standard deviation of z_t^ν	Inverse gamma	0.500	inf	0.561	[0.352, 0.766]
σ_r	Standard deviation of z_t^r	Inverse gamma	0.500	inf	0.123	[0.106, 0.141]
σ_{mq}	Standard deviation of me_t^{mq}	Inverse gamma	0.500	inf	6.986	[6.033, 7.936]

Table 2: Comparison of models

	Baseline	$\xi = 0$	$\phi_{x.s} = 0$	$\xi = \phi_{x.s} = 0$
ξ	0.046	0	0.050	0
h	0.174	0.145	0.162	0.149
χ	0.031	0.027	0.029	0.042
θ_p	0.883	0.319	0.882	0.296
θ_w	0.216	0.525	0.187	0.436
ι_p	0.041	0.050	0.042	0.058
ι_w	0.057	0.046	0.059	0.057
ϕ_π	1.671	1.691	1.681	1.776
$\phi_{x.y}$	0.137	0.148	0.136	0.159
$\phi_{x.s}$	0.164	0.452	0	0
ϕ_r	0.958	0.849	0.964	0.797
Log-marginal likelihood	−641.23	−626.92	−641.53	−631.01

Table 3: Comparison of models

	$\phi_{x.s} = 0.164$	$\phi_{x.s} = 0.25$	$\phi_{x.s} = 0.5$	$\phi_{x.s} = 0.75$
ϕ_π	1.671	1.662	1.675	1.687
$\phi_{x.y}$	0.137	0.139	0.132	0.132
ϕ_r	0.958	0.954	0.967	0.976
Log-marginal likelihood	−641.23	−640.31	−641.27	−643.20

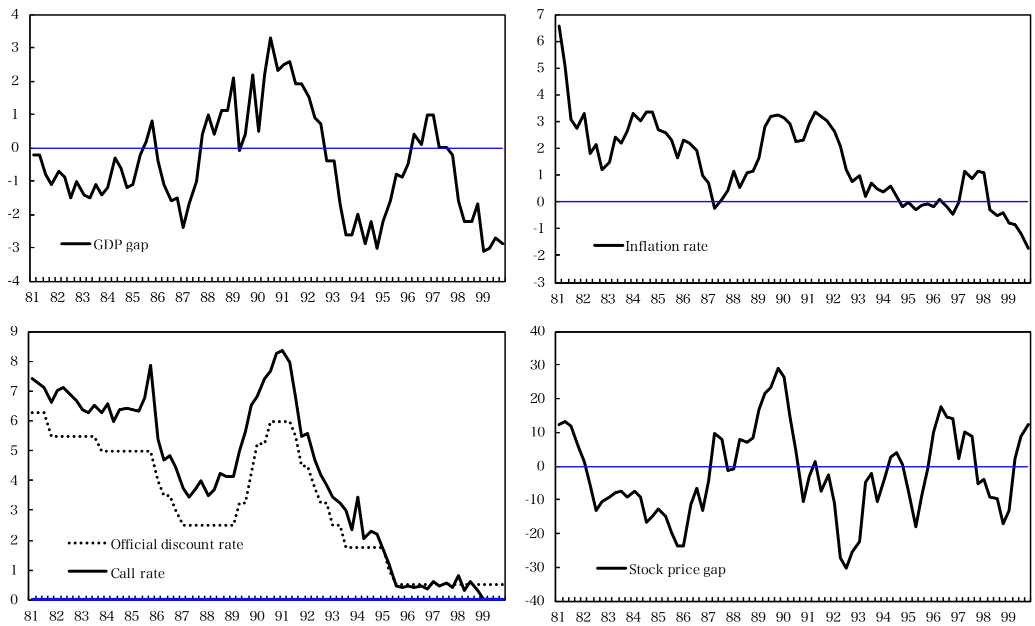
Table 4: Variance decomposition

Shock		Stock price gap $T=8$	Stock price gap $T=32$	Stock price growth $T=8$	Stock price growth $T=32$	Inflation $T=8$	Inflation $T=32$
z_t^γ	Neutral technology shock	4.8	3.4	3.9	3.9	0.2	0.2
z_t^p	Price markup shock	3.1	2.8	0.1	0.1	92.1	85.5
z_t^w	Wage markup shock	14.5	10.2	0.3	0.3	0.2	0.2
z_t^g	Exogenous demand shock	45.3	49.9	0.3	0.3	1.2	1.8
z_t^b	Preference shock	7.2	5.0	0.0	0.0	0.0	0.0
z_t^ν	Financial shock	18.7	14.0	0.7	0.7	4.4	8.3
z_t^r	Monetary policy shock	5.9	14.6	0.0	0.0	1.5	3.6

Shock		Output gap $T=8$	Output gap $T=32$	Output growth $T=8$	Output growth $T=32$	Interest rate $T=8$	Interest rate $T=32$
z_t^γ	Neutral technology shock	7.0	6.9	82.5	82.5	0.0	0.0
z_t^p	Price markup shock	1.6	1.6	0.5	0.5	4.9	4.1
z_t^w	Wage markup shock	22.2	22.0	2.5	2.5	0.3	0.4
z_t^g	Exogenous demand shock	14.8	14.6	4.6	4.6	2.2	9.6
z_t^b	Preference shock	8.2	8.1	3.7	3.7	0.1	0.0
z_t^ν	Financial shock	36.0	36.1	5.1	5.1	2.4	9.0
z_t^r	Monetary policy shock	9.9	10.3	0.9	0.9	89.7	76.5

Table 5: Comparison of models: Robustness check

	Baseline	$\xi=0$	$\phi_{x.s}=0$	$\xi=\phi_{x.s}=0$
$\phi_{x.s}$	0.008	0.001	0	0
Log-marginal likelihood	−643.76	−641.09	−642.02	−636.69



Source: Bank of Japan (call rate, GDP gap, offical discount rate), Cabinet Office National Accounts (GDP deflator), Nikkei industry Research Institution via FRED, Federal Reserve Bank of St. Louis (Nikkei Stock Average Nikkei 225)

Figure 1: Time series data in the Japanese economy: From 1980s to 1990s

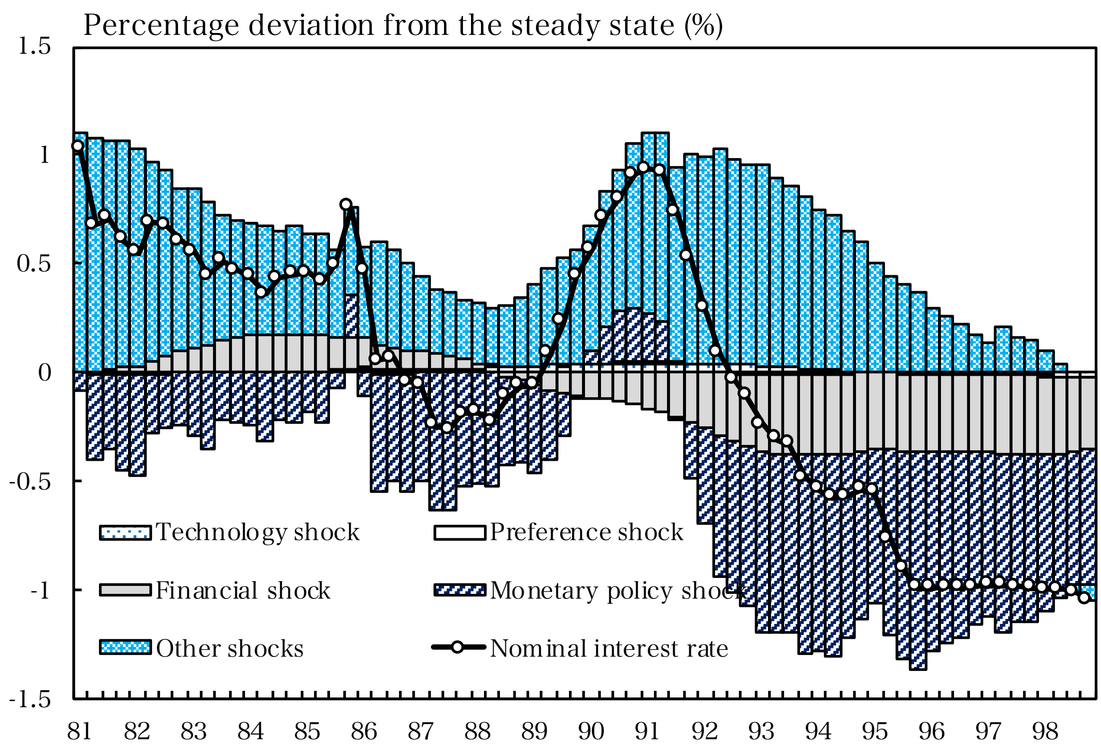


Figure 2: Historical decomposition of nominal interest rate

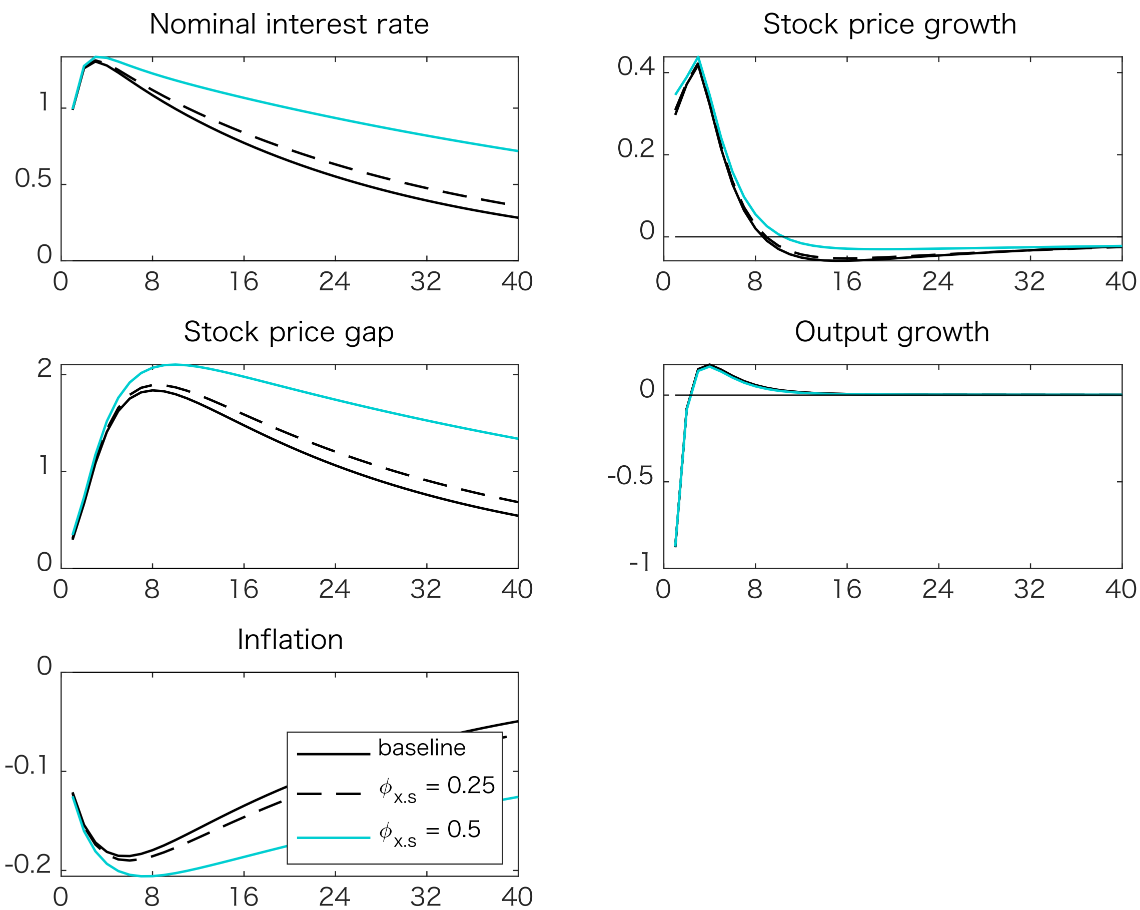


Figure 3: Impulse responses to the monetary policy shock

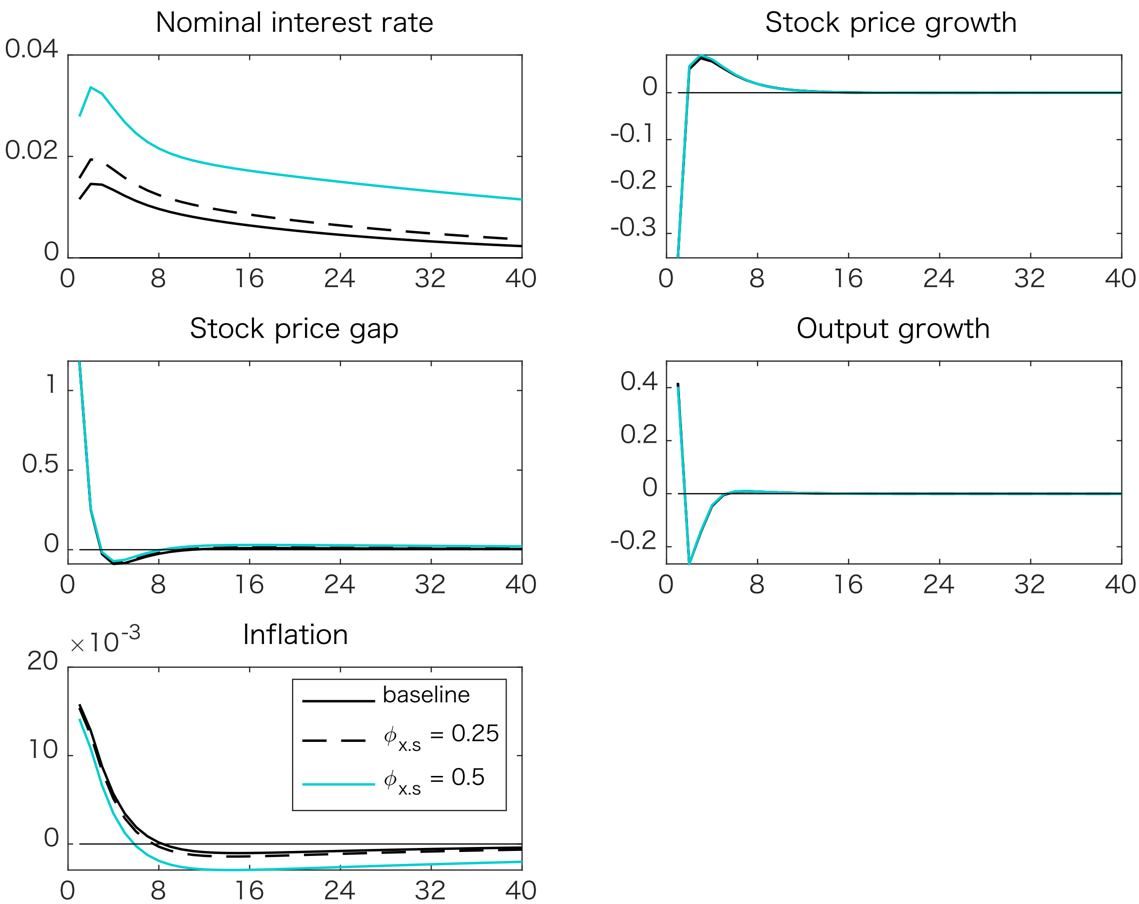


Figure 4: Impulse responses to the preference shock

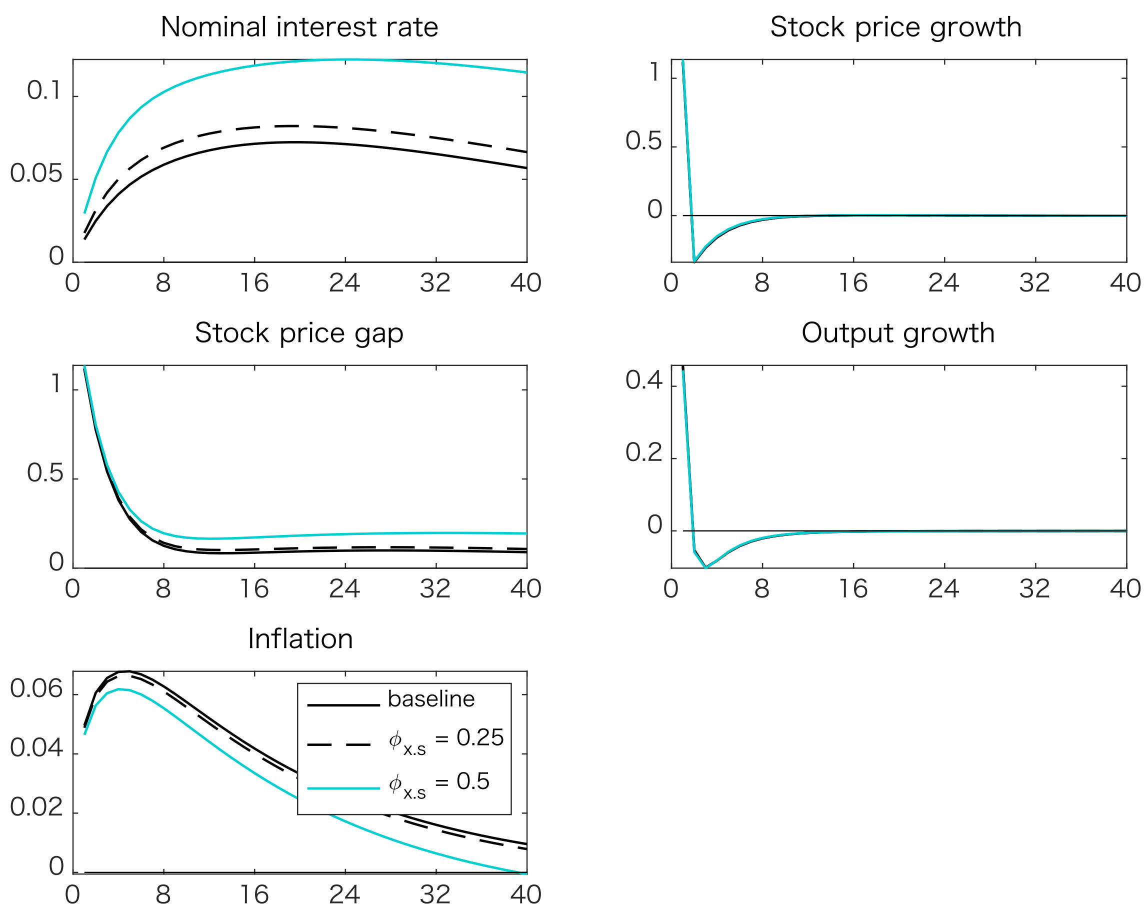


Figure 5: Impulse responses to the financial shock

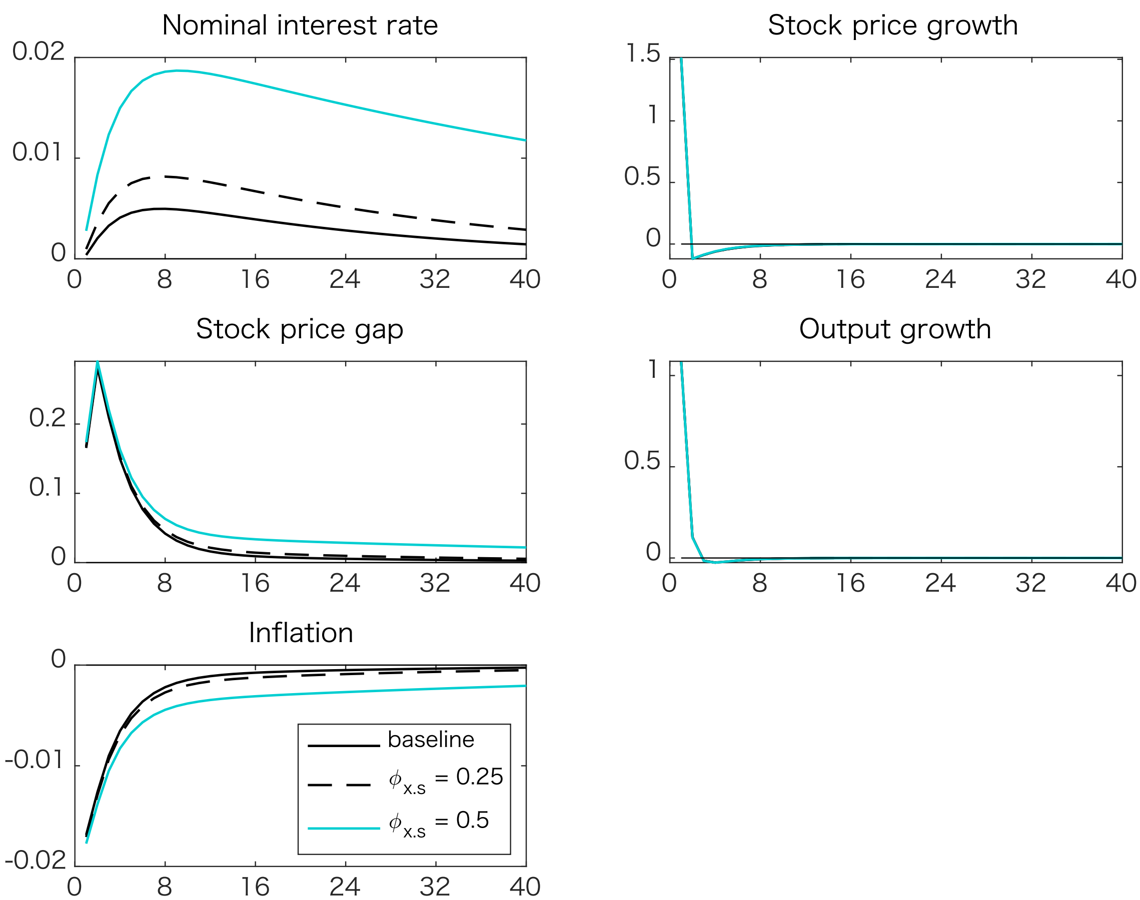


Figure 6: Impulse responses to the neutral technology shock

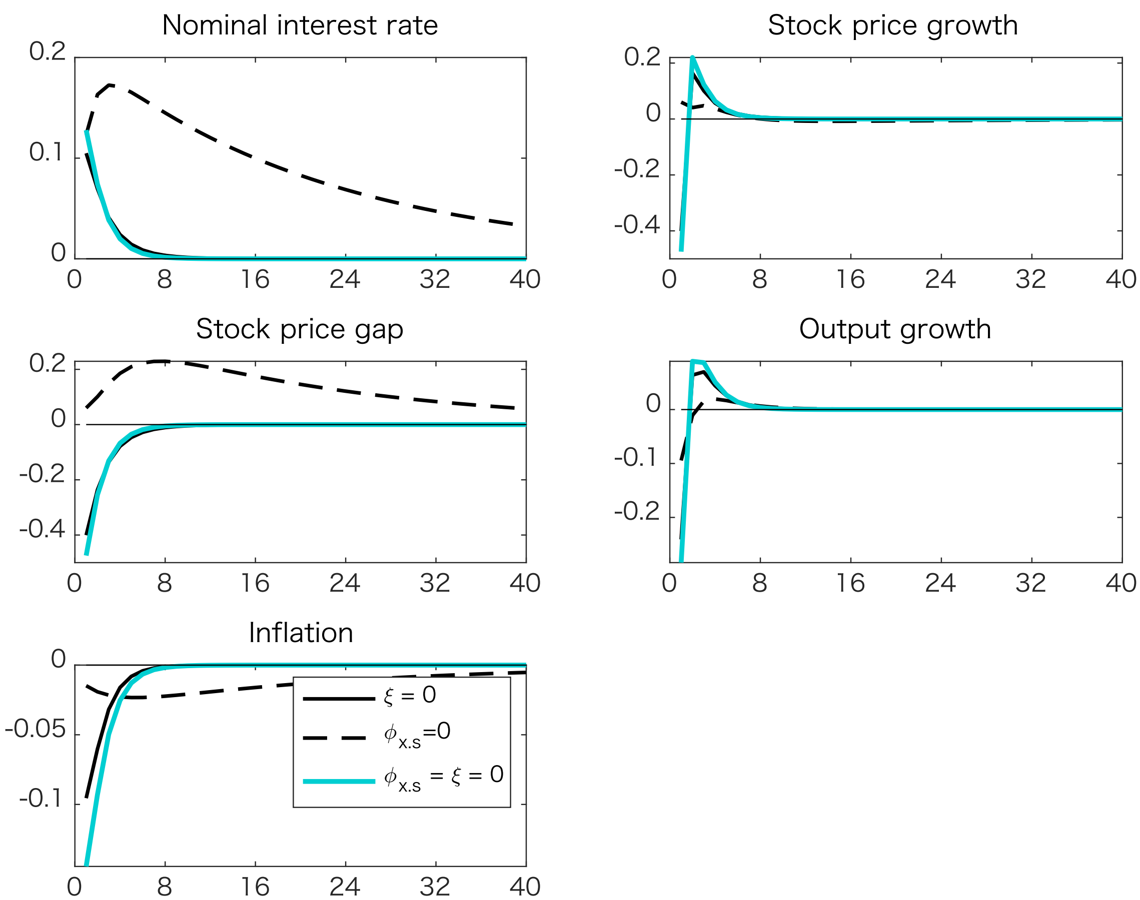


Figure 7: Impulse responses to the monetary policy shock

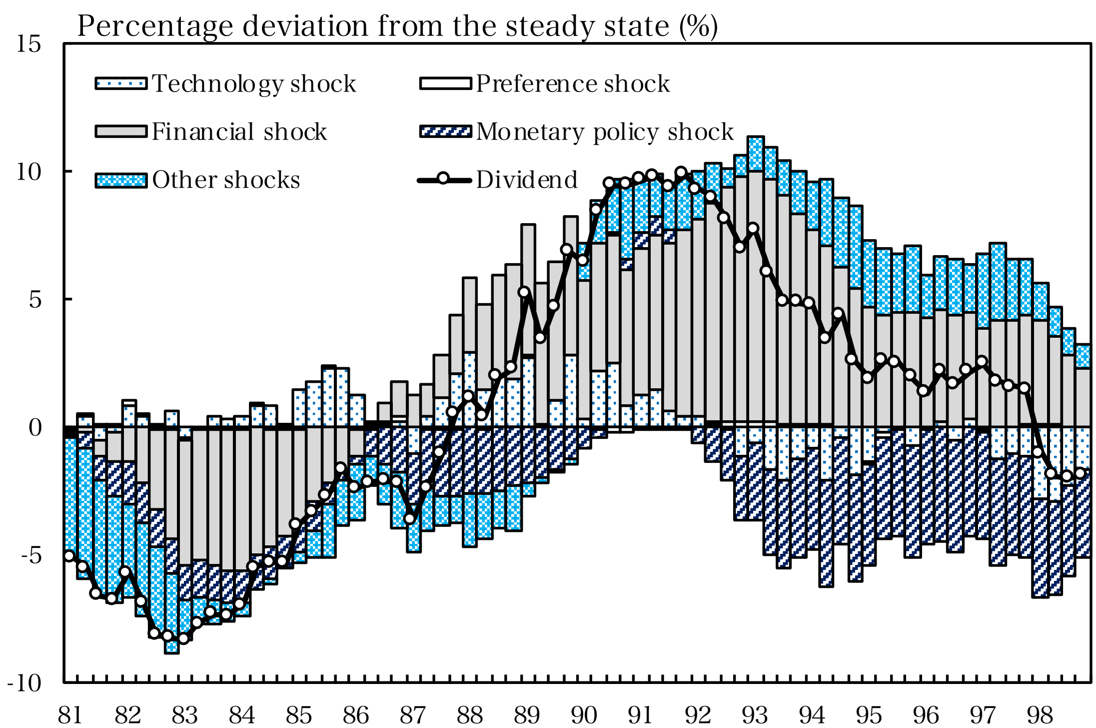


Figure 8: Historical decomposition of dividend