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Japanese Monetary Policy during the Collapse of the Bubble Economy: A View of Policy-making under Uncertainty

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Abstract

Focusing on policy-making under uncertainty, we analyze the Bank of Japan's monetary policy in the early 1990s when the bubble economy collapsed. Conducting stochastic simulations with a large-scale macroeconomic model of the Japanese economy, we find that the BOJ's monetary policy at that time was essentially optimal under uncertainty about the policy multiplier. On the other hand, we also find that the BOJ's policy was not optimal under uncertainty about inflation dynamics, and that a more aggressive policy response than actually implemented would have been needed. Thus, optimal monetary policy differs greatly depending upon which type of uncertainty is emphasized. Taking into account the fact that overcoming deflation became an important issue from the latter 1990s, it is possible to argue that during the early 1990s the BOJ should have placed greater emphasis on uncertainty about inflation dynamics and implemented a more aggressive monetary policy. The result from a counter-factual simulation indicates that the inflation rate and the real growth rate would have been higher to some extent if the BOJ had implemented a more accommodative policy during the early 1990s. However, the simulation result also suggests that the effects would have been limited, and that an accommodative monetary policy itself would not have changed the overall image of the prolonged stagnation of the Japanese economy during the 1990s.

Keywords: Collapse of the Bubble Economy; Monetary Policy; Uncertainty

JEL classification: E17, E52

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1. Introduction

Some hold that the prolonged stagnation of the Japanese economy in the 1990s was primarily caused by a delay in monetary easing by the Bank of Japan (BOJ) during the early 1990s.[1] Most of these assertions are based on research findings that the level of the actual policy rate (call rate) tended to be high compared with the rate indicated by the Taylor rule.[2] Others claim that compared with an estimated policy response function during the period 1975-1985, when the Japanese economy demonstrated good performance, the monetary policy tended to be tight during the early 1990s (Jinushi et al. [2001]).

Needless to say, these positions assume that their benchmark policy rules were optimal for the Japanese economy in the early 1990s. However, it is not possible to discuss whether or not the concerned rules were really optimal without taking the economic structure into account. For example, the original Taylor rule is a depiction of the monetary policy of the US Federal Reserve Board (FRB) during 1987-1992, and not an indication that this rule was ideal for achieving the stability of the US economy at that time (Taylor [1993]). Moreover, even if we hypothetically assume that the Taylor rule was optimal for the US at that time, this provides no guarantee that it was also optimal for the Japanese economy of the 1990s. Furthermore, the research by Jinushi et al. [2001] which uses the estimated policy response function during 1975-1985 as a benchmark may be considered to have similar problems since their analyses are not based on a macroeconomic model of the Japanese economy.

In contrast, the analyses in Ahearne et al. [2002], which similarly maintains that deflation could have been averted through early monetary easing, do conduct simulations using a macroeconomic model of the Japanese economy (FRB/Global).

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1 For example, Hamada [2004] makes the following comment. “Deflation has continued from the 1990s to the present. Therefore, the prolonged economic stagnation is a deflationary problem, and the argument that the prolonged stagnation was caused by the failure of monetary policy is entirely reasonable.” See Noguchi and Okada [2003] and Okada and Iida [2004] for similar opinions.

2 For example, Bernanke and Gertler [1999], McCallum [2001], and Taylor [2001] note that the interest rate level during the early 1990s was high compared with that indicated by the Taylor rule, or that the pace of monetary easing was slow compared with that indicated by the Taylor rule.

Specifically, Ahearne et al. [2002] finds that deflation could have been avoided if interest rates had been permanently decreased by 2.5% at the beginning of 1991, the beginning of 1994, or the beginning of 1995. However, this retrospective policy prescription of "early and large-scale monetary easing" takes a particular economic model as a given and assumes that the BOJ had accurate knowledge regarding the economic structure. Can such a policy prescription be considered realistic?

In practice, central banks always face uncertainty about the economic structure, and have to conduct monetary policy under such uncertainty. In the early 1990s, the BOJ was facing uncertainty about the effects of its unprecedented low interest rate policy on the economy, i.e. multiplier uncertainty. In fact, the BOJ was then being subjected to harsh criticism that its long maintenance of the historically very low official discount rate of 2.5% during the latter 1980s had caused the emergence of the economic bubble. So it may be not at all unreasonable that at that time the BOJ was hesitant about dropping interest rates below 2.5% and particularly cautious regarding the risks of diverse side effects if low interest rates were maintained for a long period of time. Some suggest that when faced with this sort of multiplier uncertainty it is desirable for the authorities to implement conservative monetary policy (Brainard [1967]). Specifically, when the "Brainard conservatism" is considered, the BOJ's decision to cautiously advance monetary easing in the early 1990s can be theoretically justified.

Based on all the above points, to evaluate the BOJ's monetary policy during the early 1990s it is necessary not only to use a macroeconomic model of the Japanese economy, but also to implement analyses which consider the uncertainty confronting the BOJ. There are various types of uncertainty aside from multiplier uncertainty, such as uncertainty about the inflation process and about the persistence of demand shocks. Hence we need to evaluate whether the BOJ, while considering such uncertainty regarding the economic structure, could have or should have implemented monetary easing earlier in terms of a real time policy judgment.

Based on this awareness of the issues, we evaluate the BOJ's monetary policy during the early 1990s by introducing the uncertainty regarding the economic structure into the

JEM (Japanese Economic Model), a quantitative macroeconomic model developed by the BOJ's Research and Statistics Department. In this paper, we employ two approaches that the authorities can utilize to policy conduct, facing uncertainty about parameters of economic structure. The first is to aim at minimizing the expected loss, given a prior belief about the distribution of uncertain parameters. Hereafter, for convenience, this is referred to as the "Bayesian Approach." The second approach is to adopt the best policy assuming the parameter values which cause the worst case scenario for the authorities within the some range of uncertain parameters. This is referred to as the "minimax approach" (or the "robust approach") in the sense that it aims at minimizing the maximum loss. This paper evaluates the BOJ's policy via stochastic simulations based on these two approaches. The four main conclusions reached are as follows

(1) The stochastic simulation using the JEM suggests that the BOJ's monetary policy during the early 1990s was essentially optimal under uncertainty about the policy multiplier. This conclusion holds under both the Bayesian and the minimax approaches.
(2) On the other hand, the BOJ's policy at that time was not optimal under uncertainty about the inflation process, such as the inflation persistence and fluctuations in import prices. Specifically, under both the Bayesian and the minimax approaches, it would have been desirable for the BOJ to have implemented a more aggressive policy response under uncertainty about the inflation process.
(3) According to the Quarterly Economic Outlook released by the BOJ in the early 1990s, the Bank judged that "prices are stable" during periods when the CPI inflation rate was within the range of 0%-2%. Under that price judgment, the concern toward uncertainty about the inflation process may have been weak because the CPI inflation rate remained within the range of 0%-2% throughout the period from the 1980s through the early 1990s, with the one exception of the period right near the end of the bubble. However, given the fact that overcoming deflation became an important policy issue in the late 1990s, it is possible to argue that during the early 1990s the BOJ should have placed greater emphasis on uncertainty about

the inflation process and have implemented a more aggressive monetary policy.

(4) From that perspective, we conduct a counter-factual simulation to examine how the shape of the economy would have changed if the BOJ had implemented more aggressive monetary easing in the early 1990s. While the simulation results indicate that this would have provided some support for the inflation rate and the real growth rate, the effect would have been limited. The results suggest that implementing monetary easing earlier itself would not have changed the overall image of the prolonged stagnation during the 1990s.

The remainder of this paper is organized as follows. Chapter 2 explains the Bayesian and the minimax approaches to deal with parameter uncertainty. Chapter 3 explains the JEM and clarifies exactly which parameters of the model are assumed to be uncertain. Chapter 3 also introduces the evaluation criteria of policy performance in the stochastic simulation. Chapter 4 presents the stochastic simulation results. Chapter 5 reviews the BOJ's monetary policy during the early 1990s, and then provides a theoretical explanation of what degree of weight the BOJ should have placed on the price stability when considering uncertainty about the inflation process. Chapter 6 presents a counter-factual simulation showing the developments in the inflation rate and the output gap had the BOJ emphasized uncertainty about the inflation process during the early 1990s. Finally, Chapter 7 offers conclusions.

2. Parameter Uncertainty and Policy Response – Two Approaches

We consider the following simple model to examine how parameter uncertainty affects monetary policy.

$$\pi_t = \theta \pi_{t-1} + \lambda x_t + \varepsilon_t \tag{1}$$

Here π_t expresses the inflation rate, x_t the policy variable, and ε_t exogenous shocks (such as fluctuations in import prices). The parameter λ measures the policy multiplier, and the parameter θ measures the inflation persistence. The large value of θ means a high degree of the inflation persistence, and suggests that when the previous period's inflation rate π_{t-1} is high, the current period's inflation rate π_t tends to remain at a high level. Regarding the central bank's policy variable x_t, the short-term interest rate is usually assumed. But, here we adopt the output gap as the policy variable. In other words, we assume that the central bank can completely control the output gap by controlling interest rates. Then this means that equation (1) is the Phillips curve and parameter λ measures both the policy multiplier and the slope of the Phillips curve.

The objective of the central bank is to minimize the following loss function subject to equation (1).

$$E_t \sum_{j=0}^{\infty} \beta^j [(\pi_{t+j} - \pi^*)^2 + \chi(x_{t+j})^2] \tag{2}$$

Here π^* is the inflation target and β is the discount factor. Parameter χ is the relative weight on the output gap stabilization.[3] Equation (2) is the conditional expected value based on the information set available to the central bank Ω_t^{CB}. The central bank determines policy after observing the exogenous shocks ε_t in the current period, but the future shocks in the subsequent periods are unknown ($\varepsilon_t \in \Omega_t^{CB}, \varepsilon_{t+j} \notin \Omega_t^{CB}, \forall j \geq 1$). With these preparations, we now consider how parameter uncertainty ($\theta, \lambda \notin \Omega_t^{CB}$) affects the form of the optimal monetary policy.

(1) Bayesian Approach

Under the Bayesian approach, the central bank determines policy based on a prior belief about the distribution of the parameters θ, λ. While the central bank does not know the exact values of the parameters θ, λ, the bank does know their means ($E[\theta], E[\lambda]$) and their variances ($V[\theta]$, $V[\lambda]$).

A. Static Model

First we consider the static model ($\theta = 0$) and examine how the multiplier uncertainty, that is, uncertainty about the parameter λ, affects the policy. In the case of the static model, the loss function (2) can be simplified as follows.

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[3] As is clear from equation (1), when exogenous shocks ε occur, the central bank faces a trade-off between the inflation rate stabilization and the output gap stabilization.

$$E[(\pi-\pi^*)^2+\chi(x)^2]=[E(\pi)-\pi^*]^2+V[\pi]+\chi(x)^2 \tag{3}$$

This equation suggests that the central bank minds not only the bias of the inflation, i.e. the deviation of the mean of the inflation rate from the target (the first term on the right-hand side of the equation), but also the variance of the inflation (the second term on the right-hand side). Here, the mean and the variance of the inflation rate are expressed by the following equation.

$$E[\pi]=E[\lambda]x+\varepsilon, \quad V[\pi]=V[\lambda]x^2 \tag{4}$$

As is clear from equation (4), when the parameter λ is uncertain, i.e. $V[\lambda]>0$, the variance of the inflation rate $V[\pi]$ depends on the central bank's policy variable x. As the central bank tries to reduce the bias of the inflation by changing the policy variable x, this leads to the increase in the variance of the inflation. In other words, under uncertainty about the parameter λ, the central bank faces a trade-off between the bias and the variance of the inflation.

The optimal policy under parameter uncertainty can be derived as policy x^* which minimizes the loss function (3) subject to equation (4).

$$x^*=\frac{E[\lambda]}{E[\lambda]^2+V[\lambda]+\chi}(\pi^*-\varepsilon) \tag{5}$$

This equation means that as the degree of uncertainty about the parameter λ, i.e. $V[\lambda]$, increases, the central bank should respond less aggressively to shocks ($\pi^*-\varepsilon$).

Thus when the policy multiplier is uncertain, a less aggressive policy response is optimal for stabilizing the economy. This understanding was noted long ago in Brainard [1967]. Ever since it was advocated as the "Brainard conservatism" by the former FRB Vice-Chairman Alan Blinder, it has gained notable attention among policymakers.

> *My intuition tells me that this finding [Brainard conservatism] is more general – or at least more wise – in the real world than the mathematics will support. And I certainly hope it is, for I can tell you that it was never far from my mind when I occupied the Vice Chairman's office at the Federal Reserve. In my view as both a citizen and a policymaker, a little stodginess at the central bank is entirely appropriate.* (Blinder [1998], p. 12)

According to the recent research, however, the understanding that conservative policy is desirable under parameter uncertainty is not as general as Blinder says. While Brainard conservatism does hold in a static model, it does not necessarily hold in a dynamic model.[4] This point is explained as below.

B. Dynamic Model

We consider the case $\theta \neq 0$ to examine how the uncertainty about economic dynamics affects policy stance. When the central bank determines monetary policy for the current period, it must take into account how today's policy affects inflation in subsequent periods; hence it must include in its calculations not only the bias and variance of inflation in the current period but also those in subsequent periods. To simplify the discussion we assume that while there is no uncertainty about the policy multiplier λ, the parameter θ is uncertain. While the central bank does not know the exact value of the parameter θ, the bank does know its mean $E[\theta]$ and variance $V[\theta]$.

With these preparations, we first consider the optimal policy in the case where there is no uncertainty about the inflation persistence ($V[\theta]=0$) as a benchmark. In Chart 1, the right graph depicts the relationship between the current inflation rate π_t and the current output gap x_t, and the left graph draws the relationship between the current inflation rate π_t and the subsequent period's inflation rate π_{t+1}. For simplification, we assume that the inflation target π^* is 0%.

The right graph shows the case with a decline in import prices, as an example of a negative exogenous shock ($\varepsilon_t < 0$). To bring the inflation rate π_t back to the target of 0% in response to this decline in import prices, the output gap x_t must be expanded back to Point A. In order to minimize the loss function (2), however, it is optimal for the central bank to stabilize the output gap x_t to some degree and set it at Point B, which has a smaller fluctuation compared with Point A. In this case, the current inflation rate π_t is at Point C, which is below the target of 0%, and the subsequent period's inflation rate π_{t+1} is expected to reach Point F on the left figure. (The horizontal axis of the left figure, which indicates the subsequent period's inflation rate, shows a greater decline in

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4 See, for example, Söderström [2002] and Kimura and Kurozumi [2007].

the inflation rate moving to the right along the axis.)

However, when the current inflation rate π_t is set at Point C and the degree of the inflation persistence is uncertain (when $V[\theta]>0$), the variance of the subsequent period's inflation rate $V[\pi_{t+1}]$ becomes rather large. (In the left graph, the area bounded by the two dotted lines shows the variance of the subsequent period's inflation rate, $V[\pi_{t+1}]$, caused by uncertainty about the persistence θ.) Here the important point is that the variance $V[\pi_{t+1}]$ depends on the current period's inflation rate π_t.[5]

$$V[\pi_{t+1}] = V[\theta](\pi_t)^2 + V[\varepsilon_{t+1}] \tag{6}$$

Therefore, if the central bank tries to reduce the variance of the subsequent period's inflation rate to decrease the loss (2), it must make the absolute value of the current period's inflation rate π_t smaller. To those ends it is desirable for the bank to raise the current output gap x_t compared with the case with no uncertainty. In terms of the right graph, this means setting the current output gap x_t at Point D rather than at Point B. In other words, it is desirable to change policy more aggressively. As a result, the current inflation rate π_t reaches Point E, and the variance of the subsequent period's inflation rate $V[\pi_{t+1}]$ becomes smaller.

This leads to the conclusion that it is desirable to implement aggressive rather than conservative policy when there is uncertainty about economic dynamics.[6] In short, when there exists uncertainty about the inflation persistence, if the inflationary (or deflationary) buds are not nipped today they may grow into greater inflation (or

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5 Based on the Phillips curve (1) for the subsequent period ($\pi_{t+1} = \theta\pi_t + \lambda x_{t+1} + \varepsilon_{t+1}$), we can derive equation (6).

6 This conclusion is derived under the dynamic model because the influence of exogenous shocks on the economy is not completely offset at the current period and it can be carried over to subsequent periods. In fact, as explained in this paper, because the price shock that shift the Phillips curve up or down leads to a trade-off between the inflation rate stabilization and the output gap stabilization, the shock effect is carried over to the subsequent period. On the other hand, when there is a demand shock that shifts the IS curve, theoretically its influence can be completely offset by controlling interest rates. However, this only holds true when the central bank has complete information on the demand shock and can change interest rates without any cost. In reality, central banks have imperfect information and must give some consideration to interest rate smoothing in their policy conduct, so they cannot completely offset the influence of demand shocks on the inflation rate, and this influence is carried over to the subsequent period. Therefore, the considerations in this paper hold regardless of the nature of the shock. For details, see Kimura and Kurozumi [2007].

deflation) tomorrow than expected. Excess inflation (or deflation) should be nipped in the bud today to the greatest possible extent by implementing an aggressive monetary policy.

Considering our analysis with both static and dynamic models, it is important to know that the optimal policy response may differ depending on which parameter is uncertain for the central bank.

(2) Minimax Approach

Another approach to policy conduct under uncertainty is based on the idea that the objective of the central bank is to minimize the maximum loss, which is referred to as the "minimax approach" (or the "robust approach"). In this approach, instead of holding a prior belief about the distribution of the uncertain parameters (θ, λ), the central bank considers the conceivable range for them.

$$\theta \in [\underline{\theta}, \overline{\theta}], \quad \lambda \in [\underline{\lambda}, \overline{\lambda}] \tag{7}$$

The next step is to consider, within this range, which values of θ, λ will result in the greatest loss, and to then select policies that will minimize that maximum loss. This minimax approach can be expressed mathematically as follows.

$$\underset{\{x_t\}}{Min} \underset{\{\theta,\lambda\}}{Max} E_t \sum_{j=0}^{\infty} \beta^j [(\pi_{t+j} - \pi^*)^2 + \chi(x_{t+j})^2] \tag{8}$$

$$s.t. \ \pi_t = \theta\pi_{t-1} + \lambda x_t + \varepsilon_t$$

The following sections examine whether the central bank which adopts the minimax approach should implement more conservative or more aggressive policy under uncertainty.

A. Static Model

To simplify the discussion, we once again consider the static model ($\theta = 0$) and assume that the parameter λ is uncertain. We consider the following policy response function in which the policy variable x responds to the difference between the inflation target and the exogenous shock ($\pi^* - \varepsilon$).

$$x = h(\pi^* - \varepsilon) \tag{9}$$

In equation (9) the coefficient h denotes the degree of policy response. Chart 2 shows how the central bank's loss (3) shifts with changes in the policy response h under a given the parameter λ.[7]

Here let us assume that the true value of the parameter λ is 1.5. The central bank does not know this true value, and it considers the range for λ of between 1.0 and 2.0. If policy is determined based on the minimax approach, the central bank implements its policy assuming that $\lambda = 1.0$ because that leads to the maximum loss within that conceivable range for λ. The reason why the maximum loss occurs in the case of $\lambda = 1.0$ is that the central bank must greatly change the output gap x to stabilize the inflation rate π when the value of λ, i.e. the slope of the Phillips curve, is small. And when λ is small, the price stability will not be achieved unless the central bank sets a higher value for h and implements an aggressive policy. In this manner, when there is uncertainty about the parameter λ, it is desirable for the central bank to implement more aggressive monetary policy than under the case in which the central bank knows the true value of λ.[8]

However, the minimax approach does not necessarily always support aggressive policy. For example, if the central bank assumes the conceivable range for λ as $0.5 \le \lambda \le 2.0$, the bank will find rather more conservative policy, $\lambda = 0.5$, to be desirable.[9] Thus it is important to note that monetary policy stance under the minimax approach may be dependent on the degree of the uncertainty, i.e. the conceivable range of the parameter.

B. Dynamic Model

In recent years, research has also been advancing on the minimax approach using the

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[7] Chart 2 shows the loss in the case of χ=1.

[8] This conclusion is consistent with what the previous literature on the minimax approach suggests. See Giannoni [2002, 2006], Hansen and Sargent [2003], Sargent [1999], Stock [1999], and Onatski and Stock [2002].

[9] When the slope of the Phillips curve λ is extremely small, the change in the output gap, which must be sacrificed for inflation stabilization, is extremely large and the central bank's loss increases very significantly. In other words, when extremely poor policy efficiency is assumed as the worst case, a cautious policy response is desirable because an aggressive policy only overshoots the output gap but not contribute all that much to inflation stabilization.

dynamic model ($\theta \neq 0$). While the details are omitted here, the loss under the dynamic model is at the highest level when the value of θ is high, that is, in the case with high inflation persistence. With high inflation persistence, control of inflation via monetary policy becomes difficult because the upward pressure on inflation does not easily subside once a rise in the inflation rate gains strength. For that reason, the generally accepted view of the minimax approach is that the central bank should pursue an aggressive policy on the assumption of high inflation persistence in order to minimize the maximum loss.[10]

Although monetary policy based on the minimax approach may depend upon the degree of uncertainty, i.e. the conceivable range of uncertain parameters, the above examples suggest that it is important to consider potentially large losses, which might occur in the future, in the conduct of monetary policy. In fact, the former FRB Chairman Greenspan referred to his own policy conduct style as the "risk management approach," which can be interpreted as the one reflecting the minimax approach perspective (see Greenspan [2003]).

3. Model

(1) The JEM (Japanese Economic Model) and the Policy Rule

The JEM used in our analyses is a large-scale dynamic general equilibrium model comprising 219 equations, but one may consider its essence as being summarized in the two equations: the Phillips curve and the IS curve. These are both hybrid equations combining forward-looking and backward-looking expectations of the private sector (see Fujiwara et al. [2005]).

$$\pi_t = \theta\pi_{t-1} + (1-\theta)E_t[\pi_{t+1}] + \lambda(y_t - y_t^*) + \varepsilon_t \tag{10}$$

$$y_t - y_t^* = \phi(y_{t-1} - y_{t-1}^*) + (1-\phi)E_t[y_{t+1} - y_{t+1}^*] - \sigma(i_t - E_t[\pi_{t+1}] - r^*) + \mu_t \tag{11}$$

Here, $y_t - y_t^*$ denotes the output gap, where y_t and y_t^* are real output and potential

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[10] See, for example, Angeloni et al. [2003].

output respectively, both on a logarithmic basis. r^* is the equilibrium real interest rate. ε_t and μ_t denote price shocks and demand shocks, respectively. Equations (10) and (11) constitute a purely forward-looking New Keynesian model when $\theta = \phi = 0$.

Next, we consider the following policy rule.[11]

$$i_t = i^* + \alpha(\pi_t - \pi^*) + \beta(y_t - y^*_{t|realtime}) + \gamma\Delta y_t \tag{12}$$

$$y^*_{t|realtime} = y^*_t + \xi_t \tag{13}$$

Here, i^* shows the equilibrium nominal interest rate ($i^* = \pi^* + r^*$). $y^*_{t|realtime}$ is the potential output (trend output) measured by the central bank in real time at time *t*, and therefore $y_t - y^*_{t|realtime}$ is the output gap measured by the central bank in real time. $y^*_{t|realtime}$ deviates from the true potential output y^*_t, and that deviation is the measurement error ξ_t. In general, economic data trends cannot be accurately estimated in real time, and changes in those trends are only finally recognized when looking back quite a bit after they occur. Under these conditions, errors emerge in the measurement of the output gap.

The previous studies on the BOJ's policy during the early 1990s which use the Taylor rule for evaluation reach different conclusions, depending on which types of the output gap are used, with some papers finding that the actual interest rates were higher than those indicated by the Taylor rule and others finding them right in line with the Taylor rule.[12] It is meaningless as a policy prescription to argue with hindsight that the BOJ should have taken a particular action based on information that was not available to the BOJ at that time. Rather, we should clearly distinguish between what the BOJ could and

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[11] Regarding the policy rule, we also conducted analyses incorporating the lagged interest rate, but the results were not substantially different. Here, we focus on the policy rule without interest rate smoothing to facilitate comparison with the previous research analyzing the BOJ's monetary policy during the early 1990s, because many of those studies employ the Taylor type rules without lagged interest rate.

In the monetary policy rule in equation (12), the inflation rate π_t and the real growth rate Δy show percentage changes from the previous year (in contrast, the inflation rate π_t in equations (10) and (11) shows percentage changes from the previous period.

[12] For example, McCallum [2001] and Okina and Shiratsuka [2002] use a different output gap to evaluate monetary policy during the early 1990s. The former finds that actual interest rate levels were high compared with those indicated by the Taylor rule, while the latter finds that they were essentially consistent with those indicated by the Taylor rule.

could not have done, focusing on the information available in real time. The great importance of considering the measurement error of the output gap when conducting monetary policy is well known from US case studies. Regarding the cause of the high inflation in the US during the 1970s (the so-called "Great Inflation"), Orphanides [2001, 2003] argues that the real-time output gap, as measured at that time, was larger than the output gap based on data recorded in the revised national accounts, and the difference was sufficient to mislead the FRB implementing excessive monetary easing.

Including the real growth rate Δy_t in the policy rule (12) may be effective for the problem of the measurement error. When there is an error in the output gap measurement, an aggressive policy response to the output gap – that is, increasing the value of β in equation (12) – results in unnecessary interest rate fluctuations corresponding to the measurement error ξ_t, which may cause economic instability. One approach to averting this problem is to target the real growth rate Δy_t instead of the output gap.[13]

(2) Parameter Uncertainty Faced by the Bank of Japan

Fujiwara et al. [2005] shows that the impulse response of the JEM to various types of shocks is roughly the same as the VAR impulse response based on the sample period 1983-95. Hence, the set of parameters of equations (10) and (11), which are the basic JEM equations, adequately depict the structure of the Japanese economy during that period. On a real-time bais, however, the BOJ did not fully understand the parameters of the economic structure at that time, and in that sense it is appropriate to believe that the BOJ faced parameter uncertainty.

In this paper, we analyze the uncertainty about the following four parameters: (1) policy multiplier; (2) inflation persistence; (3) price shock persistence; and (4) demand shock persistence.

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[13] See Orphanides et al. [1999].
Another reason for incorporating the real growth rate as a target variable is that history-dependent monetary policy leads to economic stability when private-agents are forward-looking. See Giannoni [2000] and Kimura and Kurozumi [2004] for history dependence.

A. Uncertainty about the Policy Multiplier

In the IS curve (11), the parameter of the real interest rate gap, σ, can be interpreted as the policy multiplier.

$$y_t - y_t^* = \phi(y_{t-1} - y_{t-1}^*) + (1-\phi)E_t[y_{t+1} - y_{t+1}^*] - \sigma(i_t - E_t[\pi_{t+1}] - r^*) + \mu_t \qquad (11)$$

It is believed that during the early 1990s, especially during 1992-93, the BOJ conducted monetary policy under uncertainty regarding the policy effect. To be sure, the bank had experienced the call rate of 2-3% during 1987-89, so looking back from today this does not seem to have been "unprecedented" (Chart 3). Nevertheless, there was then a strong regret that the prolonged maintenance of a low interest rate of 2.5% during the latter 1980s was indeed at least one cause for the emergence of the bubble. Considering that point, it is by no means unnatural that there was some caution regarding the adoption of a low interest rate policy, with rates even lower than those of the latter 1980s. In that sense, the interpretation that the BOJ was then facing uncertainty about the policy multiplier σ can be viewed as relatively natural.

B. Uncertainty about the Inflation Persistence

In the hybrid Phillips curve (10), the parameter of the lagged inflation rate, θ, can be interpreted as the degree of the inflation persistence.

$$\pi_t = \theta\pi_{t-1} + (1-\theta)E_t[\pi_{t+1}] + \lambda(y_t - y_t^*) + \varepsilon_t, \quad \text{where } 0 \le \theta \le 1. \qquad (10)$$

The higher the parameter θ, the higher the inflation persistence. The case $\theta = 1$ corresponds to the backward-looking Old Keynesian Phillips curve. On the other hand, the case $\theta = 0$ corresponds to the purely forward-looking New Keynesian Phillips curve.

Even now that a substantial volume of empirical research on hybrid Phillips curves has accumulated, academics have still not reached a consensus regarding the estimation results of the parameter θ.[14] For that reason, it is appropriate to consider that not only the BOJ but all central banks are constantly facing uncertainty regarding the inflation

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[14] For details, see Kimura and Kurozumi [2007]. Regarding the estimation results of Japanese Phillips curves, see Kimura and Kurozumi [2004].

persistence. In addition, it is important to note that during the early 1990s there was no knowledge about the hybrid Phillips curves expressed by equation (10), since research had not been conducted on the New Keynesian Phillips curve.[15] In that sense, rather than saying that the BOJ faced uncertainty about the parameter θ at that time, it may be more accurate to say that there was uncertainty about the overall form of the structural equation.

The reduced form of the hybrid Phillips curve (10) can be expressed as equation (14).[16]

$$\pi_t = \Theta \pi_{t-1} + \Lambda (y_{t-1} - y^*_{t-1}) + \varepsilon_t \tag{14}$$

In the early 1990s there was a debate regarding the estimate of the parameter Θ in equation (14) inside the BOJ, while no consensus had been gained there regarding its estimated value.[17] Given the relation whereby reduced form parameter Θ in equation (14) increases as the structural parameter θ in equation (10) increases, a contemporary interpretation for the fact that there was no consensus inside the BOJ regarding the estimation of the parameter Θ would be that at that time the BOJ had no certain knowledge about the hybrid Phillips curve parameter θ. (See Chart 4 for changes in the inflation rate.)

C. Uncertainty about the Price Shock Persistence

Price shocks on the Phillips curve follow the autoregressive process as shown in equation (15).

$$\varepsilon_t = \nu \varepsilon_{t-1} + \hat{\varepsilon}_t, \quad \text{where} \quad 0 \le \nu < 1 . \tag{15}$$

Here, $\hat{\varepsilon}_t$ is white noise. The parameter ν measures the degree of shock persistence. The larger the value of the parameter ν, the higher the price shock persistence. For example, high persistence indicates conditions whereby once the foreign exchange rate

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[15] The New Keynesian Philips curve became widely discussed in academic circles following the publication of Roberts [1995].

[16] For details, see Rudebusch [2005].

[17] See, for example, Tanaka and Kimura [1998] and Watanabe [1997]. The former supports the NAIRU hypothesis (Θ=1), while the latter denies it. Both of these papers were published in the latter 1990s, but the research for both had already begun in the early 1990s.

moves toward a strong yen that trend continues thereafter with a prolonged decline in import prices. During the early 1990s, as shown in Chart 5, there was a long-term trend toward a strong yen – then referred to as the "ultra-strong yen," and it is difficult to believe that the BOJ was then able to accurately predict how far the yen would advance. In fact, at that time the dominant viewpoint in academic circles was that theory-based models could not outperform the random walk model to predict future exchange rates.[18] Considering this point, at the very least, it is appropriate to believe that the BOJ was then facing uncertainty regarding the parameter ν which measures the degree of the price shock persistence.[19]

D. Uncertainty about the Demand Shock Persistence

Demand shocks on the IS curve follow an autoregressive process as shown in equation (16).

$$\mu_t = \tau\mu_{t-1} + \hat{\mu}_t, \quad \text{where } 0 \le \tau < 1. \tag{16}$$

Here, $\hat{\mu}_t$ is white noise. The parameter τ measures the degree of shock persistence. The larger the value of the parameter τ, the higher the demand shock persistence. During the period when the bubble collapsed, the capital-stock adjustment pressures were very high, because the expected growth rate of firms suddenly and continuously declined. Moreover, the decline in stock, land and other asset prices was more prolonged than expected, and this had a large impact on balance-sheet adjustment pressures. These two adjustment pressures resulted in a persistent restriction on business fixed investment, which indicates that the value of the parameter τ was high. At that time, however, the BOJ did not have accurate knowledge about the degree of persistence in the decline in the expected growth rate or the decline in asset prices, or about the persistence of their macroeconomic impact.[20] It seems appropriate to believe

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[18] See Meese and Rogoff [1983].

[19] Since $\hat{\varepsilon}_t$ in equation (15) is additive uncertainty, certainty equivalence holds and the degree of this uncertainty does not influence the policy stance. On the other hand, because the uncertainty about parameter ν is multiplicative, certainty equivalence does not hold and the degree of uncertainty about parameter ν does influence the policy stance.

[20] Regarding this point, Mori et al. [2001] makes the following comment concerning the monetary policy at that time. "There was not sufficient awareness that the size of the balance-sheet adjustment pressures would increase over time."

that at that time the BOJ was facing uncertainty about the parameter τ, which measures the degree of the persistence of demand shocks.

(3) Policy Evaluation Criteria

In the limit when the discount factor approaches unity, i.e. $\beta \rightarrow 1$, the central bank's loss function (2) is proportional to the following weighted sum of the variances.[21]

$$Var[\pi_t - \pi^*] + \chi Var[y_t - y_t^*] \tag{17}$$

It is desirable for the central bank to set the policy rule to minimize the loss given by equation (17). In the following, we discuss how the bank should set the relative weight on the output gap stabilization χ.

A. New Keynesian Economics and the Price Stability

The new Keynesian economics has theoretically derived the value of χ to reflect social welfare losses, which depend on the variance of the output gap and on the magnitude of the price dispersion across firms.[22] There are two major specifications of firms' pricing behavior that the New Keynesian economics suggest: random-duration contracts called the "Calvo-style" (Calvo [1983]) and fixed-duration contracts called "Taylor-style" (Taylor [1980]). Under the specification of random-duration contracts, some contracts remain unchanged over long stretches of time, even if the average contract duration is relatively short; thus, fluctuations in aggregate inflation tend to have highly persistent effects on relative price dispersion, so that the welfare cost of the inflation volatility is roughly two orders of magnitude greater than that of the output gap volatility (cf. Rotemberg and Woodford [1997]).

In contrast, fixed-duration contracts induce much less intrinsic persistence of the relative price dispersion, and hence imply that the welfare cost of inflation volatility is much smaller, and in fact roughly comparable in magnitude to that of the output gap volatility. As shown in Erceg and Levin [2002], using an appropriate parameter set with

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[21] Note that x_t in equation (2) is the output gap $(y_t - y_t^*)$.

[22] See the survey in Kimura, Fujiwara and Kurozumi [2005].

Taylor-style contracts, the relative weight on the output gap stabilization χ is around unity.

B. The Weight on the Price Stability in Japan

In Japan, there is a tendency toward "synchronized price setting" whereby firms revise their prices simultaneously at specific times of year, typically in April and October.[23] So the actual welfare losses due to the relative price dispersion cannot be large to the extent posited by Taylor [1980]. For this reason, $\chi > 1$ may be a good approximation of social welfare in Japan.

Regarding the welfare cost of the inflation volatility, it is also necessary to consider the fact that the CPI inflation rate remained in a range between 0% and 2% from the 1980s through the early 1990s, excluding the brief period 1990-1991. According to the Quarterly Economic Outlook, the BOJ judged that price was stable when the CPI inflation rate remained within that range (Chart 6 and Chart 7). In other words, we may interpret that at that time the BOJ placed a large weight on the output gap stabilization in its policy conduct as long as the CPI inflation rate remained in a range between 0% and 2%. This interpretation may also support the view that the BOJ conducted monetary policy based on the loss function of $\chi > 1$.[24]

C. Loss Function used in the Simulation

Based on the above considerations, as a concrete example of $\chi > 1$, we set $\chi = 2$ and consider this as the benchmark for the BOJ's monetary policy during the early 1990s. We also examine $\chi = 1$ and $\chi = 0.5$ as alternative cases.[25]

Some also hold the view that the interest rate smoothing should be included among the policy evaluation criteria from the practical perspective of the central bank, even

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[23] See Saita et al. [2006] regarding the Japanese price revisions.

[24] The loss function (17) assumes that the central bank adopts the inflation target π^* as a point target. For that reason, strictly speaking, equation (17) cannot be directly applied to "inflation zone targeting" which aims at keeping inflation rate within a specific range. Out approach is based on the understanding that for equation (17) to approximate zone targeting with a range of 2%, the weight given to price stability is relatively low compared with that under point targeting.

[25] Most of the research on the monetary policy of the FRB, which has the dual mandate of price stability and full employment as a legal obligation, sets $\chi = 1$ as the benchmark.

though it is difficult to derive a clear reason for this from the economic theory. This view is based on the belief that less volatility in interest rates results in the capital market stability and leads to stable bank profits and even to the stability of the financial system.[26] Okina and Shiratsuka [2002] write "It is established as a practice of central banks worldwide, including that in Japan, to avoid unexpected large changes in interest rates. Thus, it is undeniable that ignoring such practices might trigger financial system turbulence." In this paper, considering this practical perspective, we adopt the following loss function, which incorporates the interest rate smoothing, for the policy evaluation criteria.

$$Var[\pi_t - \pi^*] + \chi Var[y_t - y_t^*] + \delta Var[\Delta i_t] \tag{18}$$

Specifically, in line with some previous studies, we set $\delta = 0.5$ as a benchmark, and $\delta = 0$ as an alternative case.[27]

We now advance the analyses with the understanding that the BOJ implemented policy in the early 1990s to minimize the loss function under the combination $\chi = 2$ and $\delta = 0.5$.

4. Results of the Analyses

(1) Estimation Results of Policy Rule

We estimate the policy rule (12) to evaluate the BOJ's actual policy conduct.

$$i_t = \alpha(\pi_t) + \beta(y_t - y^*_{t|realtime}) + \gamma\Delta y_t + c, \tag{12}$$

where the constant term $c = i^* - \alpha\pi^*$.

Two types of estimates for the potential output and the output gap used for the estimation are shown in Chart 8. Based on the production function approach, we estimate TFP by applying a Hodrick-Prescott (HP) filter to the Solow residual. The "final estimates" for potential output in the chart are the estimates applying the HP filter

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26 See Goodfriend [1991]. Another reason for the interest rate smoothing is the view that averting frequent policy reversals helps to secure policy credibility (Goodhart [1999]).

27 Some previous studies analyzing FRB monetary policy adopt the settings $\chi = 1$ and $\delta = 0.5$ (see, for example, Rudebusch [2001] and Williams [2004]).

to the Solow residual up to 2005. The "real-time estimate" for potential output at a certain quarter is obtained by applying the filter to the Solow residual up to that quarter. For example, the "real-time estimate" for the output gap in 1991Q1 means the output gap measured using the data up until 1991Q1. The retroactive revision in potential output from real-time estimates to final estimates is the measurement error ξ_t in equation (13). In practice, the real-time estimates will be greatly revised retroactively by applying the HP filter again after adding subsequent economic data. Thus, it is difficult to accurately estimate the economic trend in real time, particularly near the end of history. In reality, the standard deviation of the measurement error during 1986-95 is 1.9%. Therefore, it is inappropriate to ignore the existence of measurement error in potential output on estimating the policy rule.[28]

Estimation results of the policy rule (12) are as follows.[29]

$$\underset{(11.63)}{i_t = 1.58\pi_t} + \underset{(3.44)}{0.51}(y_t - y^*_{t|realtime}) - \underset{(-0.75)}{0.10}\Delta y_t + \underset{(5.49)}{2.78}, \quad \overline{R}^2 = 0.83,\ S.E. = 0.83 \tag{19}$$

Note: *t* values in parentheses. Sample period is from 1986 Q1 through 1995 Q4.

Since the coefficient of the real growth rate Δy_t is not statistically significant, we estimate the policy rule without Δy_t.

$$i_t = \underset{(12.32)}{1.60}\pi_t + \underset{(7.05)}{0.41}(y_t - y^*_{t|realtime}) + \underset{(11.22)}{2.43}, \quad \overline{R}^2 = 0.84,\ S.E. = 0.81 \tag{20}$$

As the estimation results $(\alpha, \beta) = (1.6, 0.4)$ are very close to the original Taylor rule $(\alpha, \beta) = (1.5, 0.5)$, the actual policy interest rates were essentially determined in line with the Taylor rule.[30] Hereafter, we assume that the BOJ's monetary policy during the early 1990s can be depicted by the policy rule with $(\alpha, \beta, \gamma) = (1.6, 0.4, 0.0)$. Moreover, taking into account the estimation error of the policy rule, we will use confidence

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[28] Incidentally, according to Orphanides et al. [1999], the standard deviation of the output gap measurement error in the US was 1.8% during 1980-1994 and 3.8% during 1966-1994.

[29] The estimation is based on the OLS, but essentially the same results were obtained when the estimation was conducted using instrument variable method.

[30] Adopting 1% as the inflation target π^* to the equation below, we obtain the equilibrium real interest rate r^* around 3%.

$$c = i^* - \alpha\pi^* = r^* - (\alpha - 1)\pi^* = 2.43$$

intervals as well as specific values for α and β to express them on policy assessment. This point is considered as needed in the following analyses.

We also find that when the final estimates ($y_t - y_t^*$) rather than the real-time estimates ($y_t - y_{t|realtime}^*$) are used for the output gap, Taylor's principle ($\alpha > 1$) is not satisfied, and the coefficient of determination $\overline{R}^2$ worsens considerably.

$$i_t = \underset{(3.94)}{0.93}\pi_t + \underset{(3.63)}{0.46}(y_t - y_t^*) + \underset{(8.33)}{3.33}, \quad \overline{R}^2 = 0.73,\ S.E. = 1.04 \tag{21}$$

Thus, as is clear from the difference in the estimation results under equations (20) and (21), it is important to consider the measurement error of the output gap in the policy evaluation.

(2) Simulation Results without Parameter Uncertainty

To examine how parameter uncertainty exerts on monetary policy implementation, we first derive the optimal policy when there is no uncertainty as a benchmark. Specifically, we conduct a stochastic simulation whereby the innovations $\hat{\mu}_t$ and $\hat{\varepsilon}_t$ for the demand shocks and price shocks occur randomly each period, and seek the policy rule coefficients (α, β and γ) that minimize the loss function (18). The variances of the innovations are set based on the data during 1983-95.[31] We also generate random shocks for the measurement error of the output gap ξ_t, assuming that the error process ξ_t follows an AR(2) model estimated with the data in Chart 8.

Chart 9 presents the simulation results for six cases of the loss function (18) with the relative weight $\chi = (0.5, 1, 2)$ and $\delta = (0, 0.5)$. The following three findings are of particular interest.

First, when there is some weight on the interest rate smoothing δ in the loss function, it is desirable to set small values for all the policy rule coefficients (α, β and γ). This is because the stability of the inflation rate and of the output gap must be sacrificed to smooth interest rate changes.

Second, as the relative weight on the output gap stabilization χ increases, it is

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[31] As stated above, the JEM impulse response during this period was essentially the same as the VAR impulse response.

desirable to set higher values for the output gap coefficient β and the real growth rate coefficient γ, but a lower value for the inflation rate coefficient α of the policy rule. This is because when the central bank faces a trade-off between the inflation rate stabilization and the output gap stabilization, it cannot simultaneously achieve both.

Third, under the benchmark loss function ($\chi = 2$, $\delta = 0.5$), the optimal policy coefficient combination is $(\alpha, \beta, \gamma) = (1.6, 0.2, 0.1)$, which is very close to the BOJ's actual policy conduct ($(\alpha, \beta, \gamma) = (1.6, 0.4, 0.0)$). Hence, under the assumption of no parameter uncertainty, the actual policy conduct during the early 1990s can be judged as having been optimal (Chart 10).[32]

(3) Simulation Results with Parameter Uncertainty

Next, we seek to derive the optimal policy under parameter uncertainty.[33]

A. Uncertainty about the Policy Multiplier

To begin with, we examine the Bayesian approach when the policy multiplier σ is uncertain. Here, we assume that the central bank's prior belief about σ is formed with a normal distribution. We set the JEM's estimated parameter as the mean of the normal distribution and set the variance of the estimated parameter as that of the distribution. We then generate normal random numbers for σ, conduct the stochastic simulation, and seek the inflation coefficient α of the policy rule which minimizes the loss function.[34]

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[32] Chart 10 takes the actual policy rule ($(\alpha, \beta, \gamma) = (1.6, 0.4, 0.0)$) as a benchmark, and measures the loss changing one coefficient while leaving the other two coefficients fixed. As shown in the chart, for the inflation coefficient α, the actual policy was a good approximation of the optimal policy. Both the output gap coefficient β and the real growth rate coefficient γ deviated slightly from the optimal values, but because the shape of the loss function is rather flat near the optimal values, these coefficients can be evaluated as having been within the optimal range.

[33] Ideally, it is necessary to simultaneously change the three coefficients (α, β, γ) in order to find a coefficient combination that minimizes the loss function. However, the solution algorithm for the minimax approach, which introduces uncertainty into a large-scale model, has not yet been established, and seeking to minimize the maximum loss while changing three coefficients simultaneously is very difficult. For that reason, this paper adopts the method of taking the actual policy rule ($(\alpha, \beta, \gamma) = (1.6, 0.4, 0.0)$) as a benchmark and changing one coefficient while leaving the other two coefficients fixed.

[34] The explanations for β and γ are omitted here because parameter uncertainty does not

As shown in Chart 11(1), as the variance of the parameter σ increases – that is, as the degree of uncertainty faced by the BOJ increases – the inflation coefficient α which minimizes the loss decreases. In other words, the Brainard conservatism holds in this case. Under the benchmark loss function ($\chi = 2, \delta = 0.5$) that the BOJ is believed to have been tacitly striving to minimize during the early 1990s, the actual monetary policy ($\alpha = 1.6$) is found to be within the optimal range, or is rather aggressive under multiplier uncertainty. Also under the cases where the loss function weights are $\chi = 1$, $\delta = 0.5$ and $\chi = 2$, $\delta = 0.0$, the policy with $\alpha = 1.6$ can be viewed as generally optimal. These evaluations are even clearer when the BOJ's actual monetary policy is expressed as the confidence interval of the inflation coefficient α. That is to say, the inflation coefficient α of the policy rule which minimizes the loss under multiplier uncertainty is within the confidence interval associated with the estimated rule, so the policy conduct at that time may be judged as having been generally optimal.

Next, we examine the minimax approach to multiplier uncertainty. We set the upper and lower limits of the conceivable range of the parameter σ at the estimated parameter ± two standard errors. The optimal inflation coefficient α of the policy rule is that which realizes the smallest value on the maximum loss envelope curve. Chart 11 (2) shows that the actual monetary policy ($\alpha = 1.6$) achieves the smallest value on the maximum loss envelope curve in the cases of both the benchmark loss function ($\chi = 2, \delta = 0.5$) and an alternative one ($\chi = 2$, $\delta = 0.0$).

To summarize the above, from the perspectives of both the Bayesian and the minimax approaches, the BOJ's monetary policy at that time was generally optimal under multiplier uncertainty, or at the very least it can be said that the extent of monetary easing was not insufficient and that the tempo of the easing was not too slow.

B. Uncertainty about the Inflation Persistence

We now conduct similar analyses regarding uncertainty about the inflation persistence θ. Since we allow the parameter θ to lie anywhere in the interval [0,1], we assume that the central bank's prior belief about θ is formed with a beta

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substantially change the optimal values of those coefficients.

distribution or a uniform distribution, whose probability densities of continuous random variables take on values in the interval [0,1].[35] As shown in Chart 12 (1), the variance of the uniform distribution is greater than that of the beta distribution, and the inflation coefficient α which minimizes the loss is greater in the former than in the latter. This means that as the variance of the parameter θ (i.e. the degree of uncertainty faced by the BOJ) increases, the inflation coefficient of the policy rule increases. In other words, the Brainard conservatism does not hold when there exists uncertainty about the inflation persistence. If the inflationary (or deflationary) buds are not nipped today, they may grow into greater inflation (or deflation) tomorrow than expected. Therefore, excess inflation (or deflation) should be nipped in the bud today to the greatest possible extent by implementing an aggressive monetary policy. This finding is consistent with the simple dynamic model explained in Chapter 2 (1) B. Thus the conclusion is that regardless of what weight criteria are adopted for the loss function, the BOJ's actual monetary policy ($\alpha = 1.6$) was too conservative under uncertainty about the inflation persistence.

The same conclusion is reached under the minimax approach. The maximum loss occurs when the value of θ is large, that is, when the inflation persistence is high. The policy response that minimizes that maximum loss should be more aggressive compared with the actual policy with $\alpha = 1.6$.

To summarize the above, when uncertainty about the inflation persistence is taken into account, the BOJ's monetary policy at that time was conservative from the perspectives of both the Bayesian and the minimax approaches, and the bank should have pursued a more aggressive monetary policy. This conclusion is based on the finding that when the degree of uncertainty is high, the optimal inflation coefficient α of the policy rule under both approaches is larger than the upper limit of the confidence interval of the BOJ's actual policy.

C. Uncertainty about the Price Shock Persistence

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[35] The mean of both distributions is set as the JEM's estimated parameter. Note that in some special case the beta distribution reduces to the uniform distribution over [0,1].

Next we explain the results regarding the price shock persistence ν. To save space, Chart 13 only presents the results of the minimax approach. We set the upper and lower limits of the conceivable range of the parameter ν at the estimated parameter ± two standard errors. The maximum loss occurs when the value of ν is large, i.e. price shocks are very persistent. And the monetary policy which minimizes the maximum loss is more aggressive than the BOJ's actual monetary policy. When the value of ν is large, the optimal inflation coefficient α of the policy rule is larger than the upper limit of the confidence interval of the BOJ's actual policy.

Thus, the BOJ's policy was not optimal under uncertainty about the inflation persistence θ and about the price shock persistence ν. The BOJ should have pursued a more aggressive policy under uncertainty about the inflation process.

D. Uncertainty about the Demand Shock Persistence

Finally, we explain the results regarding the demand shock persistence τ. To save space, in Chart 14(1), we only show the results of the minimax approach with the loss function weights set at $\chi = 2$ and $\delta = 0$. We set the upper and lower limits of the conceivable range of the parameter τ at the estimated parameter ± two standard errors. Chart 14 shows the loss reaches the maximum level when the value of τ is large, i.e. demand shocks are very persistent. In this case, it is optimal to set the output gap coefficient β of the policy rule at a level higher than that under the BOJ's actual policy ($\beta = 0.4$).[36]

However, as the output gap coefficient β of the policy rule increases, the bank also responds to the measurement error of the output gap. If the measurement error is large, there arises risk that the larger output gap coefficient β may lead to an increase in the loss, as shown in Chart 14(2). Thus, from the perspective of the minimax approach to the measurement error of the output gap, it is optimal to set a low value for the output gap coefficient β.

Therefore, in order to set the appropriate output gap coefficient β of the policy rule,

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[36] The introduction of uncertainty about the demand shock persistence to the JEM does not change the optimal values of coefficients α and γ substantially.

the central bank needs to consider not only uncertainty about the demand shock persistence but also the measurement error of the output gap. The BOJ's actual policy (in the vicinity of $\beta = 0.4$) may be evaluated as generally desirable, as being neither too small nor too large.

5. Monetary Policy under Uncertainty about Inflation Dynamics

(1) Review of the Policy Conduct during the Collapse of the Bubble

Ever since the speech by the former FRB Chairman Greenspan (Greenspan [2003]), policy conduct considering uncertainty about economic structure has frequently been referred to as the "risk management approach." The effectiveness of this approach depends on distinguishing which uncertainty is most costly – or more precisely, which risk, if once realized, would result in the most severe loss.

The analyses in the previous chapter demonstrate that when uncertainty about economic structure is considered, the conclusions vary depending on which type of uncertainty is emphasized. Specifically, if uncertainty about the policy multiplier and about the demand shock persistence as well as the measurement error of the output gap is considered important, the BOJ's policy conduct during the early 1990s can be said to have been within the optimal range. However, when uncertainty about the inflation process is emphasized, the policy conduct at that time cannot be deemed to have been optimal.

As mentioned in Chapter 3, in the early 1990s, the BOJ was facing uncertainty about the effects of its unprecedented low interest rate policy on the economy. In addition, the BOJ was also facing uncertainty about the scale of the stock adjustment pressures which greatly accumulated during the bubble era and about the wealth effect accompanying the decline in asset prices. These uncertainties correspond to uncertainty about the policy multiplier and about the demand shock persistence, and just concerning that point the BOJ's policy response was by no means insufficient.

Given the stable developments in the actual CPI from the 1980s, however, the possibility that the Bank's caution toward uncertainty about the inflation process –

especially toward deflationary risk – had weakened cannot be denied. As noted above, during periods when the CPI inflation rate remained in a range between 0% and 2%, the BOJ judged that price was stable. If the BOJ had a stronger awareness of the potential risks that the inflation rate broke out of this range, the monetary policy would have been more aggressive.[37] Let us look at the economic situation in 1994 as an example. At that time, the business cycle entered a recovery phase (Chart 15) and the official discount rate was kept unchanged (Chart 3), although disinflation continued to progress and the CPI inflation was approaching its tacit lower boundary of 0% (Chart 7). Thus, if uncertainty about the inflation process such as the continued appreciation of the yen was emphasized, criticism that the central bank should have implemented monetary easing within 1994 may be warranted. However, what was recognized at that time was primarily the downside risk from the influence of the yen's appreciation on the real economy, and there was almost no discussion regarding the deflationary concerns for general prices.[38] This indicates that when adopting the risk management approach, it is important to distinguish which uncertainty confronting the central bank is most costly – or more precisely, which risk, if once realized, would result in the most severe loss.

(2) Relative Weight on the Price Stability and Uncertainty about the Inflation Persistence

The analyses in Chapter 4 are based on given weights (χ, δ) for the loss function (18). However, the New Keynesian economics suggests that as the degree of uncertainty about inflation dynamics increases the central bank should place much more weight on the price stability, that is, reduce the values of χ and δ.[39] This section summarizes the background to this way of thinking.

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[37] Under inflation zone targeting, a policy response is needed before the inflation rate reaches the lower limit of target zone, since inflation persistence makes the central bank unable to stop a decline in inflation immediately. For details, see Orphanides and Wieland [2000].

[38] Jinushi et al. [2001] criticize the BOJ for leaving the official discount rate unchanged in 1994: "A further loosening in 1994 might have prevented the abnormal yen appreciation in March 1995 and might have accomplished stronger recovery afterward." However, this is only a retrospective argument from the hindsight of 2001.

[39] See Kimura and Kurozumi [2007] and Walsh [2005].

The absolute value of social welfare losses is expressed by the following equation.

$$\Omega_\pi Var[\pi_t - \pi^*] + \Omega_y Var[y_t - y_t^*] + \Omega_i Var[\Delta i_t] \tag{22}$$

The loss function (18) and the relative weight have the following relationship.

$$\chi = \Omega_y / \Omega_\pi, \ \ \delta = \Omega_i / \Omega_\pi \tag{23}$$

The first term of equation (22), $\Omega_\pi Var[\pi_t - \pi^*]$, is the welfare cost of inflation volatility, and the parameter Ω_π has a close relationship with the parameter θ which measures the inflation persistence.[40] In the Phillips curve (10), it is assumed that a fraction $1-\omega$ of firms set prices based on marginal costs in a forward-looking manner and remaining fraction ω uses a backward-looking rule to set prices ($0 \le \omega \le 1$). An increase in the fraction ω has highly persistent effects on the relative price dispersion across firms and hence fluctuations in aggregate inflation increase welfare cost. This means that as the fraction ω increases the parameter Ω_π rises. Simultaneously, an increase in the fraction ω makes inflation more persistent, that is, it raises the parameter θ of the Phillips curve. In other words, the root of the inflation persistence lies in the existence of firms which uses a backward-looking rule to set prices, and the uncertainty about the inflation persistence results from the central bank's lack of information regarding the fraction ω of firms that use a backward-looking rule. When the fraction ω is uncertain for the central bank, it faces both uncertainty about the inflation persistence θ and about the welfare parameter Ω_π.

It is known that the welfare parameter Ω_π is a non-linear function of the fraction ω, and thus as the degree of uncertainty about ω increases the expected value of Ω_π rises drastically. So from the perspective of the Bayesian approach, when the central bank faces uncertainty about the inflation persistence, it is desirable for the bank to place much more weight on the price stability, i.e. to decrease the values of χ and δ in the loss function (18). Similarly, from the perspective of the minimax approach, it is also desirable to give top priority to the price stability under uncertainty about the inflation persistence, because the maximum level of welfare loss occurs in the case of

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40 For details, see Kimura, Fujiwara and Kurozumi [2005].

the high fraction ω and hence the large value of Ω_π.

Therefore, when the central bank faces uncertainty about the inflation persistence, it should place much more weight on the price stability by reducing the values of χ and δ, and set the inflation coefficient α and the real growth rate coefficient γ of the policy rule higher (see Chart 9).[41].

6. Counter-factual Simulation

Finally, we conduct a simulation to examine how the shape of the economy would have changed if the BOJ had implemented more aggressive monetary easing in the early 1990s. Specifically, we conduct a policy simulation, assuming that the BOJ considers uncertainty about the inflation process very seriously and places higher weight on the price stability, i.e. lower weight on the output gap stabilization and the interest rate smoothing in the loss function (18). We adopt the following policy rule, with reference to the optimal coefficient combination in the case of $\chi = 1.0$ and $\delta = 0.0$ (see Chart 9).[42]

$$i_t = Max\left[0,\ i^* + 2.5(\pi_t - \pi^*) + 0.5(y_t - y^*_{t|realtime}) + 0.5\Delta y_t\right] \tag{24}$$

This rule increases the inflation coefficient α and the real growth rate coefficient γ compared with their values of the policy rule (20) which represents the BOJ's actual policy conduct. Equation (24) uses a *Max* function considering the zero interest rate bound throughout the simulation period.

Chart 16 shows the result of the simulation which sets the beginning at 1991 Q1, i.e. the peak of the business cycle at that time. If monetary policy had been conducted based on equation (24), the BOJ would have implemented more aggressive monetary easing, decreasing nominal interest rates by as much as an additional 1% from the first half of 1993 through the first half of 1995. As a result, over the same period the negative output

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[41] When lowering the relative weight on interest rate smoothing δ, it is desirable to raise the real growth rate coefficient γ and the output gap coefficient β of the policy rule. However, as is clear from the analyses in Chapter 4(3), it is important to note that raising the value of β has the weakness of also responding to the measurement error of the output gap.

[42] We set the inflation target π^* at 1%.

gap (the deflationary gap) would have been narrowed and the CPI inflation rate would have been about 0.2% higher than its actual levels. Subsequently, in the late 1990s the CPI inflation would have continued to be higher than actual.

However, as shown in Chart 16, aggressive monetary policy would not have resulted in an outstanding reduction in the deflationary gap.[43] This is because the stock adjustment pressures and balance sheet adjustment pressures from the collapse of the bubble were strong. Similarly, there was a great influence of the credit crunch that resulted from the financial system shock at the end of 1997, so the deflationary gap would have remained substantial through 1998. As a result, even under an aggressive policy response the CPI inflation would have driven back into negative territory once again in 2000.

The above simulation indicates that while a more aggressive policy response following the collapse of the bubble would have provided some underpinning to the inflation rate and the real growth rate, its effect would have been limited and just implementing monetary easing earlier would not have changed the overall image of the prolonged stagnation of the 1990s.[44]

7. Conclusions

To date, diverse debates have developed regarding the prolonged stagnation of the Japanese economy during the 1990s. Broadly speaking, there are two main ways of thinking regarding the prolonged stagnation: the supply-side view (decline in the potential growth rate); and the demand-side view (insufficient demand). As a specific example of the demand-side view, we examined the position asserted by many advocates that "the delay in monetary easing in the early 1990s caused insufficient

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[43] In the JEM, these two adjustment pressures are represented by the negative demand shock $\mu_t < 0$ in the IS curve (11).

[44] Kawasaki and Aoki [2004] conduct a simulation using a macroeconometric model of the Japanese economy and derive similar results to ours. On the other hand, Ahearne et al. [2002] derive the conclusion that deflation could have been avoided if interest rates had been permanently decreased by 2.5% from their actual levels in the early 1990s. However, a 2.5% decrease in interest rate can be considered as an unrealistic setting that cannot be derived under any optimal rule in Chart 9.

demand.”

We found that the BOJ’s policy at that time was basically optimal under uncertainty about the policy multiplier, but that the policy was not optimal under uncertainty about the inflation process and a more aggressive policy response would have been needed. Considering the fact that the Japanese economy fell into a deflationary state from the late 1990s, it seems difficult to deny that in the early 1990s the BOJ should have placed greater emphasis on uncertainty about the inflation process and implemented monetary easing earlier. Nevertheless, the counter-factual simulation indicates that more aggressive monetary easing would not have changed the overall image of the prolonged stagnation. In this sense, the position that the delay in monetary easing was the primary cause of the prolonged stagnation is not supported. A more appropriate viewpoint is that in addition to both demand and supply side problems, the prolonged stagnation resulted from multiple factors such as the non-performing loan problem and other deterioration in bank functions.

In closing, as an implication derived from our analyses, we would like to note that the policy judgment of where the greatest risk lies is a critical point in risk management. Our analyses do indicate that in the early 1990s the BOJ should have given greater emphasis to uncertainty about the inflation process over multiplier uncertainty, but this does not imply that the former will constitute the greater risk at all times in the future. It is necessary to examine in real time what is the greatest risk in the economic assessment.

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(Chart 1)

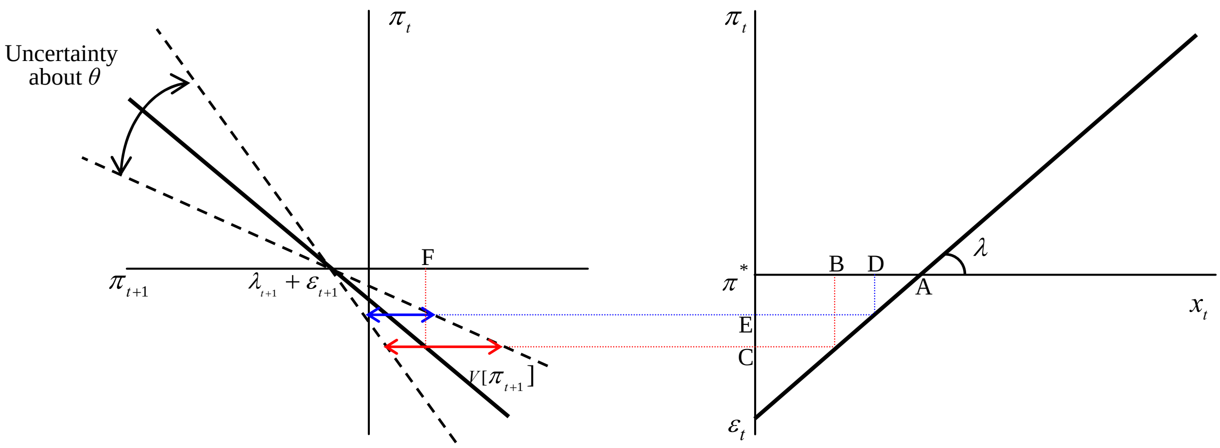
Parameter Uncertainty and Policy Response in a Dynamic Model

Relationship between the current period's inflation rate π_t (vertical axis) and the subsequent period's inflation rate π_{t+1} (horizontal axis)

$$\pi_{t+1} = \theta\pi_t + \lambda x_{t+1} + \varepsilon_{t+1}$$

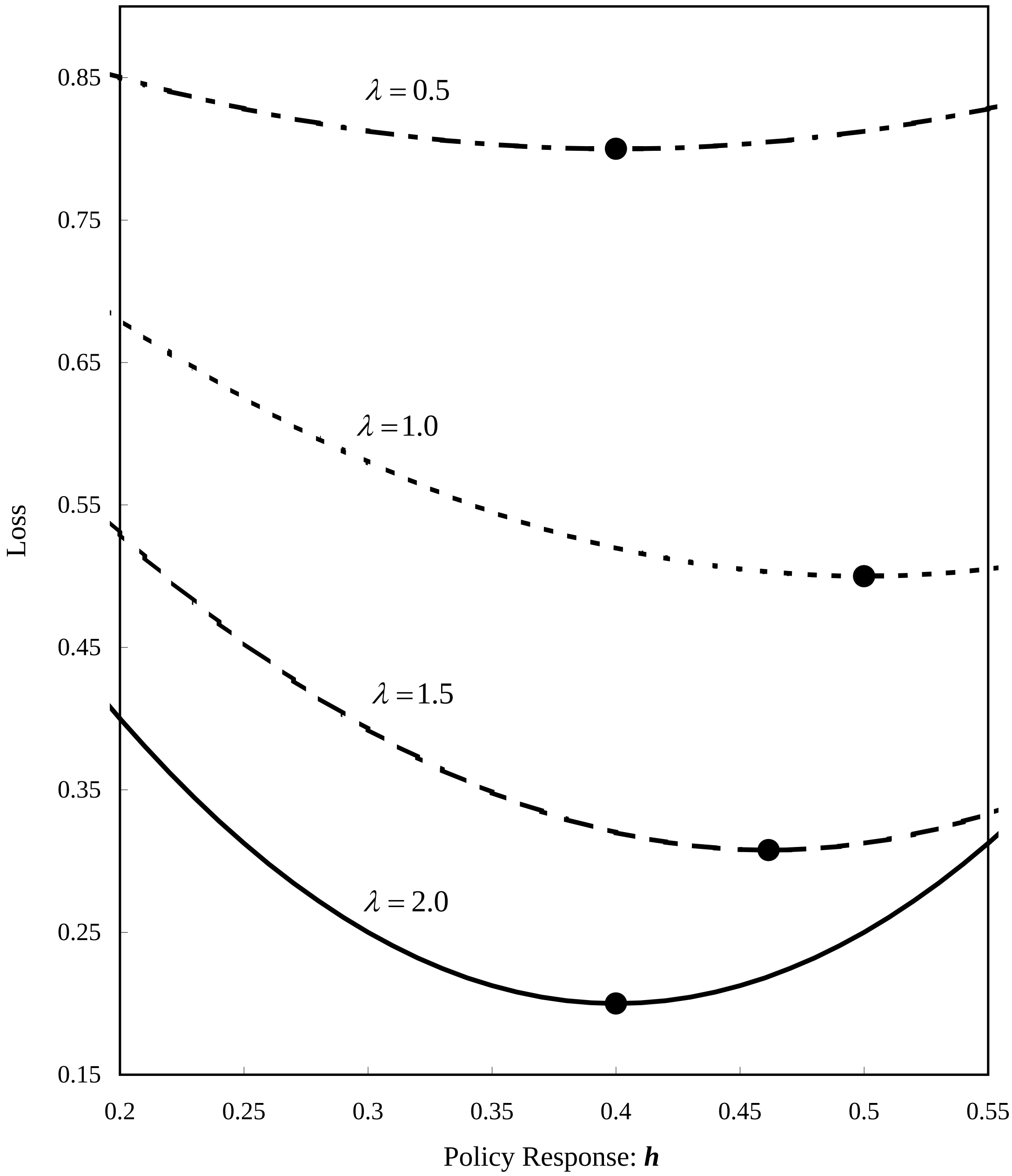
Relationship between the current period's inflation rate π_t (vertical axis) and the current period's output gap x_t (horizontal axis)

$$\pi_t = \lambda x_t + \varepsilon_t$$



(Chart 2)

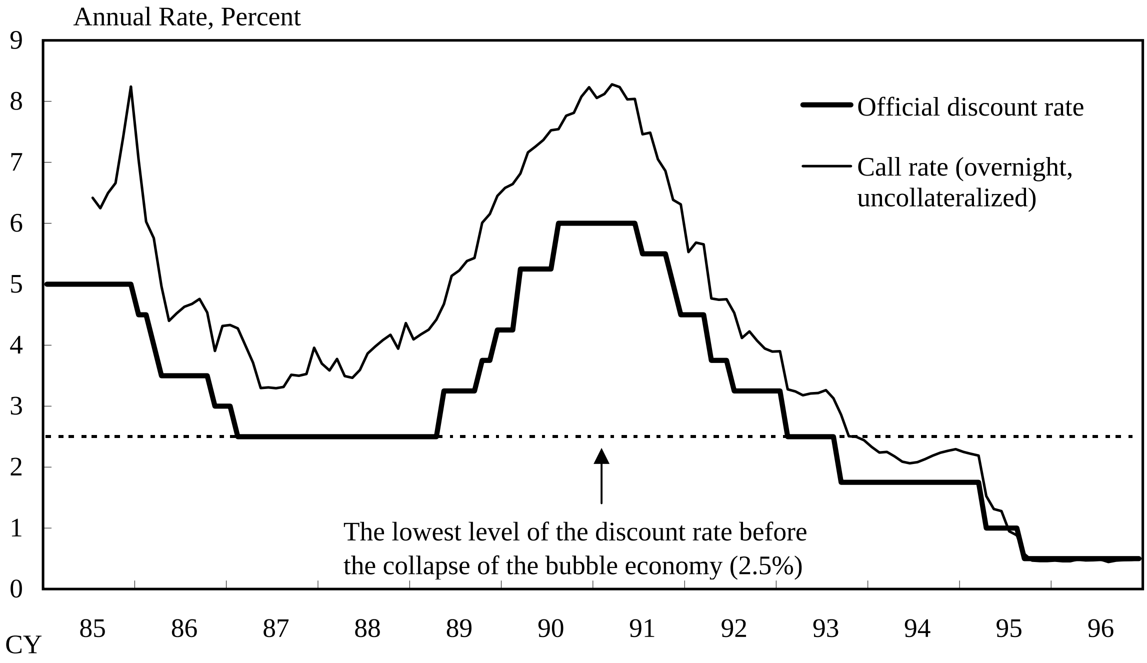
Minimax Approach



Note: ● indicates the point where the loss is minimized for each parameter λ .

(Chart 3)

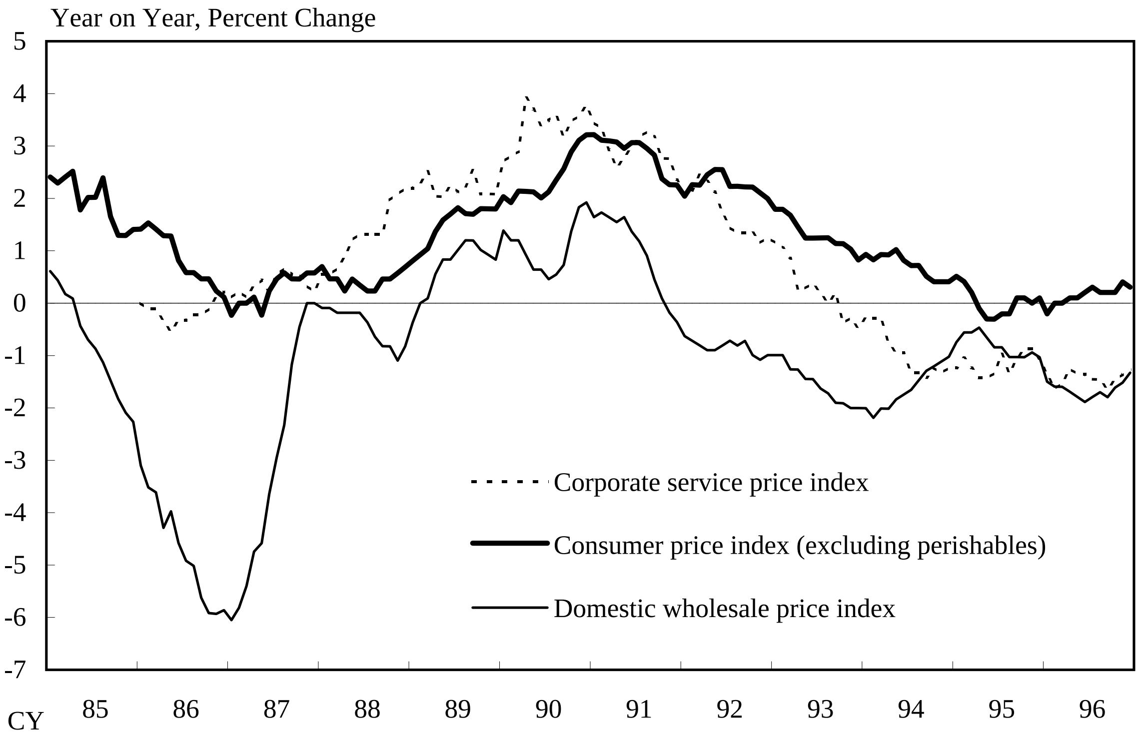
Policy Interest Rates



Source: Bank of Japan.

(Chart 4)

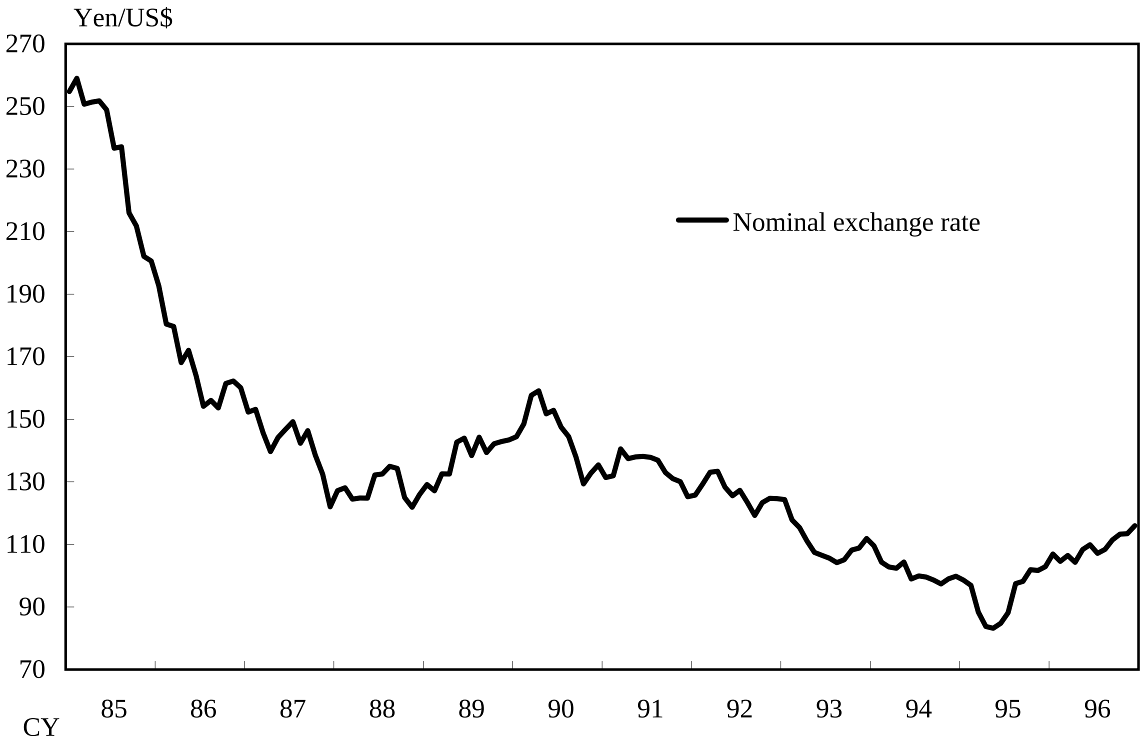
Prices



Note: Figures are adjusted to exclude the effects of the consumption tax hike in April 1989.
Sources: Bank of Japan, Ministry of Internal Affairs and Communications.

(Chart 5)

Exchange Rate



Source: Bank of Japan.

(Chart 6)

BOJ's Assessment on Price Developments during the Collapse of the Bubble Economy
—— Excerpts from the BOJ's Quarterly Economic Outlook Report ——

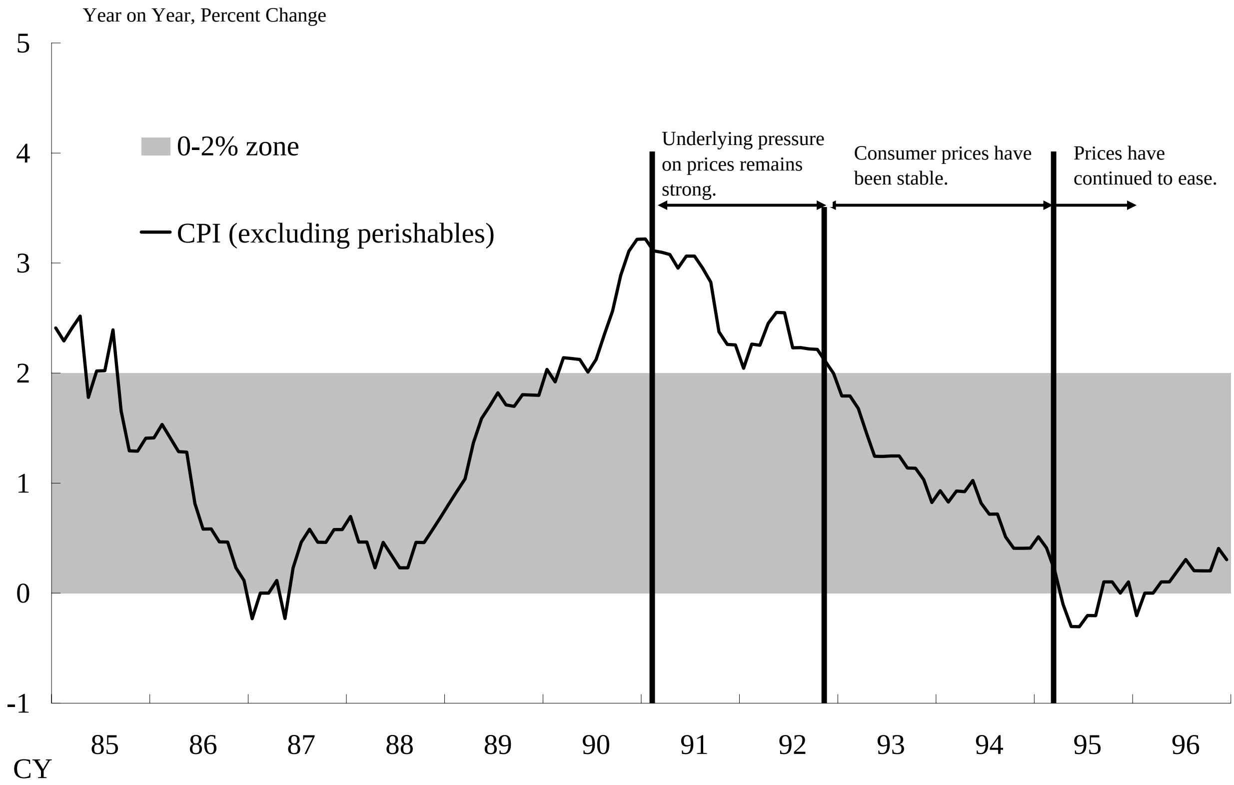
	Recent Developments	Outlook
January 1991	Although price movements on the whole remain within a largely stable trend, both domestic wholesale and consumer prices **have slightly accelerated** recently owing to price increases in petroleum products and perishable foodstuffs, among other items.	(Under such conditions,) **vigilance is called for concerning future price developments, especially in view of pressures** arising from such factors as aforementioned tight market conditions and increasing labor costs, although further acceleration could be avoided against the background of a slowing economy provided crude oil prices and foreign exchange rates remain stable and inflationary expectations subdued.
April 1991	Although prices, on balance, remain within a generally stable range, **moves to pass through cost increases to product/service prices amid tight market conditions are being widely observed**.	Although petroleum-related product prices are projected to drop, **underlying pressure on prices remains strong** because of rises in labor and distribution costs reflecting tight market conditions, and thus an optimistic view with respect to prices is quite premature at this juncture.
July 1991	**Inflation is also slowing down:** The rate of domestic wholesale price increases has decelerated in the past several months owing to declines in the price of petroleum and its related products and **while consumer prices have moderated somewhat, the year-to-year change remains high**.	As economic growth slows gradually, the product and labor markets are expected to become less tight albeit only marginally. This will, it is hoped, stabilize domestic wholesale prices further, provided no large change in exchange rates and commodity prices occurs. Consumer price increases can also be expected to decelerate, albeit gradually, as manufactured goods prices become stable. However, partial economic slowdown may create only limited breathing space in the current environment of near-full employment and capacity utilization, **posing a continued risk of a wide range of output prices drifting upward**.
October 1991	While domestic wholesale prices have stabilized, **consumer price increases, particularly those of services, have come down only marginally**.	With easing in the product markets, wholesale prices are expected to remain stable. **However, a sharp deceleration in consumer price increases, particularly service prices, cannot be expected**.
January 1992	While **the stabilization of consumer prices remains a policy task, especially with respect to persistently high increases in service prices**, wholesale prices have further stabilized. On balance, prices are stabilizing.	Domestic wholesale prices are expected to maintain a stable trend owing to relaxed product conditions and softening international commodity prices. Although **manufactured product prices will lead to stable consumer prices, service prices will continue to exert upward pressure on overall consumer prices amid tight labor market conditions**.
April 1992	Further stabilization of wholesale prices is particularly noteworthy. **The rate of increase in consumer prices, although there remains some upward pressure with regard to service prices**, is falling due to the slowing momentum of industrial product prices.	Domestic wholesale prices are forecast to remain stable owing to steady international commodity prices and moderate domestic demand growth. **As for consumer prices**, although the increase rate in public utility charges might rise, the ongoing favorable influence of stable wholesale prices on industrial product prices will continue. **There remains, however, upward pressure on service prices reflecting tight labor market conditions**.
July 1992	Wholesale prices have been on a stabilizing trend. **The rate of increase in consumer prices is declining as well, on balance, owing to the stabilization of industrial product prices, although some upward pressure appears to remain with regard to service prices**.	(Under such circumstances,) **both domestic wholesale prices and consumer prices are expected to remain stable**, since supply/demand conditions in product and labor markets are not likely to tighten rapidly even after final demand and production recover.
October 1992	Wholesale prices have been on a stabilizing trend and **the rate of increase in consumer prices is also gradually declining reflecting calm industrial product prices, although no significant decline has been observed with respect to service prices**.	(Under such circumstances,) **both domestic wholesale prices and consumer prices will likely remain stable**, since no significant tightening of supply and demand conditions in product and labor markets is expected, at least not for the moment.
January 1993	Wholesale prices have been on an easing trend, and **the stabilization of consumer prices has become evident since the rate of increase in service prices, which has remained high, appears to have started declining**.	(Given the economic outlook as described above,) **both domestic wholesale prices and consumer prices will likely remain stable**, since no significant tightening of supply and demand conditions in product and labor markets is expected, at least not for the moment.
April 1993	In terms of price developments, domestic wholesale prices have been easing and **consumer prices have stabilized considerably**, since the rate of increase in service prices, which remained high last year, seems to be declining somewhat.	(Given the economic outlook as described above,) **both domestic wholesale and consumer prices will likely remain stable**, since no significant tightening of supply and demand conditions in product and labor markets is expected for the foreseeable future.

July 1993	With respect to inflation performance, domestic wholesale prices continue to decline, and **increases in consumer prices have been slowing, both for product prices and service charges**.	On the inflation front, **both domestic wholesale and consumer prices will likely remain stable** because product as well as labor market conditions are unlikely to tighten rapidly in the immediate future and as the recent appreciation of the yen will put some downward pressure on prices.
October 1993	Wholesale prices have declined and rises in the corporate service prices index have slowed. With respect to consumer prices, prices of perishables went up in July and August because of bad weather. **The underlying trend in the CPI, however, has been stable**.	**Domestic wholesale prices, the corporate service prices and consumer prices are all expected to continue to be stable** under loose labor and product markets.
January 1994	With respect to price performance, domestic wholesale prices continue to ease, and both the corporate service prices and **consumer prices have stabilized**.	Both labor and product markets will continue loose. The recent decline in oil prices will have additional downward pressure on prices. Therefore, domestic wholesale prices will likely continue to ease in the immediate future, while corporate service prices and **consumer prices are expected to be stable**.
April 1994	With respect to price performance, domestic wholesale prices have continued to ease, while the Corporate Service Price Index and **consumer prices have both been stable**.	Prices are expected to remain stable. Domestic wholesale prices will continue to be stable while the corporate service prices and **consumer prices will probably add to stability**.
July 1994	With respect to price performance, domestic wholesale prices have continued to ease, while both the Corporate Service Price Index and **consumer prices have been stable**.	**Prices are anticipated to remain stable in general**. Year-to-year declines in domestic wholesale prices will become slower as product markets become tighter. However, **increases in consumer prices will probably come down further**.
October 1994	Both domestic wholesale prices and corporate service prices have remained below the level of the previous year, and **the rate of increase in consumer prices has also declined**.	**Prices will be stable**. While the slack in product markets will narrow, the rise in unit labor costs will slow down against the background of production increase, and cheaper imports will increase. In terms of domestic wholesale prices, the decline year to year will become smaller, while **the rate of consumer price increase (excluding perishables) will continue to decline in the near future**.
January 1995	With regard to inflation performance, the declines in domestic wholesale prices year to year have slowed somewhat. Declines in corporate service prices, however, have accelerated and **the rate of increase in consumer prices has continued to come down**.	**Prices will be stable**. Possible upward pressures from rises in international commodity prices and recovery in domestic demand are unlikely to materialize given the remaining wide output gap in the economy and downward pressures from increases in cheap imports. In terms of domestic wholesale prices, their decline year to year will become smaller and the rate of increase in consumer prices (excluding perishables) may virtually stop dwindling. Under the influence of intensified competition in the distribution sector, however, **consumer prices are likely to remain stable** despite diminishing downward pressures on domestic wholesale prices.
April 1995	**Price conditions have continued to be weak**. While domestic wholesale prices have virtually stopped declining, **the year-to-year rise in consumer prices has gradually been coming down**, and the declines in corporate service prices have accelerated.	As growth momentum is weak, the output gap is large, and import prices decline, **price conditions will continue to be weak**. To be specific, domestic wholesale prices have now stopped declining but are likely to go down again. **The year-to-year increase in consumer prices will stay about zero as the increase in cheap imports will exert downward pressures on consumer prices, the so-called "price destruction" phenomenon**.
July 1995	**Prices have continued to ease**. Domestic wholesale prices had virtually stopped declining before the upsurge of the yen in March 1995, but have begun to decline again. **The year-to-year change in consumer prices (excluding perishables) went below zero for the first time in eight years**, while corporate service prices have continued to decline significantly year to year.	**Prices are expected to continue a weak trend** owing to the weak economic recovery, the large output gap in the domestic market, and declines in import prices that accompany the appreciation of the yen. To be specific, the declining trend of domestic wholesale prices is expected to persist while consumer prices (excluding perishables) are also forecast to decrease somewhat year to year, influenced by increased penetration of inexpensive imports.
October 1995	**Although prices in general continued to ease**, the tempo has slowed against the background of production cutbacks and the depreciation of the yen. To be specific, the decline in domestic wholesale prices has slowed recently. **The consumer price index (CPI, nationwide, excluding perishables) had decreased year to year for five consecutive months until August 1995**, but the provisional report on Tokyo CPI exceeded the previous year's level in September 1995.	Although declines in prices are expected to slow down, reflecting the recent depreciation of the yen and some narrowing of output gaps owing to progress in inventory adjustments, **prices are expected to remain unchanged or decline marginally** because of structural downward pressures such as an increase in import penetration.

Source: Bank of Japan

(Chart 7)

CPI and BOJ's Assessment

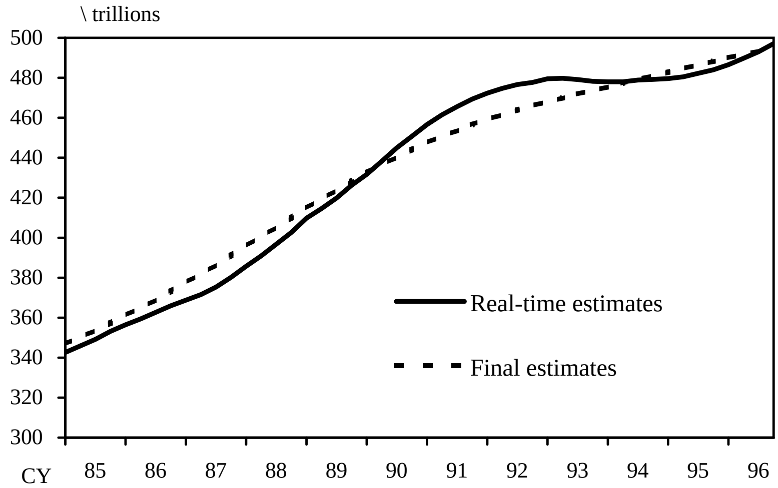


Note: Figures are adjusted to exclude the effects of the consumption tax hike in April 1989.
Sources: Bank of Japan, Ministry of Internal Affairs and Communications.

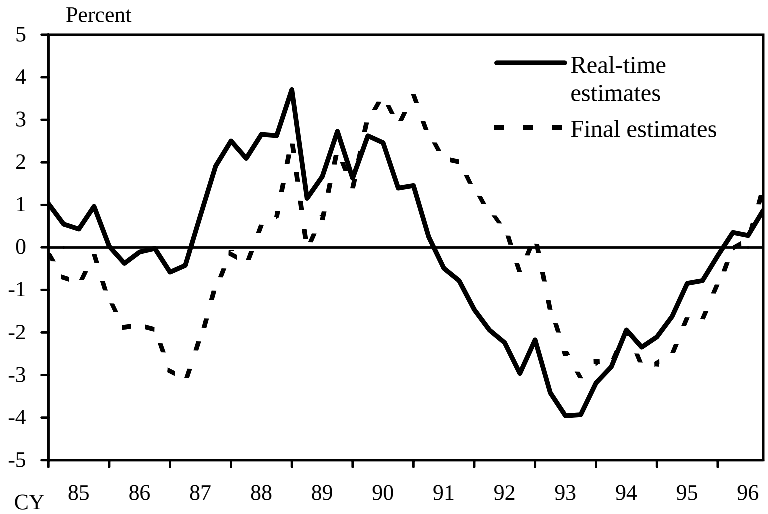
(Chart 8)

Measurement of Output Gap

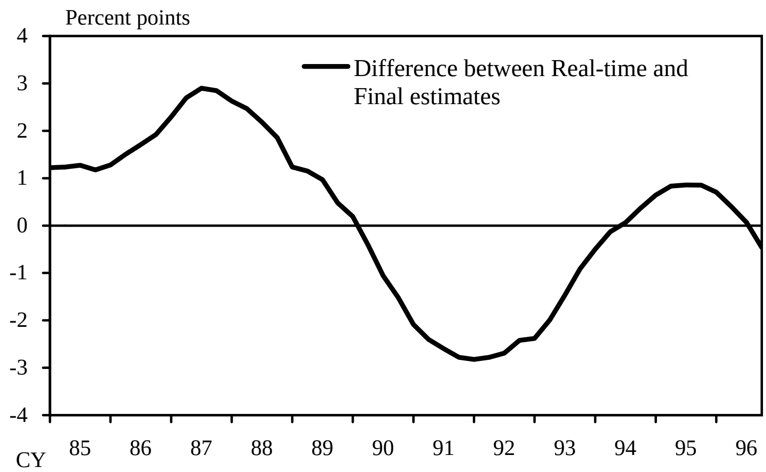
(1) Potential Output



(2) Output Gap



(3) Measurement Errors of the Output Gap ξ_t



(Chart 9)

Simulation Results without Parameter Uncertainty

$$Loss = Var[\pi_t - \pi^*] + \chi Var[y_t - y_t^*] + \delta Var[\Delta i_t]$$

$$i_t = i^* + \alpha(\pi_t - \pi^*) + \beta(y_t - y^*_{t|realtime}) + \gamma \Delta y_t$$

Parameter set of optimal policy rule

	δ=0.5	δ=0.0
χ=0.5	α=1.9 β=0.0 γ=0.0	α=3.7 β=0.0 γ=0.4
χ=1.0	α=1.8 β=0.1 γ=0.0	α=2.7 β=0.1 γ=0.7
χ=2.0	α=1.6 β=0.2 γ=0.1	α=2.0 β=0.6 γ=0.9

large small small

↑ ↑ ↑

α β γ

↓ ↓ ↓

small large large

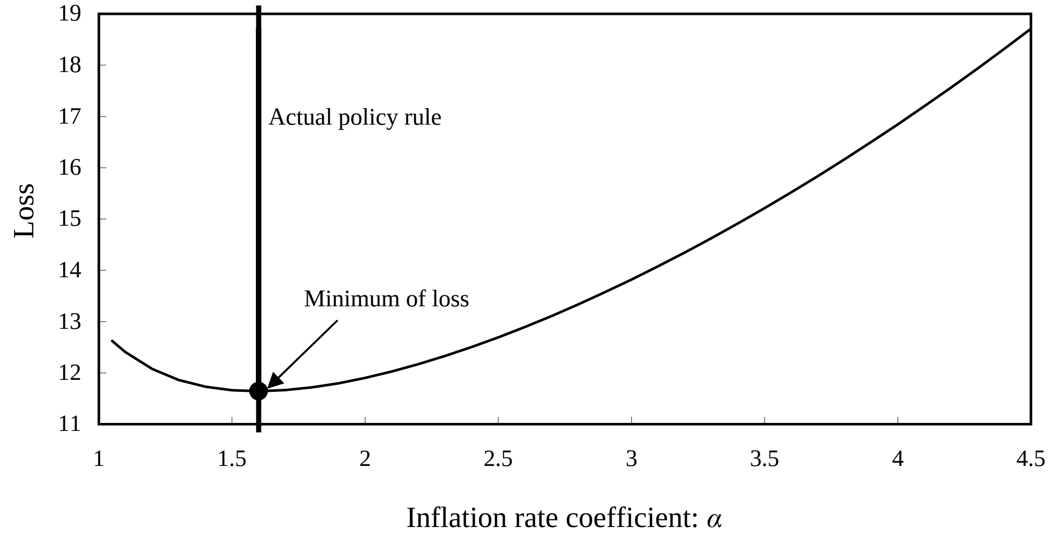
small ← α, β, γ → large

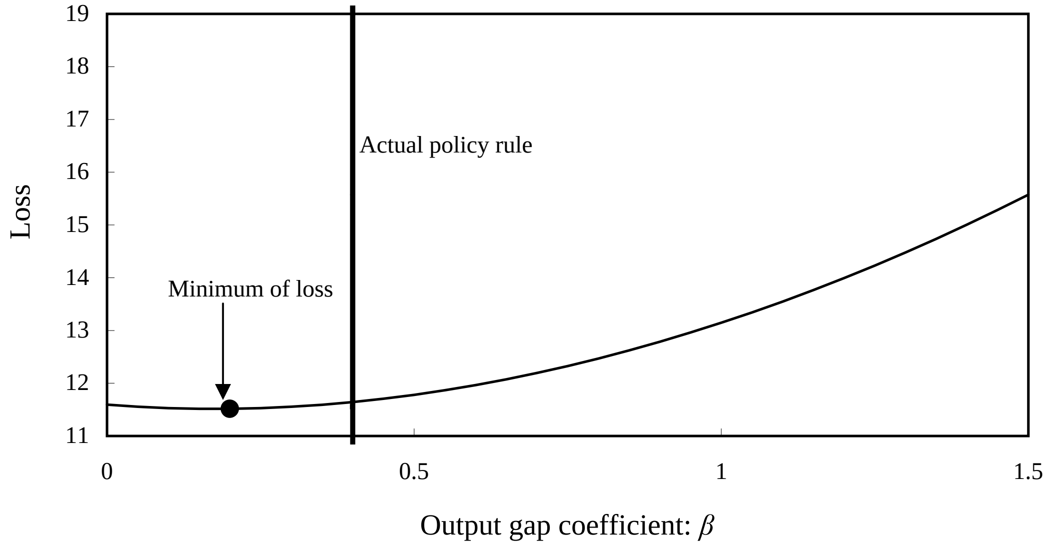
Almost the same as the BOJ's actual policy rule

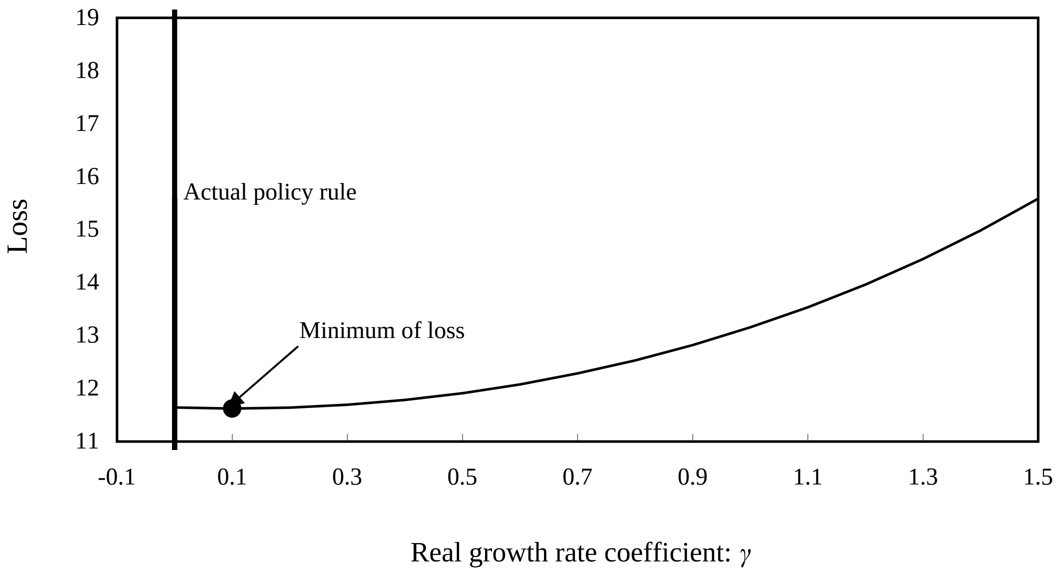
Policy Rule and Loss (χ =2.0, δ =0.5)

$$Loss = Var[\pi_t - \pi^*] + \chi Var[y_t - y_t^*] + \delta Var[\Delta i_t]$$

$$i_t = i^* + \alpha(\pi_t - \pi^*) + \beta(y_t - y^*_{t|realtime}) + \gamma \Delta y_t$$





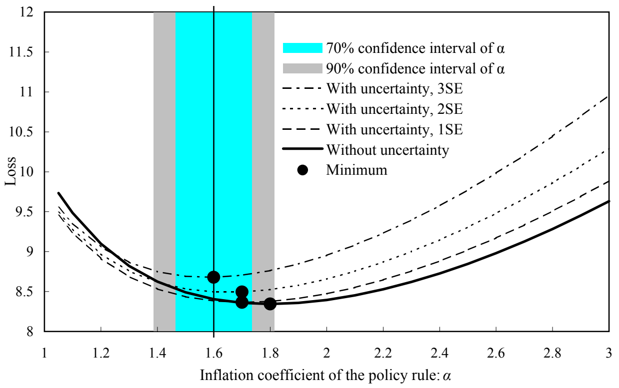


(Chart11)

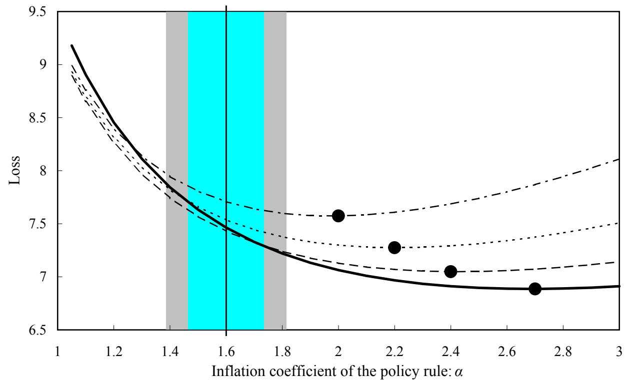
Uncertainty about Policy Multiplier σ and Inflation Coefficient α of the Policy Rule

(1) Bayesian Approach

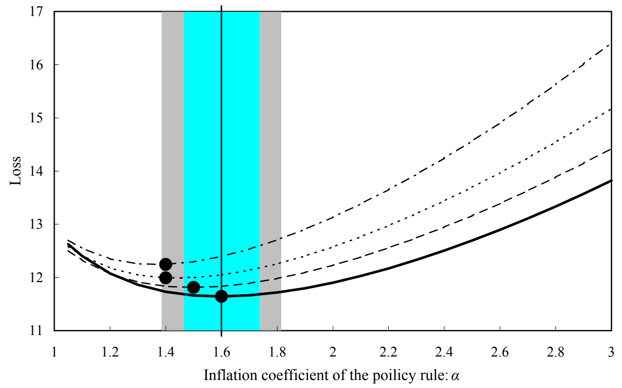
χ=1, δ=0.5



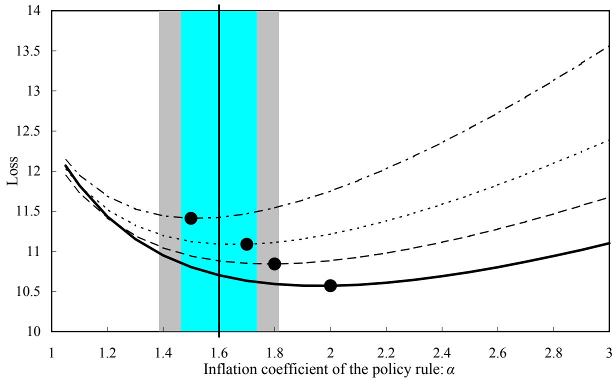
χ=1, δ=0



χ=2, δ=0.5

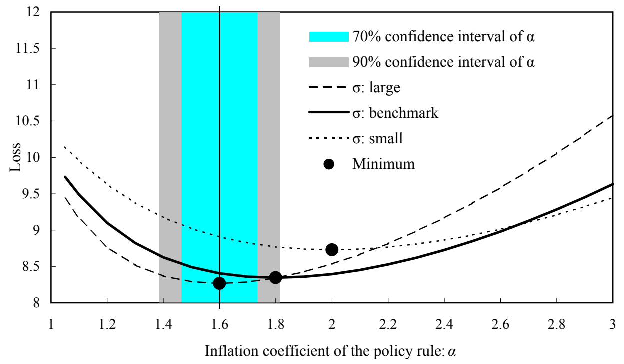


χ=2, δ=0

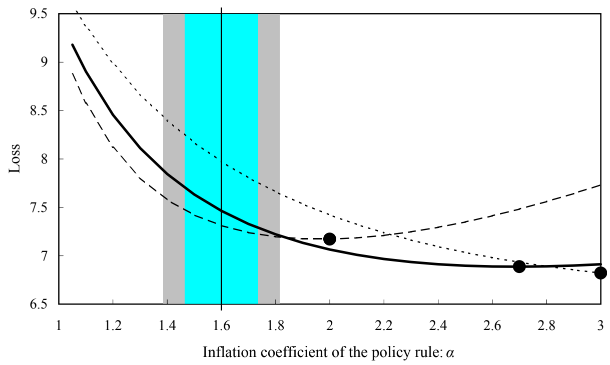


(2) Minimax Approach

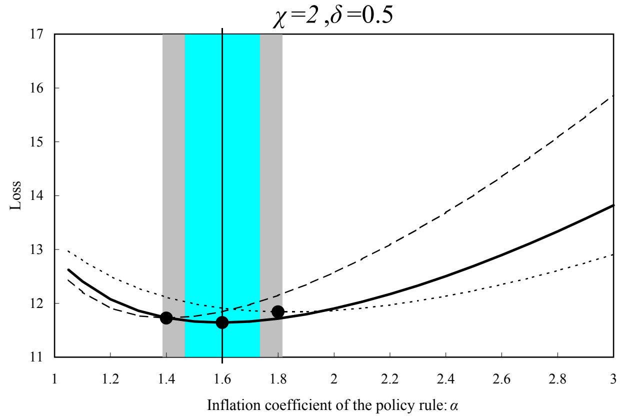
χ=1, δ=0.5



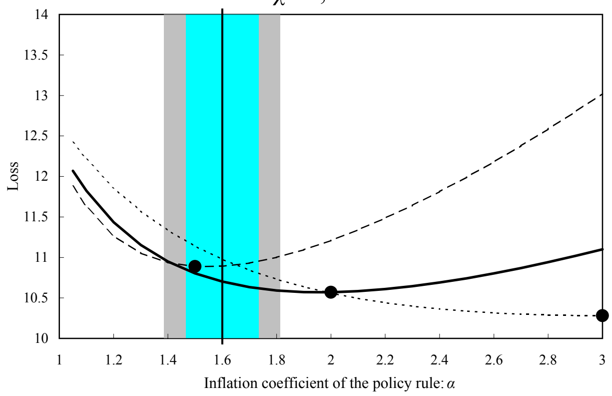
χ=1, δ=0



χ=2 ,δ=0.5



χ=2, δ=0



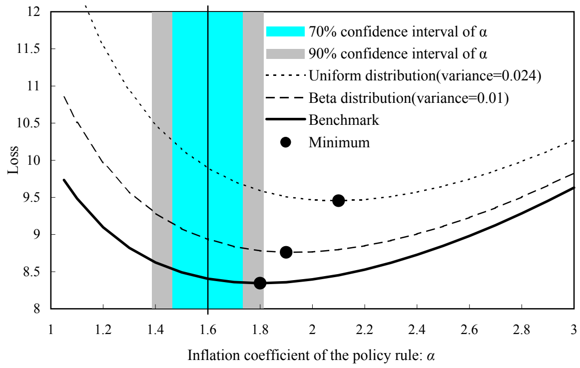
Notes: The confidence interval is based on the standard error of the estimated parameter α of the policy rule (20).
σ: large/small in Chart (2) indicates the case that policy mutiplier σ is larger/smaller than the benchmark by +2SE/-2SE.

(Chart12)

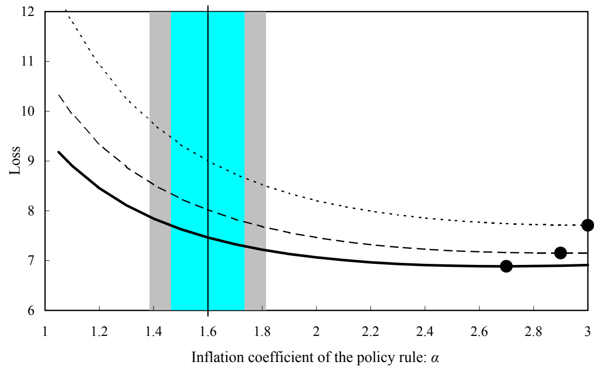
Uncertainty about Inflation Persistence θ and Inflation Coefficient α of the Policy Rule

(1) Bayesian Approach

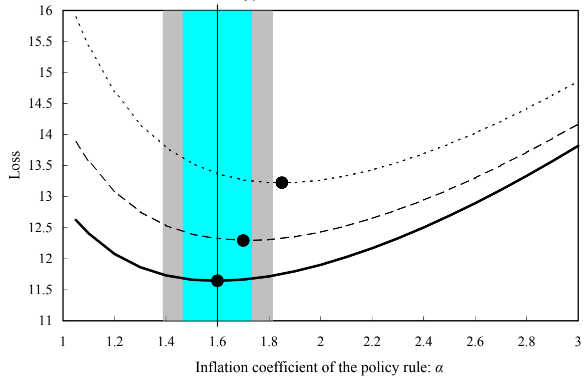
$\chi = 1, \delta = 0.5$



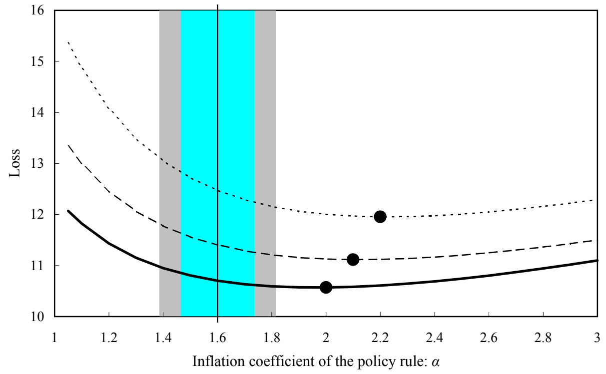
$\chi = 1, \delta = 0$



$\chi = 2, \delta = 0.5$

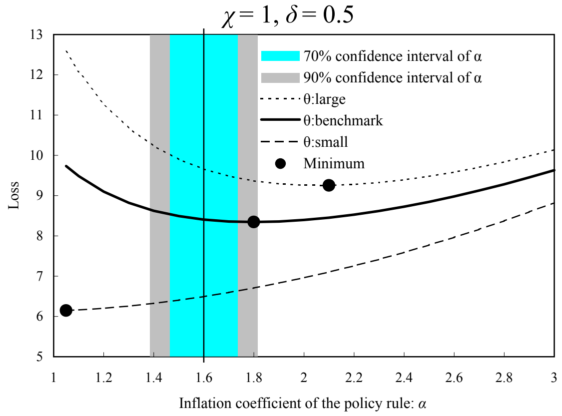


$\chi = 2, \delta = 0$

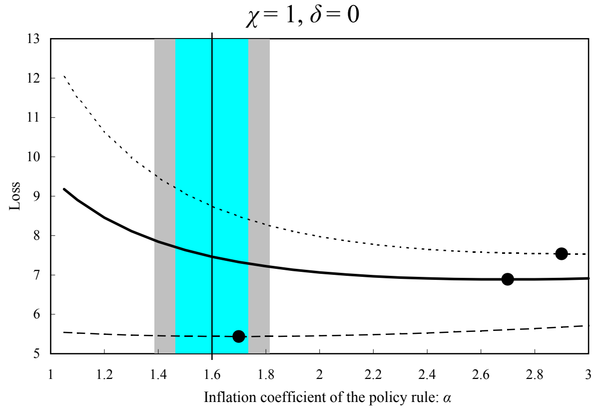


(2) Minimax Approach

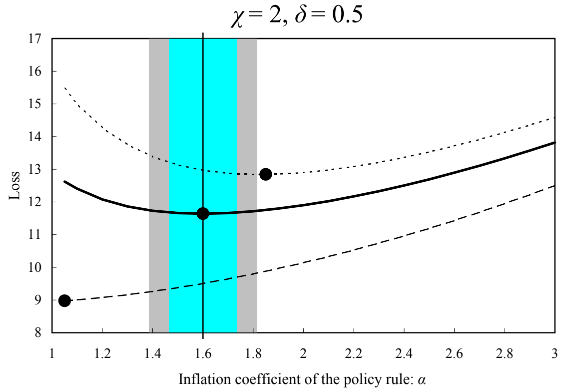
$\chi = 1, \delta = 0.5$



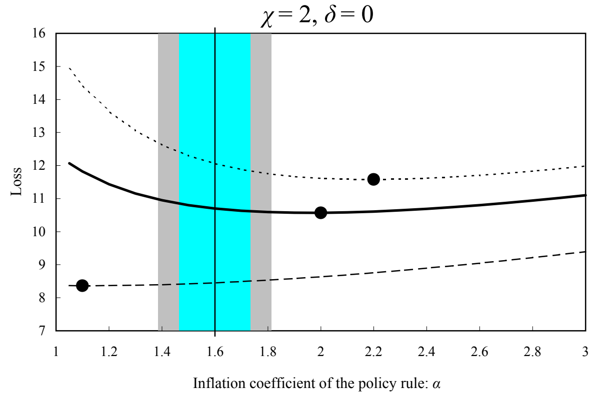
$\chi = 1, \delta = 0$



$\chi = 2, \delta = 0.5$



$\chi = 2, \delta = 0$

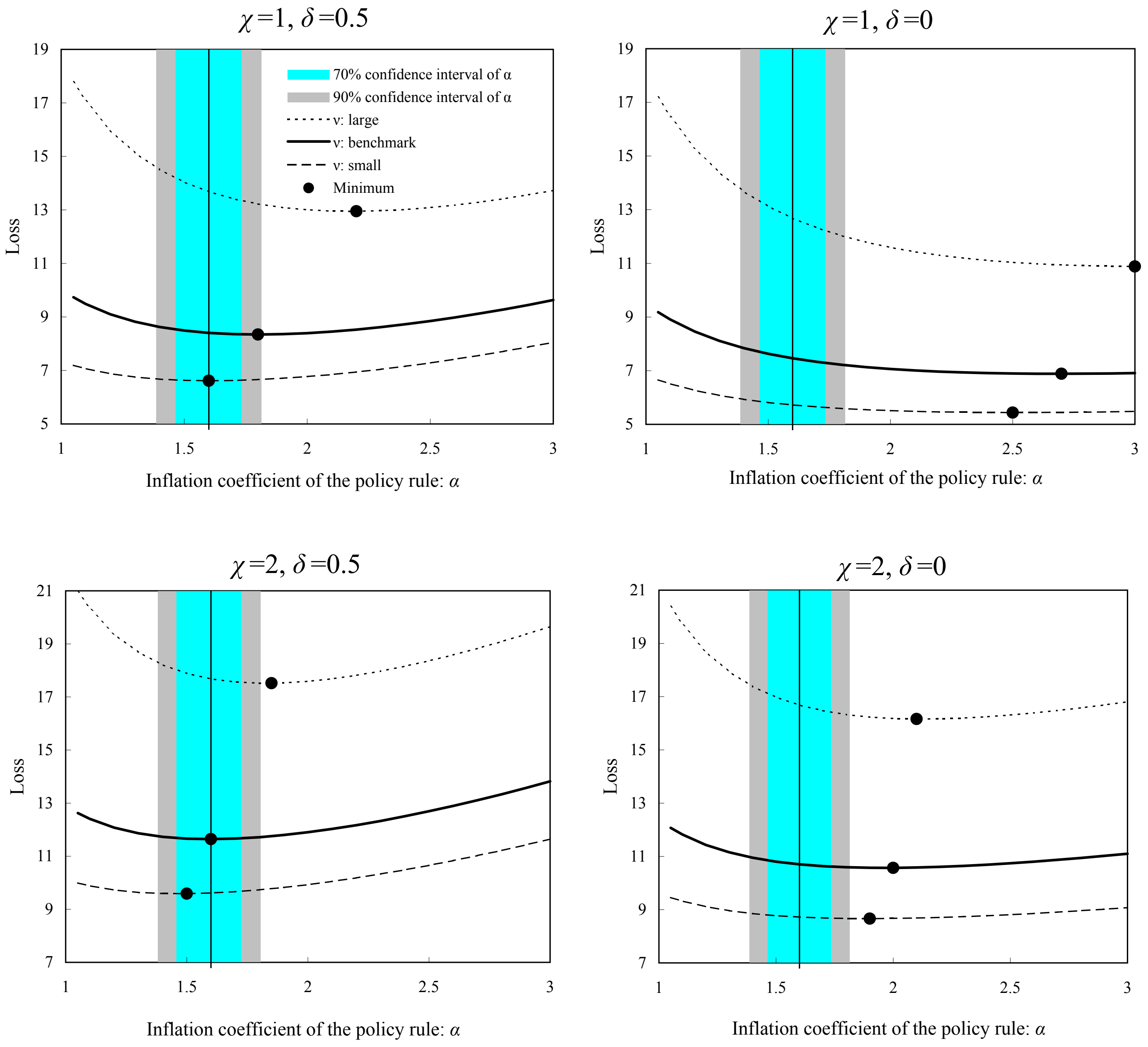


Notes: The confidence interval is based on the standard error of the estimated parameter α of the policy rule (20).
θ: large/small in Chart (2) indicates the case that inflation persistence θ is larger/smaller than the benchmark by +2SE/-2SE.

(Chart13)

Uncertainty about Price Shock Persistence ν and Inflation Coefficient α of the Policy Rule

Minimax Approach



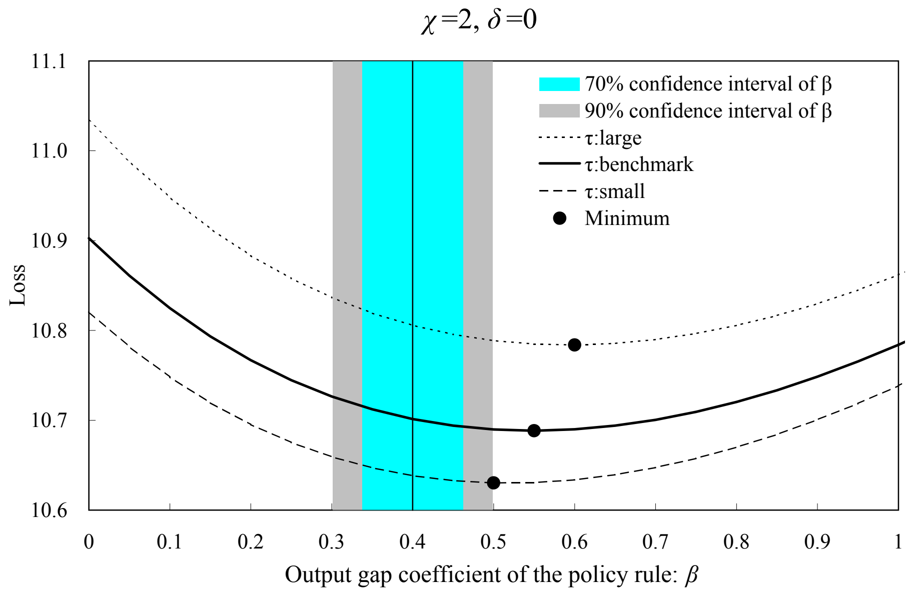
Notes: The confidence interval is based on the standard error of the estimated parameter α of the policy rule (20).
ν : large/small indicates the case that price shock persistencev is larger/smaller than the benchmark by +2SE/-2SE.

(Chart14)

Output Gap Coefficient β of the Policy Rule

(1) Uncertainty about Demand Shock Persistence τ and Policy Reaction

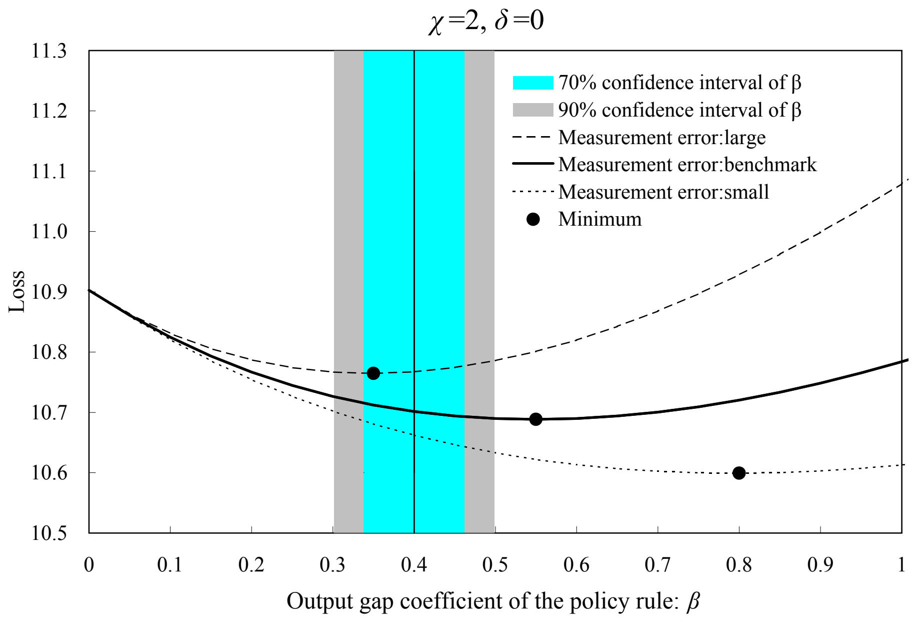
Minimax Approach



Notes: The confidence interval is based on the standard error of the estimated parameter β of the policy rule.
τ: large/small indicates the case that demand shock persistence τ is larger/smaller than the benchmark by +2SE/-2SE.

(2) Measurement Error of Output Gap and Policy Reaction

Minimax Approach

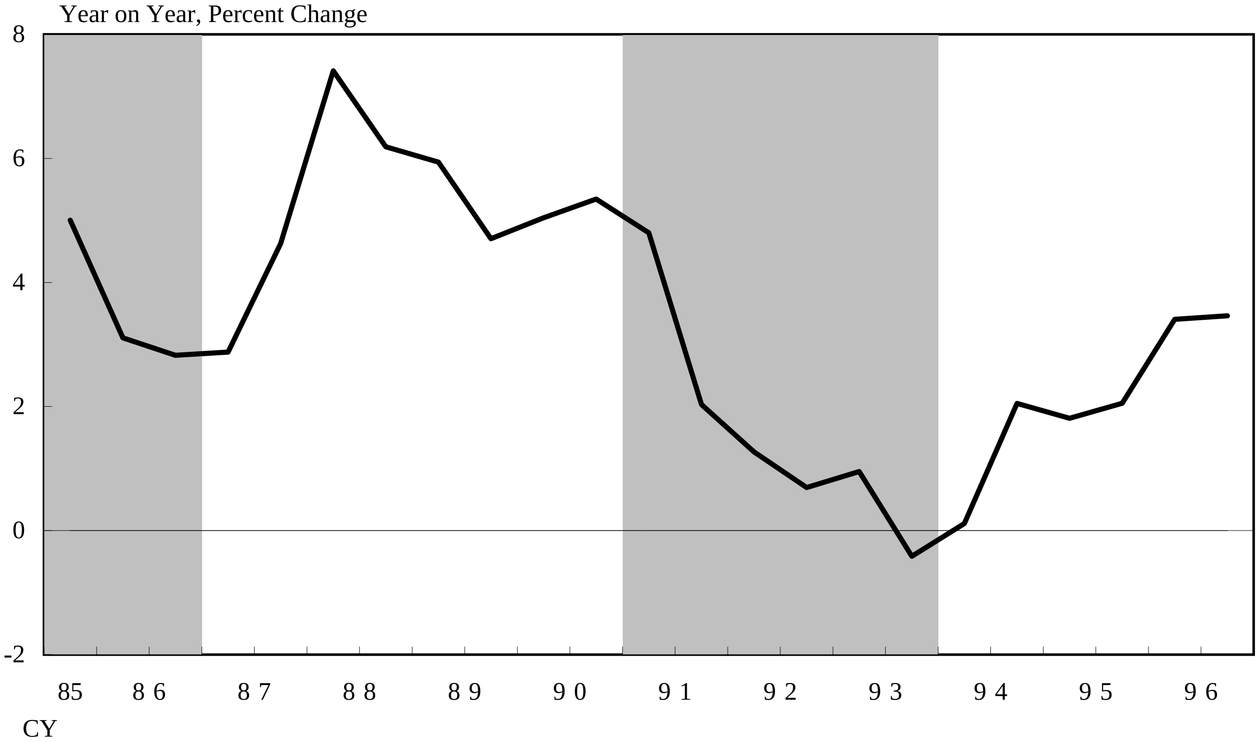


Notes: 1. The confidence interval is based on the standard error of the estimated parameter β of the policy rule (20).
2. The measurement error process ξ_t of Chart 8 is estimated with the AR(2) model, which is used as the benchmark in Chart (2).
Measurement error: large/small indicates the case that the variance of white noise in the AR(2) model is twice/half the benchmark.

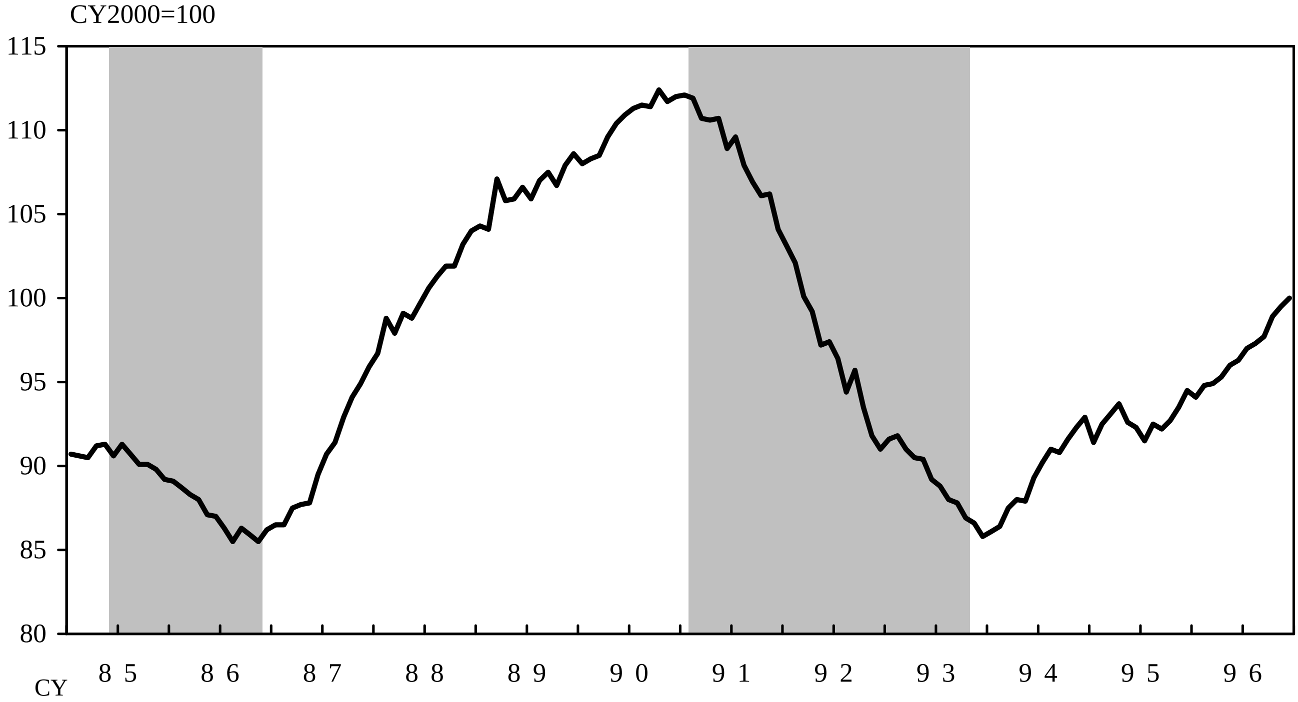
(Chart15)

GDP growth rate and Indexes of Business Conditions (CI)

(1) Real GDP Growth Rate



(2) Indexes of Business Conditions (CI, Coincident Index)

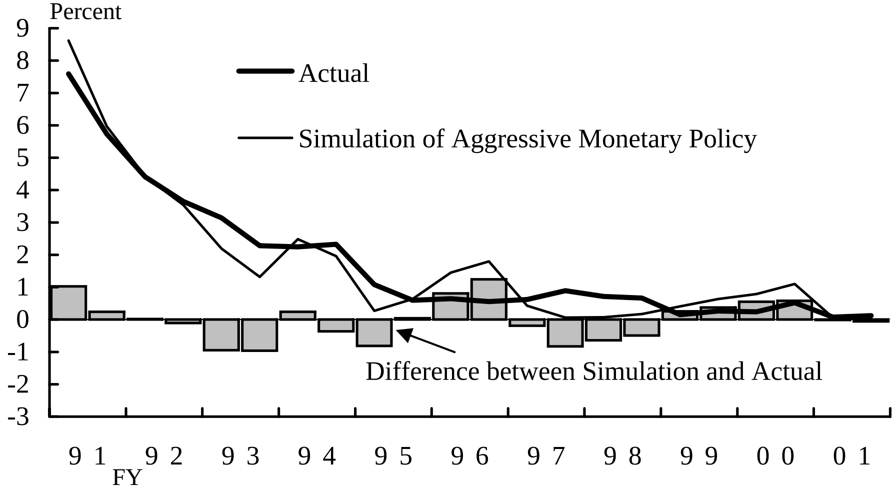


Note: Shaded areas indicate recession periods.
Source: Cabinet Office.

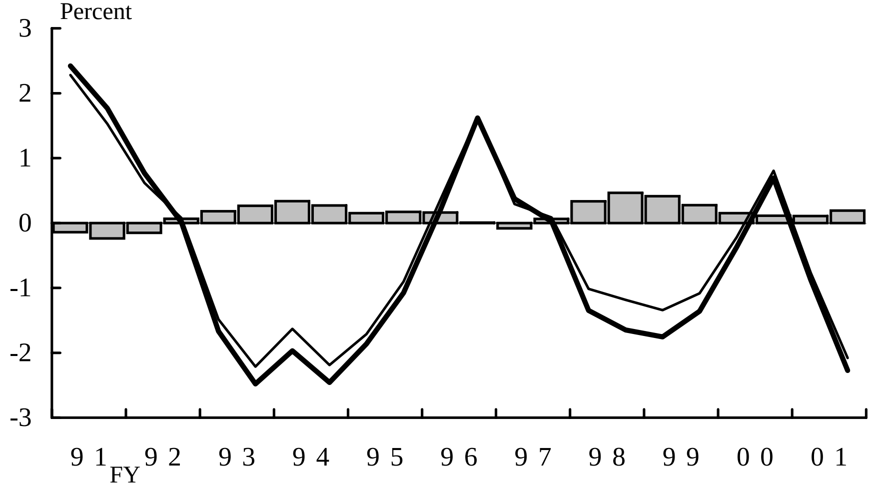
(Chart16)

Counter-factual Simulation

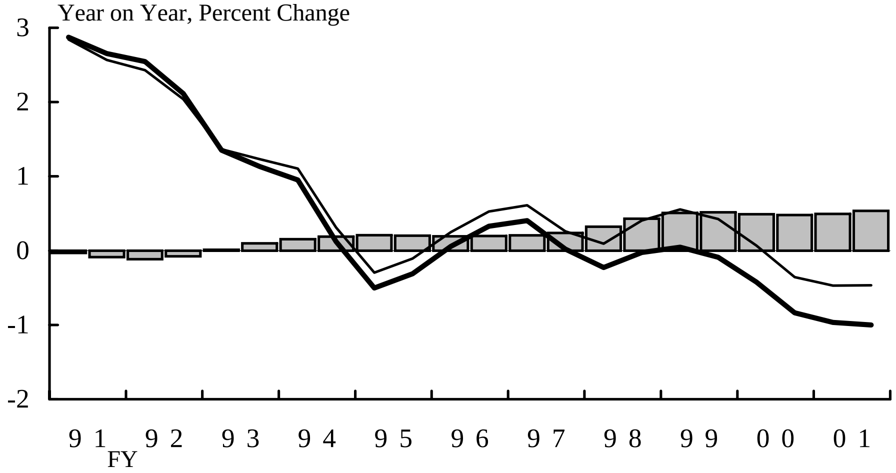
(1) Nominal Short-term Interest Rate (3 months)



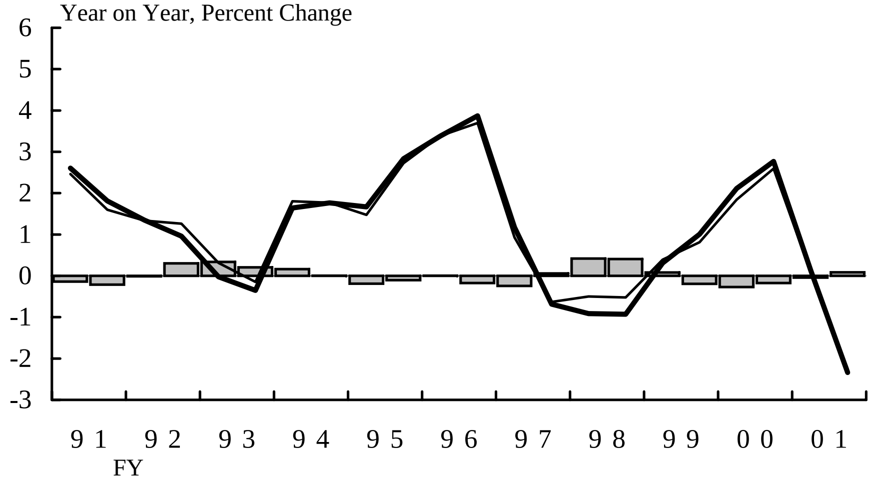
(2) Output Gap



(3) CPI (excluding perishables and public utilities charge)



(4) GDP Growth Rate



Sources: Bank of Japan, Cabinet Office, Ministry of Internal Affairs and Communications.