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Real-Time Estimation of the Output Gap in Japan and its Usefulness for Inflation Forecasting and Policymaking

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Real-Time Estimation of the Output Gap in Japan and its Usefulness for Inflation Forecasting and Policymaking

Koichiro Kamada
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Abstract:

This paper examines the methods used by the Bank of Japan for the estimation of the output gap. Attention is paid to the real-time estimation problem. After reviewing the evolution of output gap estimation at the Bank, I discuss advantages and disadvantages of the various output gap measures. First, I examine the usefulness of the output gap for inflation forecasting and show that the real-time output gap sometimes includes much noise. Second, I investigate the implications of the real-time estimation problem for the policy evaluation. Third, I exploit TANKAN to enhance the usefulness of the real-time output gap.

Keywords: output gap, real-time estimation, inflation forecasting, Taylor Rule

JEL-Classification: E31, E32, E52, E58

Non-Technical Summary

This paper introduces the six measures of Japanese output gap used by the Bank of Japan (BOJ) and discusses their advantages and disadvantages from the viewpoint of the real-time estimation problem.

The paper divides the six measures of output gap into two categories: three of GDP type and three of non-GDP type. The GDP data is an indispensable statistic for the construction of the former measures, while labor statistics and the capacity utilization rate are enough for the latter. The paper has a special interest in the prototype output gap belonging to the latter category, because the Bank staff kept this measure in mind when discussing the relationship between inflation rates and production activity during the period of the Japanese asset-price bubble in the late 1980s and the early 1990s.

To begin with, this paper examines a discrepancy between real-time and final output gap for each output gap measure. The GDP type output gap measures suffer from serious real-time estimation problem due to the revision of source data and the accumulation of new data (e.g, the end-of-sample problem). In contrast, the non-GDP type measures are little affected by the real-time estimation problem. The reasons are that the data revision is finished so quickly as to be assumed away for non-GDP type measures and that the source data of non-GDP type output gap have virtually no trends, whereby the data accumulation causes only a minor problem.

This paper explores the usefulness of the output gap in inflation forecasting. For this purpose, an inflation-forecasting function is estimated with each of the six output gap measures as an explanatory variable. Three output-gap-based forecasting functions are outperformed by a simple AR model in out-of-sample forecasts. The paper also shows that forecasts based on the GDP-type output gap are improved by the Koenig-Dolmas-Piger approach, which makes use of all vintages of data in the estimation of forecasting functions, instead of depending on only one vintages of data.

It is also examined whether the six output gap measures are useful ingredients in the formation of monetary policy. Applying the prototype output gap to the original Taylor rule (with the target of zero inflation) shows clearly that the BOJ’s monetary policy was consistent with this rule during the period of Japanese asset-price bubble from 1988 to

1992. Put differently, the Taylor rule was an incomplete guideline for preventing the asset bubble and should have been modified in some ways. For instance, the BOJ could adjust the level of call rates more quickly and react to output gap more aggressively.

Finally, the paper discusses how to improve the performance of the output gap by utilizing information from TANKAN (Short-Term Economic Survey of Enterprises in Japan). The business-conditions diffusion index (DI) in TANKAN is found significant when used with real-time output gap in forecasting final output gap. In addition, the business-conditions DI is useful in inflation forecasting. As for monetary policymaking, even if improved by the TANKAN information, the GDP-type-output-gap-based Taylor rule is far from being a reliable policy guideline in a real policy formation process.

Nicht technische Zusammenfassung

In dem Diskussionspapier werden die sechs von der Bank von Japan verwendeten Messgrößen für die japanische Produktionslücke vorgestellt und ihre Vor- und Nachteile vor dem Hintergrund des Problems der auf Echtzeitdaten basierenden Schätzungen erörtert.

Die sechs Messgrößen für die Produktionslücke lassen sich in zwei Gruppen einteilen: drei auf dem BIP basierende Messgrößen und drei anderweitig abgeleitete Indikatoren. Die BIP-Daten sind statistisch unverzichtbar für die Erstellung der erstgenannten Messgrößen, während Arbeitsmarktstatistiken und der Kapazitätsauslastungsgrad zur Erstellung der letztgenannten Werte ausreichen. Das Papier konzentriert sich besonders auf die für die zweite Gruppe, da diese Messgröße im Blickpunkt der Mitarbeiter der japanischen Zentralbank stand, als sie den Zusammenhang zwischen Inflationsraten und Produktionstätigkeit während der japanischen Vermögensblase Ende der Achtziger und Anfang der Neunzigerjahre diskutierten.

Zunächst untersucht das Diskussionspapier für jeden der Produktionslückenindikatoren die Abweichung zwischen der aus laufenden und der aus endgültigen Daten errechneten Produktionslücke. Die BIP-bezogenen Messgrößen werden durch das gravierende Problem der laufenden Schätzung beeinträchtigt, das in der Revision der ursprünglichen Daten und der Hinzufügung neuer Daten (z. B. das Problem des Stichprobenendes) begründet liegt. Im Gegensatz dazu sind die zur nicht-BIP-bezogenen Gruppe zählenden Messgrößen von diesem Problem kaum betroffen, da hier zum Einen die Datenrevision so rasch abgeschlossen ist, dass das Problem als irrelevant gelten kann, und da zum Anderen die der nicht-BIP-bezogenen Produktionslückenschätzung zugrunde liegenden Daten praktisch keine Trends beinhalten und die Datenakkumulation lediglich geringe Probleme aufwirft.

Dieses Papier untersucht, inwieweit die Produktionslücke für die Inflationsprognose von Nutzen ist. Zu diesem Zweck wird eine Inflationsprognosefunktion geschätzt, in die jede der sechs Messgrößen der Produktionslücke als erklärende Variable eingesetzt wird. Drei auf der Produktionslücke basierende Prognosefunktionen werden von einem einfachen AR-Modell in „Out-of-Sample“-Prognosen übertroffen. Das Diskussionspapier zeigt auch, dass Prognosen auf der Basis einer BIP-abgeleiteten Produktionslücke durch den Ansatz von Koenig, Dolmas und Piger verbessert werden, der vorsieht, bei der Schätzung von Prognosefunktionen alle Datenjahrgänge zu verwenden, statt sich auf lediglich einen Datenjahrgang zu verlassen.

Es wird ebenfalls untersucht, ob die sechs Messgrößen für die Produktionslücke für die Gestaltung der Geldpolitik von Nutzen sind. Wendet man die prototypische Produktionslücke auf die ursprüngliche Taylor-Regel (mit Null-Inflation als Ziel) an, so zeigt sich deutlich, dass die Geldpolitik der Bank von Japan während der Vermögensblase in Japan von 1988 bis 1992 mit dieser Regel im Einklang stand. In anderen Worten: die Taylor-Regel war eine unvollkommene Orientierungsgröße, um die Vermögensblase zu vermeiden, und hätte in verschiedener Hinsicht verändert werden müssen. Beispielsweise hätte die Bank von Japan das Tagesgeldniveau rascher anpassen und aggressiver auf die Produktionslücke reagieren können.

Abschließend wird erörtert, wie die Ergebnisse aus der Produktionslücke durch die Nutzung von Informationen aus der TANKAN-Erhebung (kurzfristige Unternehmensumfrage in Japan) verbessert werden können. Dabei hat sich der Diffusionsindex (DI) des TANKAN-Berichts als signifikant erwiesen, wenn er zusammen mit der laufenden Produktionslücke zur Prognose der tatsächlichen Produktionslücke herangezogen wird. Darüber hinaus ist der DI nützlich für die Inflationsprognose. Im Bereich der Geldpolitik ist die auf der BIP-bezogenen Produktionslücke basierende Taylor-Regel, selbst wenn sie durch Informationen aus dem TANKAN-Bericht verbessert wird, kaum als verlässliche geldpolitische Richtgröße im konkreten politischen Entscheidungsfindungsprozess geeignet.

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Real-Time Estimation of the Output Gap in Japan and its Usefulness for Inflation Forecasting and Policymaking*

1 Introduction

Measurement of the output gap is clouded in uncertainty. In particular, uncertainty in the real-time estimate of the output gap stems mainly from two sources: the revision of source data and the arrival of new data. The extent of this uncertainty depends on the method used for estimating the output gap. Here, interest is focused on the six output gap measures developed by the Bank of Japan (BOJ) to aid in preparing its economic outlook and in the formation of monetary policy. I review the history of output gap estimation at the BOJ and offer a brief explanation of the construction of the six output gap measures. These measures are then compared with one another, and their advantages and disadvantages are discussed from the viewpoint of vulnerability to data-revision and data-arrival.

This paper quantifies the seriousness of the effect of output gap uncertainty on inflation forecasting as well as on monetary policymaking in Japan. The standard tool for forecasting future inflation rates is the Phillips curve, but the resulting forecasts are often far from satisfactory for real policymaking purposes due to their large errors. The paper estimates a generalized forecast function and shows to what extent forecast uncertainty exists. I show that the output gap often exacerbates the degree of disturbance in inflation rate forecasting. There are some cases where it is better to get rid of the output gap measure from the forecast function altogether.

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Regarding monetary policy, I compare the original Taylor rule with the actual movement of the overnight call rate. The paper shows that BOJ policy from the late 1980s to the early 1990s was basically consistent with the Taylor rule prescription. Remembering the experience in the "lost decade" since the early 1990s, this result suggests that the Taylor rule requires some modifications. The paper investigates, with the benefit of hindsight, how the BOJ's response to the inflation rate and the output gap could have been improved. It is shown that tightening in the late 1980s and easing in the early 1990s would have been stronger and prompter if the BOJ had controlled the call rate more quickly and responded to the output gaps more strongly. It is to be questioned, however, whether such a policy stance was really appropriate or not.

This paper also devotes space to examining the usefulness of representative business cycle indicators for reducing the uncertainty in the output gap estimate. Among the various business cycle indicators published in Japan, there are some indicators that are free from data revision (e.g. the *Short-term Economic Survey of Enterprises in Japan: TANKAN*). The paper discusses how to make use of this additional information so as to eliminate or at least reduce the level of uncertainty in output gap estimates.

The remainder of this paper is constructed as follows. In section II, I review the history of the Bank's development of output gap measures and provide brief introductions to their estimation methodologies. In section III, I present six measures of the output gap with four stages of data revision, as defined in Orphanides and van Norden (2002), and show how seriously the output gap measures are distorted by the real-time estimation problem. In section IV, the usefulness of output gap measures in inflation forecasting is evaluated. In section V, the Bank's policy from the late 1980s to the 1990s is evaluated from a Taylor rule perspective and I discuss possible modifications to improve the rule as a policy reference. In section VI, a remedy for improving the real-time measure of output gap by using information from the TANKAN is introduced and its implications for inflation forecasting and policymaking are discussed. In section VII, I summarize the main results of this paper.

2 History of Output Gap Measures at the Bank of Japan

In this section, I briefly review the evolution of output gap measures at the BOJ. The output gap is an indispensable concept for evaluating the current position in the business cycle and for adopting an appropriate monetary policy stance. To my knowledge, however, the BOJ has quite a short history with regard to the development of output gap measures. It was not until 1989 that the first measure of output gap appeared explicitly in a BOJ publication. In what follows, I outline the six measures of the output gap developed at the Bank.

2.1 The Prototype Output Gap

Back in 1988, the question exercising the BOJ staff was how a stable inflation rate could coexist with an extremely high growth rate (figure 1). The Bank of Japan Research and Statistics Department (1989) claimed that the stability of inflation was attributable to a sharp increase in imports. To quantify this effect, the first measure of the output gap was developed. The measure is referred to below as the *prototype output gap*.

The prototype output gap is based on the production function approach and constructed as follows. Denote real GDP by y, the labor input by ℓ, and the capital input by k (all in logarithms). Then, the macroeconomic production function is given by

$$y = a + s\ell + (1-s)k \,, \qquad (1)$$

where s is the income share of labor; and a is the Solow residual, interpreted as total factor productivity. This residual is correctly estimated only if ℓ and k are both correctly measured. Similarly, given maximum labor input, ℓ^*, and capital input, k^*, maximum output, y^*, obtains as

$$y^* = a + s\ell^* + (1-s)k^* . \qquad (2)$$

The output gap g is the percentage deviation of actual output from maximum output, i.e. $g \equiv y - y^*$. Define $g_\ell \equiv \ell - \ell^*$ and $g_k \equiv k - k^*$. Then the output gap is given by

$$g = sg_\ell + (1-s)g_k . \quad (3)$$

With the import effect g_m taken into consideration, the output gap is given by

$$g^m = s_\ell g_\ell + s_k g_k + s_m g_m , \quad (4)$$

where s_ℓ, s_k, and s_m are cost shares of labor, capital, and import goods, respectively and sum to 1. Figure 2.a shows the prototype output gap in the case of no import effect (the case with an import effect is not relevant to the discussion below).

The production function approach suffers from the limited availability of data in practice. In Japan, in particular, there is no data that directly measures capital utilization in the non-manufacturing sector. For this reason, the prototype output gap assumes away the issue of the capacity utilization rate in the non-manufacturing sector in the calculation of the actual capital input, k.

2.2 The Conventional Output Gap

After the bursting of the asset-price bubble in the early 1990s, the Japanese growth rate fell substantially (figure 1). Faced with this slowdown in economic activity, the next question for the Bank staff was how much the potential growth rate had fallen. They also still had to deal with the unsolved question of how to calculate the capacity utilization rate in the non-manufacturing sector. Watanabe (1997) was an attempt to answer these two questions. I call his measure the *conventional output gap* below.

The following trick is employed in calculating the conventional output gap. Capital utilization in the non-manufacturing sector is provisionally assumed to be 100 percent, allowing the distorted Solow residual, $\tilde{a}$, to be obtained. Now assume that productivity grows at a constant rate. Then, true TFP, a, is obtained by regressing the distorted Solow residual on a linear trend.[1]

$$\tilde{a} = \psi_0 + \psi_1 T_t + \eta_t . \qquad (5)$$

The estimate of true TFP is captured by the fitted value, $\hat{a} = \hat{\psi}_0 + \hat{\psi}_1 T$, while the actual capacity utilization rate in the non-manufacturing sector is given by the regression residual, $\hat{\eta}$. Given maximum inputs of labor and capital, equation (2) yields the maximum level of output, from which the potential growth rate and the output gap are calculated as shown in figure 2.b.

This method was also employed by the *Economic Survey of Japan* (published by the Economic Planning Agency, currently the Cabinet Office) and was used as a benchmark in evaluating new output gap measures developed afterward at the Bank. After a few years of experiments, however, various problems emerged with the conventional output gap. Specifically, the substantial decline in the measured output gap during the late 1990s cast doubts on the reliability of the conventional output gap as a policy reference, since the decline was caused mainly by a fall in the regression residual in equation (5).[2]

2.3 The Standard Output Gap

Growing dissatisfaction with the conventional output gap spurred efforts to generate more reliable measures of the output gap. Clearly, problems with the prototype and conventional output gaps emerged from their treatment of capacity utilization in the non-manufacturing sector. Kamada and Masuda (2001) is an attempt to overcome this problem by estimating non-manufacturing-sector capital utilization with the help of various supplementary data, including electricity consumption, overcapitalization, and so forth. I refer to their measure below as the *standard output gap*.

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1 Originally, a kinked linear trend is assumed in the estimation of total factor productivity rather than equation (5), that is, $\tilde{a}_t = \psi_0 + \psi_1 T_t^1 + \psi_2 T_t^2 + \eta_t$. Nonetheless, equation (5) is assumed throughout this paper, since it is difficult to assume at what quarter the Bank staff found the kinks happen.

2 During 1998 - 1999, a series of abrupt structural changes was taking place. The Bank staff suspected that it resulted in a slowdown in the potential growth; and thus the decline in the conventional output gap should be discounted. In reality, however, it is difficult to verify that such changes actually took place and to quantify its effects on output gap, especially in real time.

Figure 3.a shows the estimated capacity utilization rate in the non-manufacturing sector. I review its construction briefly and refer readers to Kamada and Masuda (2001) for detail. Figure 3.b depicts the *electric power units for commercial use*, EPU : the ratio of actual electricity consumption to the contracted amount.[3] First, Kamada and Masuda (2001) regress it on a time trend and the production capacity BSI in the non-manufacturing sector (from the Ministry of Finance's *Business Outlook Survey,* and shown in figure 3.c).

$$EPU_t = \chi_0 + \chi_1 T_t + \chi_2 BSI_t + \zeta_t . \qquad (6)$$

Then, they obtain the capacity utilization rate by removing the trend and errors and normalizing the result with the highest value equal to 1.

$$\frac{\hat{\chi}_0 + \hat{\chi}_2 BSI_t}{\max(\hat{\chi}_0 + \hat{\chi}_2 BSI_t)} \qquad (7)$$

Once the capacity utilization rate in the non-manufacturing sector is obtained, the actual input of capital, k, is estimated correctly and equation (3) produces a correct estimate of the output gap. The resulting output gap is shown in figure 2.c. Furthermore, since the Solow residual is no longer distorted by the business cycle and reflects true total factor productivity, a, the maximum level of output may also be calculated from equation (2) and the potential growth rate obtained.

2.4 The Time-Varying NAIRU

The standard output gap is the percentage deviation of actual output from the maximum or full-employment level of output. It has nothing to do with price movements per se. To gain implications for prices, the Bank staff estimates the NAIRU version of the Phillips curve.[4] Since 1999, the output gap measure has declined steadily. Nonetheless, the inflation rate has appeared relatively stable in terms of the consumer

[3] In fact, the electricity industry uses this index as an indicator of the capacity utilization rate.

[4] Originally, the NAIRU (the non-accelerating inflation rate of unemployment) was defined in terms of an unemployment rate. Here, I define the concept in terms of an output gap.

price index (excluding fresh food) on a quarter-to-quarter basis. This suggests the possibility that the NAIRU itself has declined over time.[5]

By definition, the NAIRU, g^n, should satisfy the following Phillips curve.

$$\pi_t = \pi_t^e + \beta(g_t - g_t^n) + \gamma \cdot x_t + \varepsilon_t, \quad (8)$$

where π is the inflation rate;[6] and π^e is the expected rate of inflation. For the latter, I use the following specification.

$$\pi_t^e = \alpha \Sigma_{i=1}^4 \pi_{t-i} / 4 + (1-\alpha)\Sigma_{i=5}^8 \pi_{t-i} / 4. \quad (9)$$

The x summarizes various supply shocks. Specifically, I use the percentage deviation of import price changes from their moving average over the preceding four quarters.

I assume a random walk process for the NAIRU, namely,

$$g_t^n = g_{t-1}^n + \nu_t. \quad (10)$$

A state space model is constructed with g^n as the state variable, equation (8) as the observation equation, and equation (10) as the transition equation. The Kalman filter may then be applied to estimate the parameters, g^n, α, and β.[7]

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5 Hirose and Kamada (2002) shows that the structural parameters in the Phillips curve become more stable under the assumption of a time-varying NAIRU than a time-invariant NAIRU.

6 In the empirical analysis below, the inflation rate is measured by the consumer prices index, seasonally adjusted, excluding fresh food, and adjusted for consumption taxes.

7 Theoretically, there is no problem in estimating the variance of ε in equation (8) and ν in equation (10) separately, but the estimation is very hard in practice. Assuming that it moves at all, the NAIRU moves only slowly. This implies that the variance of ν is expected to be quite small. As pointed out by Stock and Watson (1998), when the variance of a state variable that moves very slowly is estimated by the maximum likelihood method, it is hard to reject the null hypothesis of "zero variance." In fact, when estimating the variance of ε and ν for a variety of sample periods, many cases are encountered where the variance of ν, which determines the behavior of the NAIRU, is not significantly different from zero. The current paper's approach to this problem is to choose the ratio of the variance of ν to the variance of ε so as to attain a reasonable smoothness in the movement of the NAIRU (currently the ratio is 1/5). The median unbiased estimator introduced by Stock and Watson (1998) is an alternative when the maximum likelihood estimate of the variance is expected to be very close to zero. Gordon (1998) uses this method to estimate the variance of the NAIRU in the US.

In figure 2.d, I present the time-varying NAIRU (TV-NAIRU) output gap. It is worth observing that the decline in the TV-NAIRU output gap has been smaller than the decrease in the standard output gap (figure 2.c) since the early 1990s.

2.5 The NAILO

Since the production function approach requires a lot of data, measurement errors tend to accumulate in the estimated output gap measures. In contrast, time series methods often require fewer data. Thus, measurement error problems are less severe than in the production approach.

The HP filter is one time series method frequently used when estimating the output gap (figure 2.e). An advantage of the HP filter output gap is that it is easy to calculate. Define potential output, y^{hp}, so as to minimize the following formula.

$$\Sigma_{t=1}^{T}(y_t - y_t^{hp})^2 + \lambda\Sigma_{t=2}^{T-1}(\Delta y_{t+1}^{hp} - \Delta y_t^{hp})^2, \qquad (11)$$

where Δ is the first difference operator. The output gap is defined as the percentage deviation of actual output from this potential output. A disadvantage of the HP filter output gap is its lack of a firm theoretical basis. For this reason, the HP filter output gap has played only a limited role in determining the economic outlook and formulating monetary policy at the Bank.

Hirose and Kamada (2003) introduced an output gap measure based on the NAILO (Non-Accelerating Inflation Level of Output), which established a theoretical Phillips curve basis for an HP filter output gap. Denote the NAILO by y^n. Then, by definition,

$$\pi_t = \omega\pi_{t-1} + (1-\omega)\pi_{t-2} + \phi(y_t - y_t^n) + \xi_t. \qquad (12)$$

Rearranging this gives

$$y_t - \{\pi_t - \omega\pi_{t-1} - (1-\omega)\pi_{t-2}\}/\phi = y_t^n - \xi_t/\phi \qquad (13)$$

The left hand side is inflation-adjusted output. y^n is obtained by applying the HP filter. The problem is that not only y^n, but also parameters ω and ϕ are unknown.

Hirose and Kamada (2003) present a procedure for determining ω, ϕ, and y^n, simultaneously. Figure 2.f shows the NAILO-based output gap.

3 Real-Time Estimation of the Japanese Output Gap

The measure of the output gap has become an important business-cycle indicator at the Bank, and the Bank staff uses the most recent economic data to estimate it. Policy makers, however, should keep in mind two *problems of real-time estimation*: (i) data necessary for the estimation of output gap are subject to revision over time;[8] and (ii) data accumulation alters the estimate of potential output over time. The latter is generally referred to as the *end-of-sample problem*.

The uncertainty created by data revision and accumulation may affect the behavior of a central bank. Thus, quantifying the effects of uncertainty is a vital part of a careful implementation of monetary policy. The four stages of output gap revision, defined by Orphanides and van Norden (2002), are useful for this purpose. The *real-time output gap* depends solely on data available in real time. The *quasi-real-time output gap* assumes that final data are known up to a certain point of time in the past. As for the *quasi-final output gap*, data accumulate gradually as assumed for the quasi-real-time output gap, although a structural model is estimated from the full available sample. The *final output gap* assumes that the whole set of data series is known right up to the present.

Below, I show the six measures of output gap introduced in the previous section in various stages of revision and discuss the real-time estimation problem. In doing so, all of the output gap measures are measured from the NAIRU, whether it is time-invariant or time-varying. More concretely, a fixed NAIRU is estimated in the regression of equation (8) with $g_t^n = \bar{g}^n$ for each of the prototype, standard, and conventional output gaps.

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8 For instance, the Japanese GDP statistics are revised four times: the first preliminary quarterly estimates (first QE), the second preliminary quarterly estimates (second QE), final estimates, the annual revision, and the benchmark revision. Furthermore, the Japanese *System of National Accounts* shifted its base accounting system in 2000, from the 1968 system to the 1993 system.

3.1 Non-GDP Types of Output Gap

The group of non-GDP types includes the prototype output gap, the standard output gap, and the TV-NAIRU output gap. The non-GDP types depend mainly on capital utilization and labor-related statistics. Revision is finished rather quickly for these statistics and there occurs no difference between real-time data and final data. Therefore, the non-GDP types display the general property that the real-time output gap coincides with the quasi-real-time output gap.

Since various trends are estimated for the non-GDP types, there occur differences between quasi-real-time and quasi-final output gaps. Additionally, when the output gap is measured from the NAIRU, whether fixed or time-varying, the variability of the Phillips curve parameters causes the quasi-final output gap to deviate from the quasi-real-time output gap.

In figure 4, the non-GDP types of output gap are depicted for every stage of revision. The real-time out gap (thin lines) has a downward bias in comparison to the final output gap (thick lines). For the standard output gap, a large bias is observed during the period between the late 1980s and the early 1990s.[9] Nonetheless, for the non-GDP types, on the whole the real-time estimation problem appears small.

3.2 GDP Types of Output Gap

The group of GDP types includes the conventional output gap, the HP filter output gap, and the NAILO output gap. The GDP types of output gap are subject to a severe real-time estimation problem due to the revision and accumulation of GDP data. An immediate consequence of the extensive revision of GDP data is that the real-time output gap deviates substantially from the quasi-real-time output gap.

For the HP filter output gap, no structural models are estimated; thus the quasi-real-time and quasi-final output gaps coincide. For the other GDP types, however, the quasi-final output gap deviates from the quasi-real-time output gap. For the conventional output gap, a linear trend is estimated to extract total factor productivity

[9] The reason is that there occurred large swings over time in the trend fitted on the electric power units, which was estimated to obtain the capacity utilization rate in the non-manufacturing sector.

from the Solow residual distorted by capacity utilization in the non-manufacturing sector. For the NAILO output gap, the Phillips curve has to be estimated.

In figure 5, the GDP types of output gap are depicted in every stage of revision. It is worth remarking that the real-time output gap is more volatile than the quasi-real-time output gap. The large volatility of the real-time output gap stems from the noise inherited from the data used for estimation. In particular, the first GDP figures to be released, from which the real-time output gap is calculated, depend mainly on demand side data, and these are notorious for their sampling distortion.[10] By contrast, the final GDP figures, from which the quasi-real-time output gap is calculated, depend on supply side data, which are less noisy and more reliable because of their large sampling coverage.

Also remarkable is the substantial divergence between the final output gap and the earlier revision stages of output gap. The real-time output gap, in particular, displays a tendency to swing sharply at turning points of the business cycle. The implication is that the real-time estimation problem stems from a trend shift due to data accumulation. This is the end-of-sample problem, which is emphasized by Orphanides (2003) as the most serious of the errors plaguing estimation of the output gap. While it can be easy to identify a trend around the middle of the sample, by the end of sample this trend may be significantly less evident.

The GDP figure offers a convenient and comprehensive evaluation of an economy's activity, and thus attention will continue to be paid to the behavior of GDP statistics in conducting economic policy. However, the above argument reveals the difficulty of identifying GDP trends, and there is a risk that monetary policy may be overly sensitive to incorrect estimates of the output gap.

4 The Effects of Real-Time Output Gap Estimation on Inflation Forecasting

This section investigates how informative the output gap is in forecasting future inflation rates. From the main perspective of this paper, it is also interesting to see how

[10] For instance, the private consumption component of GDP is based on the *Monthly Report on the Family Income and Expenditure Survey*. This is noisy because the personal characteristics of the surveyed families are often far from representative of those of the economy as a whole.

seriously the real-time estimation problem affects the performance of inflation forecasting.

4.1 Real-Time Forecasting of Inflation Rates

As discussed in the previous section, the GDP types of output gap suffer seriously from the problem of real-time output gap estimation, while the non-GDP types of output gap are relatively free from that problem. In the context of inflation forecasting, when the GDP types of output gap are used, there is some doubt about the performance of the forecast function estimated from the output gap. The point is that, when constructing their forecast function, forecasters have access only to the real-time output gap and not the final output gap.

It can also happen that a forecasting function, whose performance is excellent in terms of its in-sample fit, performs badly in out-of-sample forecasting. As pointed out by Orphanides and van Norden (2003), a simple AR process frequently outperforms an output-gap-based forecast function in out-of-sample forecasting.

In this section, I examine all six measures of the output gap and evaluate quantitatively how useful or damaging each is for inflation forecasting. As in Orphanides and van Norden (2003), the following general form of forecasting function is considered here.

$$\overline{\pi}_{t+4} = \gamma_0 + \Sigma_{i=0}^{n} \gamma_{1i} \pi_{t-i} + \Sigma_{i=0}^{m} \gamma_{2i} g_{t-i} + \overline{\eta}_{t+4}, \qquad (14)$$

where $\overline{\pi}_{t+4} \equiv (\pi_{t+4} + \pi_{t+3} + \pi_{t+2} + \pi_{t+1})/4$. This function makes a one-year (four-quarter) ahead inflation forecast with the help of the output gap as well as current and past inflation rates.

With regard to lag lengths on the right hand side of equation (14), I assume a maximum lag of 4 quarters for n and m, taking sample limitations into consideration. I also assume that $n = m$ for convenience. Since there is no current GDP and therefore no current GDP-type output gap available until the next quarter, the forecasting function should be estimated under the restriction of $\gamma_{2,0} = 0$. Although the non-GDP types of output gap are free from this restriction, it is imposed for the purpose of comparing forecasting performance between the GDP types and non-GDP types of output gap.

With regard to forecasting, Koenig et al. (2003) (KDP hereafter) put forward an interesting proposition, showing theoretically that forecasting errors were smaller by focusing on real-time data instead of using extensively-revised final data. Let *T*-vintage data be those available in period *T*. Denote the inflation rate and output gap in period *t* of *T*-vintage data ($t \le T$) by π_t^T and g_t^T , respectively. I assume that the inflation rate is free from revision; thus $\pi_t^T = \pi_t$. Then, equation (14) is rewritten as

$$\overline{\pi}_{t+4} = \gamma_0 + \Sigma_{i=0}^{n} \gamma_{1i} \pi_{t-i} + \Sigma_{i=0}^{m} \gamma_{2i} g_{t-i}^{T} + \overline{\eta}_{t+4} , \qquad (15)$$

where T is a forecasting date.

Alternatively, according to the KDP proposition, a forecaster can enhance forecast performance by using g_{t-i}^t instead of g_{t-i}^T. That is, the following forecast function may improve on equation (15).

$$\overline{\pi}_{t+4} = \gamma_0 + \Sigma_{i=0}^{n} \gamma_{1i} \pi_{t-i} + \Sigma_{i=0}^{m} \gamma_{2i} g_{t-i}^{t} + \overline{\eta}_{t+4} . \qquad (16)$$

Data revision is considered to be a kind of noise, insofar as it cannot be forecast in real time. Therefore, by focusing on the real-time output gap, forecast performance is enhanced in theory.

Empirically, however, the appropriateness of the KDP proposition is controversial. For instance, Orphanides and van Norden (2003) cast doubt on the KDP proposition. KDP's critical assumption is the efficiency of real-time data. The assumption cannot be justified ex ante and, if it is to be adopted, it should be supported empirically. Below, I consider the applicability of the KDP proposition in the case of the CPI inflation forecast in Japan.

4.2 Forecasting Results

Table 1 shows root mean squared errors (RMSE) of inflation forecasts for forecast functions utilizing each of the six measures of output gap. For the purposes of comparison, I also show the result for a simple AR model with no output gap measure, presented at the bottom of the table. In the *ordinary case*, I use only a forecasting date's vintage of the output gap series (i.e. equation (15)), while I use all the older vintages in the *KDP case* (i.e. equation (16)). The *in-sample* RMSE is calculated from the regression residual in the estimation of the forecasting functions, while the *out-of-sample* RMSE is calculated from the forecasting errors in the forecast of one-year-ahead inflation rates using the estimated forecasting function. The RMSE is calculated for the period of 1995-2001 for each case.

The optimal lag length is chosen according to the Akaike information criteria (AIC) and indicated by the squares in the table. I begin with a lag of four quarters due to the limitations of the small sample, though it is desirable to start with a longer lag, say 12 quarters. Fortunately, however, the optimal lag length turns out to be 1 quarter (the single exception is for the NAILO output gap in the KDP case). Furthermore, there is no gain in terms of RMSE by increasing lag length. These facts suggest that the lag selection may not affect the arguments developed below.

Three points are noteworthy. First, out-of-sample forecasting performance is much worse than is suggested by in-sample fit. Notice that the prototype and standard output gaps, although estimated in a very primitive way, show an excellent out-of-sample forecasting performance as well as a good in-sample fit. As for the others, however, a close fit of the forecasting function does not necessarily imply good performance in inflation forecasting.

Second, for three of the six output gap measures, a simple AR process outperforms output-gap-based forecasting functions in inflation forecasting. Using the AR model with a single lag as a benchmark, we observe that forecasting functions employing the TV-NAIRU, the conventional, or the NAILO output gap fail to offer any reduction in out-of-sample forecasting RMSE (the performance of the HP filter gap is almost the same as that of the AR model). In other words, forecasting performance can be worse off by incorporating output gap measures into forecast functions.

Third, forecasting performance may be improved by exploiting all the older vintages rather than by relying solely on a forecasting date's vintage of the output gap series. In the KDP case, four output-gap-based forecasting functions outperform the AR model in comparison to the ordinary case, where three output-gap-based functions defeat the AR model. Compared with the ordinary case, the KDP method is an effective way to reduce out-of-sample forecasting RMSE in the cases of the three GDP type output gaps.

5 The Effects of Real-Time Output Gap Estimation on Monetary Policymaking

In this section, I analyze how the real-time uncertainty in the estimation of output gap affects monetary policymaking in Japan. The monetary policy stance is often examined using the Taylor rule, which was originally formulated by Taylor (1993) and has since been much used.

5.1 Original Taylor Rule

Taylor's (1993) original specification is given by

$$i_t = r^* + \pi_t + \alpha_\pi (\pi_t - \pi^*) + \alpha_g g_t , \tag{17}$$

where i is the short-term interest rate that is used as a policy instrument (the federal fund rate in the US); r^* is the equilibrium real interest rate; π^* is the rate of inflation targeted by the monetary authority; α_π and α_g are parameters capturing policy responsiveness to deviations of actual inflation rates from target and to the output gap, respectively.

Taylor (1993) showed that the monetary policy conducted by the Board of Governors of the Federal Reserve System could be approximated by equation (17). Potential output is defined as a linear trend fitted on real GDP during the period 1984Q1-1992Q3; then the output gap is obtained as the percentage deviation of actual output from potential. Policy parameters are given by $\pi^* = 2$, $\alpha_\pi = \alpha_g = 0.5$, and $r^* = 2$.

There are four main factors explaining why actual interest rates can deviate from the original Taylor rule prescription: (i) discretionary monetary policy; (ii) the specification of the Taylor rule; (iii) the choice of output gap; (iv) the problem of real-time output gap estimation. The first factor, the question of why the monetary authority takes discretionary action, is interesting. It lies, however, beyond the scope of this paper. I refer readers to the excellent literature on this topic, including Okina and Shiratsuka (2002) and Jinushi et al. (2000).

As for the second factor, the applicability of Taylor's original parameters to the Japanese policy instrument (the overnight call rate), this depends on the following: (i) to what extent the Japanese economy resembles the US economy; (ii) to what extent the two countries' policy goals are similar; (iii) to what extent the two countries have learned their optimal policy rules. When investigating Taylor's original specification, I accept his original setting except that I assume $\pi^* = 0$.[11] I also use the CPI to measure the inflation rate rather than Taylor's choice of the GDP deflator.[12]

With regard to the third factor, the policy prescription depends on which output gap is used in the Taylor rule. For instance, Taylor (1993) used the percentage deviation of real GDP from its linear trend, while many economists use the HP filter output gap. To the extent that there remain competing measures of the output gap and there is no consensus on which should be substituted in the Taylor rule, a final answer to the question of whether the Bank of Japan followed the Taylor rule will inevitably prove elusive.

Finally, there is the problem of real-time output gap estimation. Corresponding to the four stages of output gap revision, I obtain four Taylor rule prescriptions: a real-time rule, a quasi-real-time rule, a quasi-final rule, and a final rule. Since a final rule uses all information available ex post, it represents the best available guideline for comparison with the actual call rate and the ex post evaluation of monetary policy.

Differences between the final rule and the actual call rate are decomposed into two parts: a discretionary policy part, which is the difference between the real-time rule and the actual call rate; and a real-time-problem part, which is the difference between the real-time and final rules. The latter part can be decomposed into three further parts,

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[11] It is not known whether zero inflation was really targeted in the 1980s and 1990s. If the π^* is positive, the original Taylor rule dictates a lower level of the call rate than in the case of zero-inflation targeting. As seen later, this implies that the actual policy stance was tighter than suggested by the rule, which contradicts the criticism that the BOJ policy was too easy in the late 1980s. In addition, with lower inflation targeted, the parameters of responsiveness, α_g and α_π, may take values other than 0.5.

[12] The inflation rate he used was the percentage change of the GDP deflator over the preceding four quarters, which he interpreted as a proxy for the expected rate of inflation. As alternative inflation measures, I also used actual inflation rates observed one-year ahead, as in Clarida et al. (1998) as well as a one-year-ahead expectations survey, as in Ahearne et al. (2002). I used the survey by the Japan Center for Economic Research (JCER) for the latter case, since this provides a longer time series than the *consensus forecast*. I do not discuss these alternatives, however, since the parameters of the Phillips curve could frequently not be estimated with the theoretically correct sign.

reflecting the four stages of output gap revision: a data-revision part between the real-time and quasi-real-time rules; a model-parameter-revision part between the quasi-real-time and quasi-final rules; and a data accumulation part between the quasi-final and final rules.

So far there has been no research that distinguishes between discretionary policy factors and real-time-estimation factors in the context of Japanese monetary policy. However, the problem of real-time output gap estimation causes actual policy to deviate from the Taylor rule even when the monetary authority is ostensibly following it closely. It should therefore be abstracted from in evaluating actual policy. In order to investigate the policy stance, the call rate should be compared with a real-time rule rather than a final rule.

5.2 Policy Evaluation Using the Original Taylor Rule

Here I evaluate the BOJ policy from the late 1980s through the 1990s from the Taylor rule perspective. There is plenty of literature criticizing the BOJ policy during this period (e.g. Bernanke and Gertler [1999], McCallum [2001], and Taylor [2001]). The common criticisim is that monetary tightening during 1987-1990 and easing during 1990-1995 were both too little and too late. In opposition to this, the claim has also been made that the BOJ followed the Taylor rule on the whole (e.g. Okina and Shiratsuka [2002]).

In figures 6 and 7, various Taylor rule prescriptions are depicted and compared with overnight call rates (shadowed area), based on the six measures of the output gap and for each stage of revision. Remarkably, the difference between the actual call rate and the real-time rule with the prototype output gap was quite small from the late 1980s to the early 1990s. Put differently, the BOJ policy can be approximated by the Taylor rule with the prototype output gap, which is believed to be the output gap measure the Bank used during this period.

There are, indeed, several minor discrepancies between the real-time rule and the actual call rate even with the prototype output gap. For instance, as some authors discuss (e.g. Okina and Shiratsuka [2002]), the monetary easing may have been too late during the 1993-1995 period. Jinushi et al. (2000) argue that the introduction of the zero interest rate policy in February 1999 may have been overly delayed. It, however, is not easy to make their argument in the figure. Note that the rise and fall in the Taylor rule during 1996-1998 reflected the demand-shift caused by the rise in the consumer tax rate scheduled in the second quarter of 1997. Thus, it is reasonable that the Bank staff did not follow the Taylor rule intentionally.

It is also noteworthy that the deviation of the actual call rate from the final rule was not due to the problem of real-time output gap estimation. Notice that no substantial difference is observed between the final and real-time rules with the prototype output gap. This suggests that it was not the real-time estimation problem that was responsible for the divergence of the BOJ policy from the final rule. This must be explained instead by the discretionary factor (a difference between the real-time and the observed call rate).

The policy prescriptions based on the other output gap measures are no more than thought experiments. Yet, close examination is valuable for the following reasons. Obviously, it is desirable to know the respective properties of Taylor rules utilizing various different measures of the output gap. Furthermore, the Bank no longer relies on the prototype output gap, because the measure has been considered to be an insufficient business cycle indicator (it does not take into consideration the capacity utilization rate in the non-manufacturing sector).

It should be remarked that the actual call rate did not deviate from the final rule substantially before the mid-1990s, whatever output gap measure was used for the Taylor rule. Particularly in the case of the TV-NAIRU output gap, the final rule was very close to the actual call rate during 1988-1995. It is also worth noting that the Taylor rules with the GDP types of output gap (conventional, HP filter, and NAILO) are seriously affected by the real-time estimation problem, while the Taylor rule with the non-GDP types (prototype, standard, and TV-NAIRU) are relatively free from the problem. With the GDP type measures, the volatility of the real-time rule is so large that the Bank's staff might hesitate to adopt the Taylor rule as a policy reference, especially when the Bank prefers controlling its instrument smoothly.*

5.3 Policy Evaluation through Estimated Taylor Rules

Consistency with the Taylor rule does not in itself represent a justification of the BOJ's policy. Rather, the "lost decade" since the early 1990s suggests that the original

Taylor rule requires modification, or alternatively that a brand new guideline should be formulated.[13] I focus on the former question here. There are two conceivable approaches. The first approach is to construct a macro-econometric model that describes the real economy and to find an optimal policy rule in terms of monetary authority's loss function. The second approach is to estimate the policy rule during a period when monetary policy functioned well.[14] For instance, Jinushi et al. (2000) defines the rule observed during the 1975-1985 period as a "good rule." They use it as a benchmark when evaluating BOJ policy during the emergence and bursting of the asset-price bubble.

The two approaches, however, often agree in saying that monetary tightening during the late 1980s and the subsequent easing during the early 1990s were both too little and too late. It is beyond the scope of this paper to test the validity of this argument. Instead, this paper proceeds in the following way. First, I estimate the BOJ policy stance by fitting a Taylor rule to the sample data during the 1988-1995 period. Next, I consider how to modify the estimated policy stance to obtain a Taylor rule that would have prescribed monetary tightening in the late 1980s and easing in the early 1990s that was both stronger and prompter.

I use the following extension of equation (17), which incorporates smooth control of the policy instrument.[15]

$$i_t = \theta i_{t-1} + (1-\theta) i_t^{target}, \tag{18}$$

$$i_t^{target} = r^* + \pi_t + \alpha_\pi (\pi_t - \pi^*) + \alpha_g g_t. \tag{19}$$

That is, actual call rates are considered to make a partial adjustment toward the estimated target rate (i^{target}) at the speed of $(1-\theta)$.

[13] Furthermore, there is also the question of whether the prices of assets (e.g., stock or land) should be targeted in addition to the prices of goods and services and the output gap. For this issue, see Okina et al. (2001), Okina and Shiratsuka (2002), and Bernanke and Gertler (1999).

[14] See Taylor (1999) and Orphanides (2003) for the historical approach to the US monetary policy rule.

[15] Equations (18) and (19) are close to those introduced by Clarida et al. (1998). A significant difference, however, is that where they use actual future observations of the inflation rate, I use the recent inflation rate as a proxy for the expected rate of inflation.

First, I consider the modifications necessary for the Taylor rule to dictate interest rate changes at the appropriate time. In figures 8 and 9, the thick lines are fitted values of equation (18), while the thin lines depict the target call rates, i.e. equation (19). The faster the adjustment speed, the nearer the Taylor rule is located to the target rate. With full adjustment speed ($\theta = 0$), the Taylor rule prescription (i) coincides with the target rate (i^{target}). In this limiting case, the Taylor rules are above the actual call rates during 1987-1990 and are below actual rates during 1991-1995, whatever output gap measures are used in the Taylor rule. This means that the appropriate timing for a policy change is obtained by increasing the adjustment speed.

Next, I consider how much the call rate should be raised. A sufficient condition for stabilizing policy is that the coefficient on the inflation rate in equation (19) is greater than one (the Taylor principle). In Table 2, we see that, for some measures of the output gap, the policy reaction turns out to be destabilizing. In particular, when the standard output gap is used, the estimated Taylor rule is stabilizing ex ante (i.e. with the real-time output gap), but is destabilizing ex post (i.e. with the final output gap).

Finally, I consider the effects of aggressive policy reaction on the target interest rate. In figures 8 and 9, the target call rate is depicted for an “anti-inflation policy” (dotted line), i.e. when the parameter value on the inflation rate is raised by + 0.5 percent. [16] Qualitatively, the target rate rises further during 1987-1990 and falls further during 1991-1995. The quantities are not large, however. For the purposes of comparison, I raise the parameter values on the output gap by + 0.5 percent (chain lines). The target rate responds similarly, but with larger effects quantitatively.

Caveats are in order here. First, even if the monetary authority adjusts its policy instrument faster, it cannot control the speed of transmission from call rates to longer-maturity financial assets, since this depends on the speed at which market participants adjust their expectations. Furthermore, the real economy is subject to a natural speed limit when adjusting to movements in call rates, and this produces economic costs in terms of resource allocation.

[16] The constant term is adjusted to compensate for the effects of raising the parameter value on the inflation rate.

6 Remedying the Real-Time Output Gap

In this section, I consider the possibility of remedying the real-time output gap to improve its usefulness for policy. To this end, prospective supplementary data is required to have the following two properties. First, it must not be subject to future revision; or if revised, the final revision must be completed within a few months. Second, supplementary data should have no trend. If there are trends in supplementary data, this creates another real-time estimation problem in the course of data accumulation.

6.1 Improving the Real-Time Output Gap

I use the *Short-Term Economic Survey of Enterprises* in Japan (*TANKAN* for short) to provide supplementary data. Real-time GDP figures are compiled mainly from demand side data, while final GDP depends mostly on supply side data. The TANKAN compiles entrepreneurs' business plans and sentiment and thus offers substantial information on the supply side of the economy. Therefore, the TANKAN has the potential to improve the real-time output gap and to approximate the final output gap.

Out of the wealth of information available in the TANKAN, I choose the *business conditions diffusion index* (DI). Figure 12 shows the behavior of the business conditions DI, d^b. One of its desirable properties is that it is revision-free. The stationarity of the business conditions DI, however, is a matter of some controversy. This controversy is side-stepped below, where I proceed under the assumption that the DI has no underlying trend factor.

Next, I examine empirically the performance of the business conditions DI as supplementary data. The question is whether the business conditions DI is helpful in forecasting the final output gap from the real-time output gap. Employing the same notation in section IV, I use the following specification.

$$g_t^{2002Q4} = \delta_0 + \delta_1 \cdot g_t^t + \delta_2 \cdot \Sigma_{q=0}^h d_{t-k-q} /(1+h) + \varepsilon_t^f \ , \qquad (20)$$

where g^{2002Q4} and g^t are the final and real-time output gaps, respectively.

If the real-time GDP data exploited all the information available, there would be no gains from forecasting final GDP data by including the business conditions DI. As discussed above, however, the business conditions DI may contain additional information that is not reflected in the real-time GDP data. If the business conditions DI includes additional information, the estimated value of δ_2 will be significantly different from zero.

Note that as the sample extends to the current period, the real-time data converges on the final data. Consequently, the divergence between the final and real-time output gaps diminishes near the end of the sample. For this reason, I discard the recent sample in the estimation of equation (20). For concreteness, I use the sample up to 2000Q4 in the estimation and discard the sample of two years from 2001Q1 through 2002Q4.

6.2 Estimation Results

Table 3 presents the results from estimating equation (20) by OLS. The business conditions DI is statistically significant in every case except one, namely the TV-NAIRU output gap. This is an interesting result, since it suggests that the business conditions DI adds no information to the TV-NAIRU output gap. A possible interpretation is that the time-varying NAIRU reflects structural changes occurring in the supply side of economy and therefore covers the same information set as the business conditions DI.

In general, for the non-GDP types of output gap, the estimated coefficient on the business conditions DI is small and that on the real-time output gap is close to one. This is a natural consequence of the real-time output gap being very close to the final output gap for the non-GDP type output gap. In contrast, for the GDP types of output gap, the estimated coefficient on the business conditions DI is large and that on the real-time output gap is falls short of 1. This suggests that the business condition DI is helpful in alleviating the real-time estimation problem for the GDP types of output gap.

In figures 11 and 12, I present the predicted final output gaps, based on the real-time output gaps and the business conditions DI. We observe that the GDP types of output gap are significantly remedied by inclusion of the business conditions DI. For the NAILO output gap, in particular, the remedy function shows excellent performance. During 2000-2001, the remedy function predicts the final output gap precisely and alleviates the real-time estimation problem for the NAILO output gap. The remedy function, however, performs badly in the case of HP filter output gap. A possible reason is that, since the HP-filter-based output gap lacks a theoretical basis, it contains too much noise to be easily remedied by the inclusion of supply side information.

6.3 Remedial Effects on Inflation Forecasting and Policymaking

First, I investigate the effects of the TANKAN remedy on inflation forecasts. I choose the RMSE of the out-of-sample forecasts in the KDP case for comparison (RMSE during 1998-2001). I estimate the following function forecasting the *i*-quarter lag of *T*-vintage output gap series from the *i*-quarter-lagged real-time output gap using the business conditions DI.

$$g_{t-i}^{T} = \rho_{0i} + \rho_{1i} g_{t-i}^{t} + \rho_{2i} d_{t-i} + \varepsilon_{t-i}^{T} . \qquad (21)$$

In estimation, I discarded some data near the end of the sample for the same reason as mentioned before.

Through this relationship, I estimate the eight-quarter-ahead final output gap, given the real-time output gap and use the result in equation (16). In table 1, the output-gap-based inflation forecasting function outperforms the simple AR model with four of the six measures of the output gap in the KDP out-of-sample case. In the left hand side of table 4, after applying the TANKAN remedy, the output-gap-based forecasting function outperforms the AR model with five measures (the NAILO case is added).

To further investigate the usefulness of the TANKAN diffusion indices, I modify equation (16) by including the change in output prices diffusion indices (prices DI for short). That is,

$$\overline{\pi}_{t+4} = \gamma_0 + \Sigma_{i=0}^{n} \gamma_{1i} \pi_{t-i} + \Sigma_{i=0}^{m} \gamma_{2i} \hat{g}_{t-i}^{T} + \gamma_{3a} p_t^{a} + \gamma_{3f} p_t^{f} + \overline{\eta}_{t+4}^{p} , \qquad (22)$$

where p^a and p^a index the actual and forecast (three-month ahead) changes in the current period, respectively (figure 10); and $\hat{g}_{t-i}^{T}$ is the forecasts of the *i*-quarter lag of *T*-vintage output gap by equation (21). The forecast results are shown in the right hand side of table 4. Combined with the simple AR model, the prices DI enhance forecast accuracy. For three of the six output gap measures, however, forecast performance deteriorates by including the prices DI and thus their usefulness is questionable when used with the business conditions DI.

Next, I investigate the effects of the TANKAN remedy on the Taylor rule. Figures 13 and 14 plot the Taylor rule with an output gap during 1988-1995, remedied by equation (20). As pointed out above, the remedial effects of including the business conditions DI are not large for the non-GDP types of output gap and thus have only a limited impact on the Taylor rule. For the GDP types, on the other hand, the business conditions DI has great remedial potential for the real-time output gap and thus has a considerable impact on the Taylor rule.

Comparing figures 13 and 14 with figures 4 and 5, the most striking improvement is found in the NAILO output gap. Also remarkable is the fact that, when the NAILO real-time output gap was used to estimate the Taylor rule without the TANKAN remedy, neither the inflation rate nor the output gap were found to be significant, as described in Table 2. When the remedied output gap was used, however, both become significant in the estimated Taylor rule, as shown in Table 5.[17] In addition, the Taylor rule with the remedied NAILO output gap is far smoother than before the remedy. These represent desirable properties which are of particular relevance when policy makers refer to the NAILO-based Taylor rule in the formation of real world monetary policy.

7 Conclusion

This paper has two purposes: to introduce the output gap measures developed at the Bank of Japan; and to quantify the real-time estimation problem. The performance of these various measures is evaluated from the perspective of inflation forecasting and policy-making.I also consider a possible remedy to alleviate the real-time estimation problem by employing information from the TANKAN.

The evaluation of inflation forecasting performance is as follows. First, the performance of out-of-sample forecasting is far worse than expected given the excellent in-sample fit of forecast functions. Second, for three of the six measures, a simple AR model outperforms an output-gap-based forecast function. For these three measures, the inclusion of the information contained in the output gap actually disturbs the forecast functions. Third, the method of Koenig et al. (2003) (KDP) may be useful for inflation forecasting in Japan. For three GDP type output gap measures, the performance of the forecast function enhances when the KDP method is employed.

The evaluation of the various output gap measures as references for policy is as follows. First, the BOJ policy from the late 1980s to the early 1990s was, on the whole, consistent with the Taylor rule. It may be that the criticisim that the Bank's response was too little and too late relative to a Taylor rule comes from the improper choice of output gap measures. Second, the Taylor rule can prescribe a higher path of call rates in the late 1980s and a lower path in the early 1990s by raising the speed at which the call rate is adjusted toward the target interest rate and simultaneously strengthening the policy responsiveness to an expansion of the output gap. The question, however, remains whether such a policy stance was really appropriate and whether it had unwelcome side-effects.

The attempt to remedy the output gap measures by incorporating information from the TANKAN produces favorable results. The TANKAN business conditions DI is helpful for forecasting the final output gap from the real-time output gap, and the number of forecast functions that outperform a simple AR model increases. The usefulness of the prices DI is questionable when used with the business conditions DI. Furthermore, for the GDP types of output gap, the large volatility of the real-time measure is reduced substantially by including the remedy function, and this enhances the usefulness of the Taylor rule for policy formation.

[17] The opposite result was found when the HP filter output gap was used: the large value of the coefficient on the inflation rate loses its significance after the remedy. In the case of the conventional output gap, the coefficients on the output gap and the inflation rate remain insignificant even after the remedy.

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Table 1: Forecast Accuracy

Output Gap	n = m	Ordinary Case			KDP Case		
		RMSE		AIC	RMSE		AIC
		in sample	out of sample		in sample	out of sample	
non-GDP type							
Prototype	1	0.223	0.279	1.673	0.244	0.301	1.762
	2	0.211	0.278	1.715	0.234	0.299	1.774
	3	0.203	0.296	1.757	0.228	0.308	1.792
	4	0.170	0.297	1.760	0.198	0.312	1.766
Standard	1	0.191	0.230	1.363	0.208	0.251	1.760
	2	0.181	0.225	1.397	0.201	0.248	1.786
	3	0.183	0.238	1.444	0.202	0.261	1.817
	4	0.172	0.235	1.483	0.195	0.265	1.845
TV-NAIRU	1	0.340	0.680	1.887	0.351	0.698	2.001
	2	0.324	0.737	1.909	0.353	0.778	2.029
	3	0.316	0.759	1.949	0.353	0.867	2.061
	4	0.307	0.763	1.985	0.353	0.922	2.092
GDP type							
Conventional	1	0.232	0.791	1.831	0.130	0.171	1.742
	2	0.253	0.786	1.859	0.136	0.198	1.771
	3	0.269	0.844	1.857	0.155	0.254	1.749
	4	0.259	0.901	1.789	0.159	0.257	1.764
HP filter	1	0.291	0.418	2.141	0.260	0.380	1.996
	2	0.277	0.539	2.166	0.243	0.355	2.009
	3	0.269	0.630	2.215	0.238	0.385	2.068
	4	0.258	0.659	2.253	0.227	0.386	2.116
NAILO	1	0.370	1.150	1.833	0.307	0.512	2.046
	2	0.361	1.213	1.824	0.293	0.492	2.033
	3	0.359	1.261	1.847	0.271	0.487	2.039
	4	0.354	1.258	1.851	0.248	0.475	2.050
AR	1	0.274	0.423	2.120			
	2	0.260	0.402	2.127			
	3	0.260	0.412	2.157			
	4	0.261	0.432	2.188			

Table 2: Estimated Taylor Rules

dependent variable call rate		adjustment speed	constant of target rate	output gap	inflation rate
non-GDP type					
Prototype	realtime	0.58177 ***	2.564795 ***	0.441111 ***	1.300578 ***
		(0.106841)	(0.282126)	(0.072366)	(0.173906)
	final	0.570786 ***	2.100814 ***	0.453201 ***	1.218486 ***
		(0.109643)	(0.251421)	(0.073121)	(0.179089)
Standard	realtime	0.708379 ***	2.598355 ***	0.654703 **	1.468469 ***
		(0.103386)	(0.797601)	(0.264630)	(0.412476)
	final	0.692622 ***	2.824352 ***	0.874322 ***	0.798356 **
		(0.081443)	(0.549373)	(0.243484)	(0.411880)
TVNAIRU	realtime	0.769313 ***	3.150256 ***	1.041646 **	1.110097 **
		(0.075683)	(0.799651)	(0.378003)	(0.443807)
	final	0.756056 ***	2.618763 ***	0.929113 ***	1.025439 **
		(0.078571)	(0.656154)	(0.331214)	(0.461470)
GDP type					
Conventional	realtime	0.902843 ***	9.024676	1.704058	-1.73971
		(0.076145)	(6.567458)	(1.455815)	(3.302445)
	final	0.843654 ***	-1.206158	-0.351504	3.361705
		(0.120147)	(5.660251)	(1.319888)	(2.968996)
HP filter	realtime	0.823769 ***	1.798735 **	0.94283 *	1.963293 ***
		(0.079384)	(0.751842)	(0.484265)	(0.403641)
	final	0.774918 ***	1.682721	0.762148	1.577106 *
		(0.106841)	(1.196000)	(0.625009)	(0.816251)
NAILO	realtime	0.901467 ***	3.86506 *	0.59146	0.161511
		(0.098352)	(2.264392)	(0.524410)	(1.722226)
	final	0.653161 ***	2.51705 ***	0.601969 ***	1.270143 ***
		(0.106103)	(0.356821)	(0.125793)	(0.225627)

1. ***, ** and * indicate the significance of the associated variable at the 1, 5 and 10 percent levels.
2. Standard errors are in ( ).

Table 3: Remedy Functions Using the TANKAN Data

dependent variable: final gap	constant		realtime output gap		bussiness condition DI	
non-GDP type						
Prototype	0.981853	***	0.869192	***	0.017328	***
	(0.031922)		(0.027479)		(0.003474)	
					[0, 0]	
Standard	0.659256	***	0.869089	***	0.021473	***
	(0.098689)		(0.072558)		(0.004843)	
					[0, 0]	
TVNAIRU	0.52464	***	0.925847	***	0.00967	
	(0.053544)		(0.055722)		(0.003073)	
					[0, 0]	
GDP type						
Conventional	-2.155948	***	0.172527	**	0.069359	***
	(0.346349)		(0.085463)		(0.013201)	
					[6, 0]	
HP filter	0.251727	**	0.278664	***	0.025847	***
	(0.119890)		(0.074877)		(0.004769)	
					[4, 0]	
NAILO	-0.269093	**	0.160136	***	0.051106	***
	(0.126053)		(0.037492)		(0.007168)	
					[0, 2]	

1. ***, ** and * indicate the significance of the associated variable at the 1, 5 and 10 percent levels.
2. Standard errors are in ( ).
3. The entries in square brackets, [ ], are *k* s and *h* s from equation (7-1).

Table 4: Forecast Accuracy after the Remedy

Output Gap	n = m	KDP Case: Without Price DI, RMSE in sample	RMSE out of sample	AIC	KDP Case: With Price DI, RMSE in sample	RMSE out of sample	AIC
non-GDP type							
Prototype	1	0.236	0.334	1.414	0.230	0.389	1.472
	2	0.223	0.308	1.331	0.206	0.351	1.368
	3	0.217	0.361	1.356	0.203	0.433	1.407
	4	0.183	0.379	1.228	0.178	0.424	1.292
Standard	1	0.264	0.529	1.824	0.235	0.571	1.702
	2	0.254	0.494	1.825	0.206	0.504	1.649
	3	0.253	0.505	1.875	0.196	0.640	1.591
	4	0.249	0.539	1.941	0.193	0.765	1.652
TV-NAIRU	1	0.319	0.946	1.998	0.210	0.721	1.658
	2	0.309	1.014	2.030	0.193	0.860	1.716
	3	0.309	1.104	2.091	0.175	0.940	1.730
	4	0.304	1.122	2.063	0.177	1.047	1.800
GDP type							
Conventional	1	0.190	0.479	1.753	0.199	0.455	1.562
	2	0.212	0.412	1.692	0.197	0.486	1.593
	3	0.203	0.486	1.588	0.191	0.538	1.589
	4	0.195	0.476	1.485	0.170	0.458	1.474
HP filter	1	0.303	0.645	1.835	0.242	0.541	1.657
	2	0.235	0.525	1.601	0.219	0.508	1.593
	3	0.221	0.453	1.516	0.217	0.473	1.553
	4	0.224	0.476	1.518	0.218	0.483	1.555
NAILO	1	0.273	0.661	1.814	0.217	0.535	1.672
	2	0.265	0.706	1.809	0.213	0.537	1.730
	3	0.267	0.786	1.843	0.222	0.593	1.801
	4	0.209	0.660	1.672	0.179	0.486	1.669
AR	1	0.286	0.670	2.127	0.234	0.507	1.664
	2	0.274	0.652	2.143	0.233	0.504	1.696
	3	0.274	0.679	2.183	0.232	0.513	1.734
	4	0.271	0.697	2.220	0.222	0.503	1.744

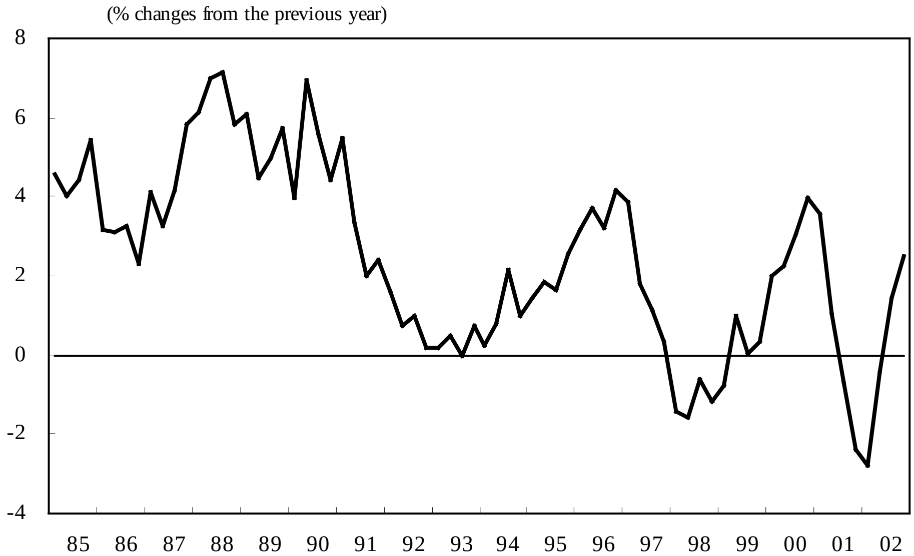
Table 5: Estimated Taylor Rules after the Remedy

dependent variable: call		adjustment speed		constant of target rate		realtime gap after remedy		inflation rate	
non-GDP type									
	Prototype	0.58127	***	2.04945	***	0.435662	***	1.318677	***
		(0.105365)		(0.251121)		(0.070642)		(0.170236)	
	Standard	0.714988	***	2.19067	***	0.644847	**	1.35149	***
		(0.091886)		(0.585633)		(0.229902)		(0.383514)	
	TVNAIRU	0.618886	***	2.467948	***	0.848439	***	1.236214	***
		(0.098641)		(0.296066)		(0.148538)		(0.193154)	
GDP type									
	Conventional	0.837237	***	-1.526184		-0.308703		3.362263	
		(0.105547)		(5.145105)		(0.846432)		(2.249546)	
	HP filter	0.804523	***	2.432232	**	2.027799	*	0.783827	
		(0.086791)		(0.953213)		(1.078535)		(0.817535)	
	NAILO	0.718679	***	2.702697	***	0.794994	***	1.09207	***
		(0.101159)		(0.474114)		(0.210196)		(0.315529)	

Same as earlier tables.

Figure 1: Output and Inflation in Japan

a. GDP Growth Rate



b. Inflation Rate

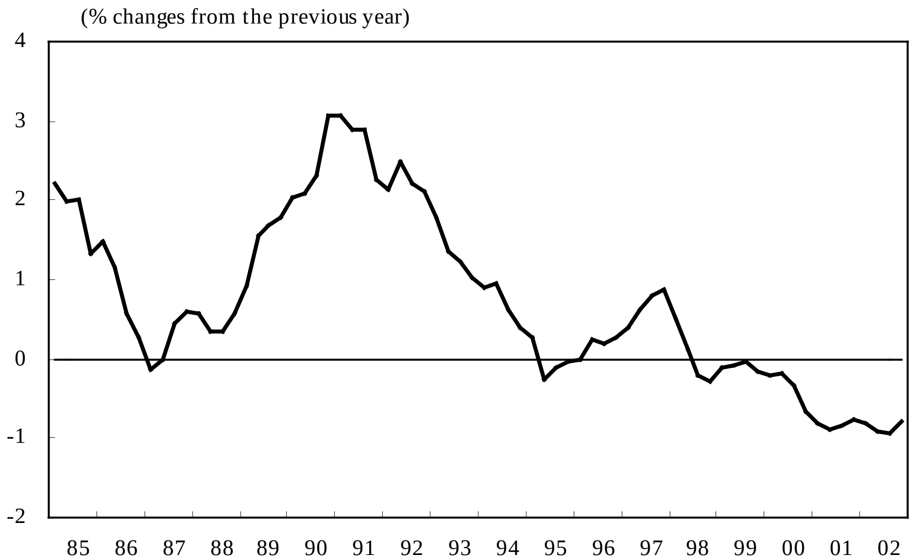
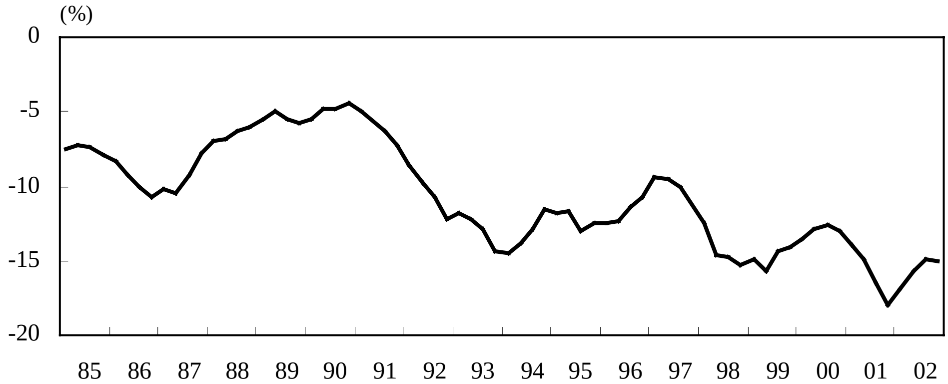
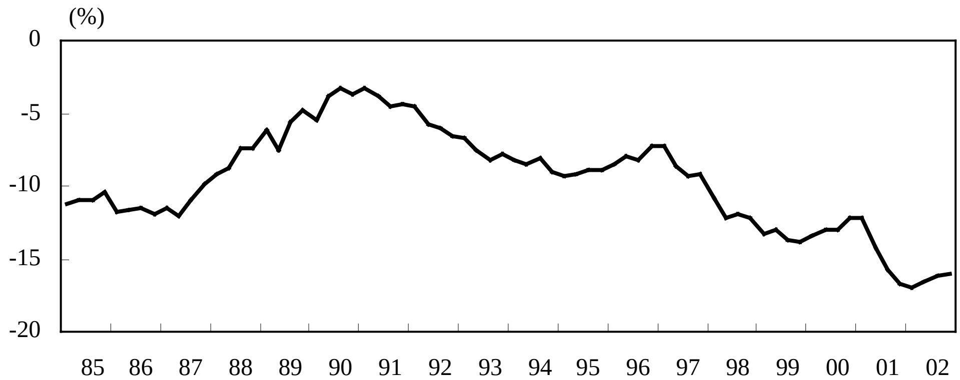


Figure 2: Measures of Output Gap at the Bank of Japan

a. Prototype



b. Conventional



c. Standard

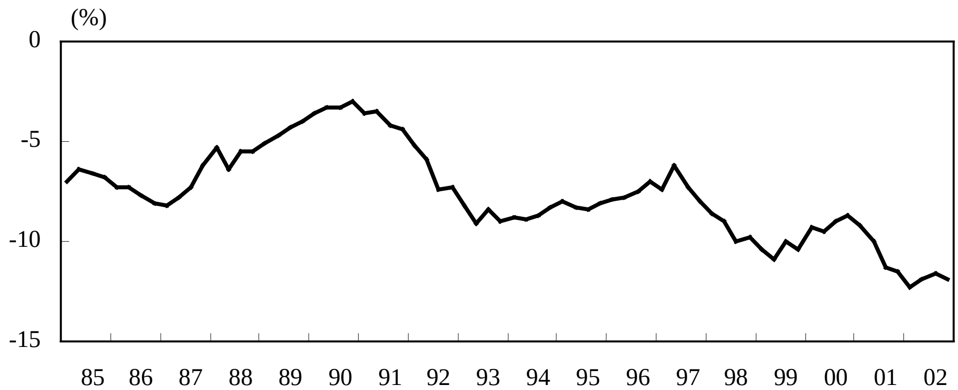
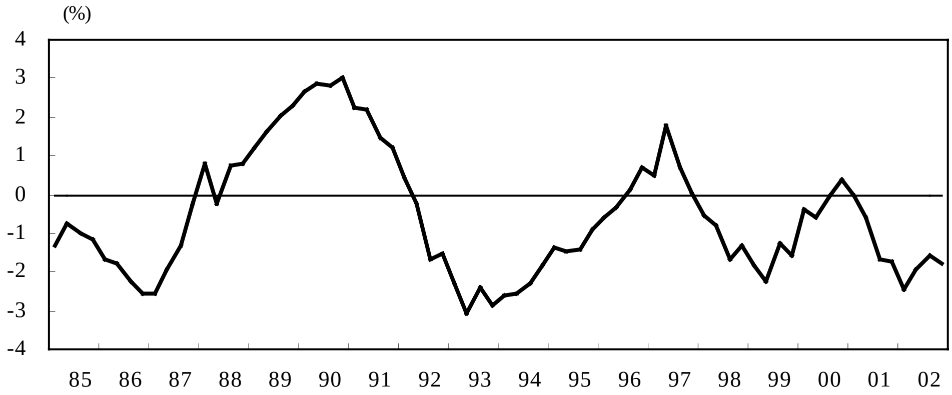
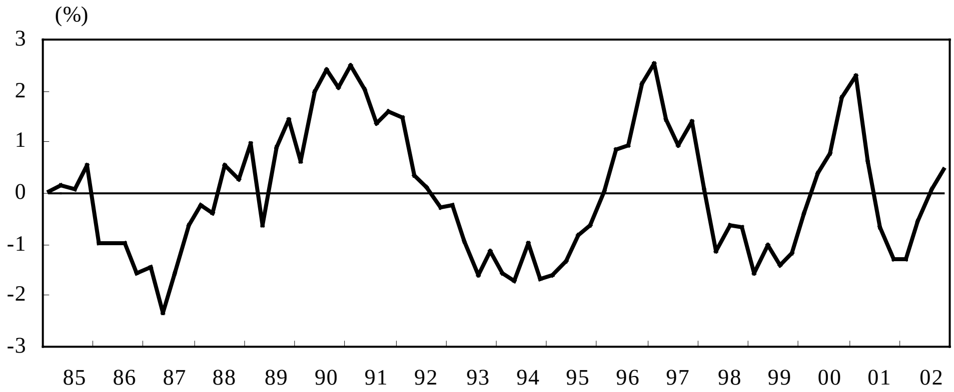


Figure 2: (continued)

d. TV-NAIRU



e. HP Filter

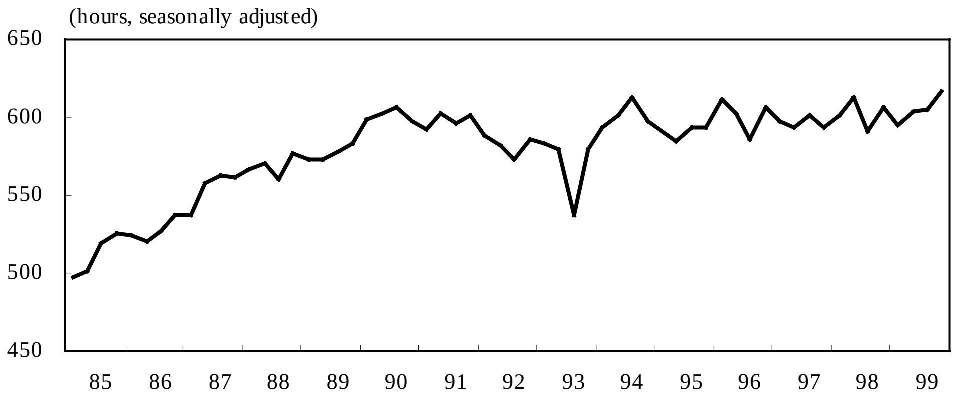


f. NAILO

Figure 3: Data for the Estimation of Standard Output Gap

a. Capacity Utilization in Non-Manufacturing Sector

b. Electoric Power Units for Commercial Power



c. Production Capacity BSI

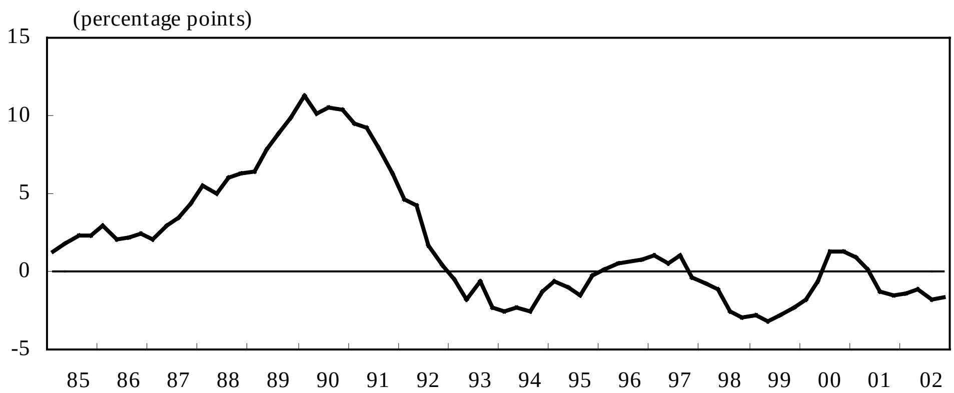
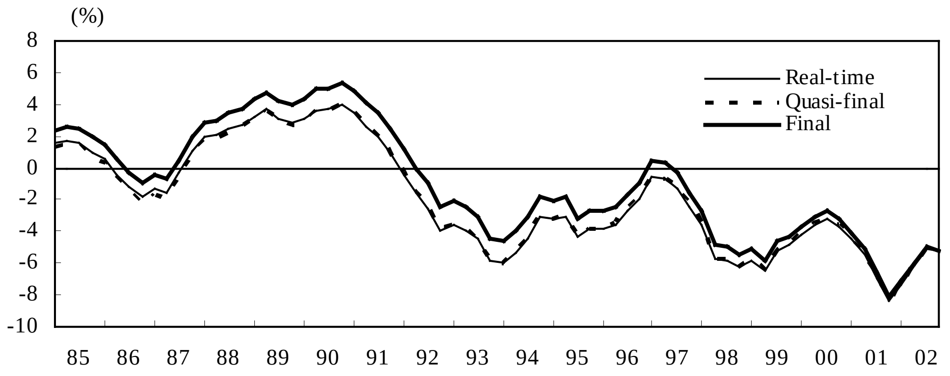


Figure 4: Output Gap in Vairous Stages of Revision (Non-GDP Types)

a. Prototye

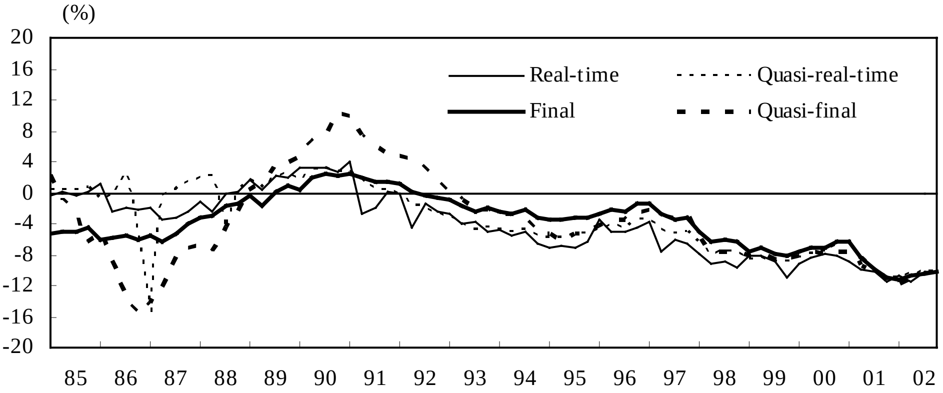


b. Standard

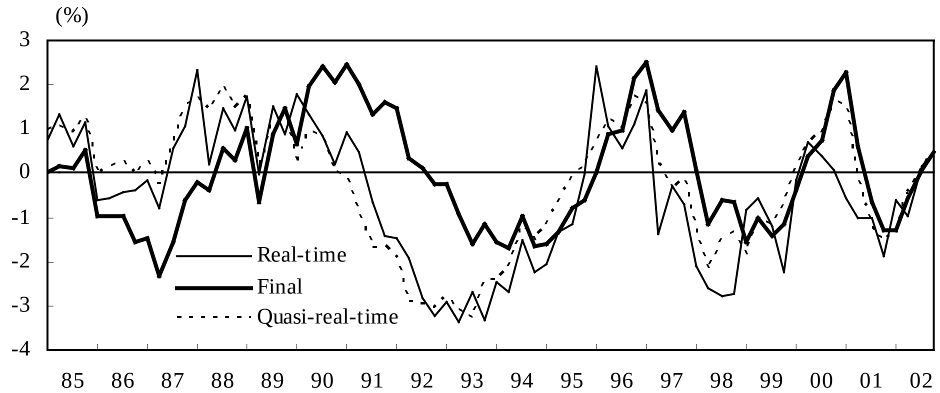
c. TV-NAIRU

Figure 5: Output Gap in Various Stages of Revision (GDP Types)

a. Conventional



b. HP Filter



c. NAILO

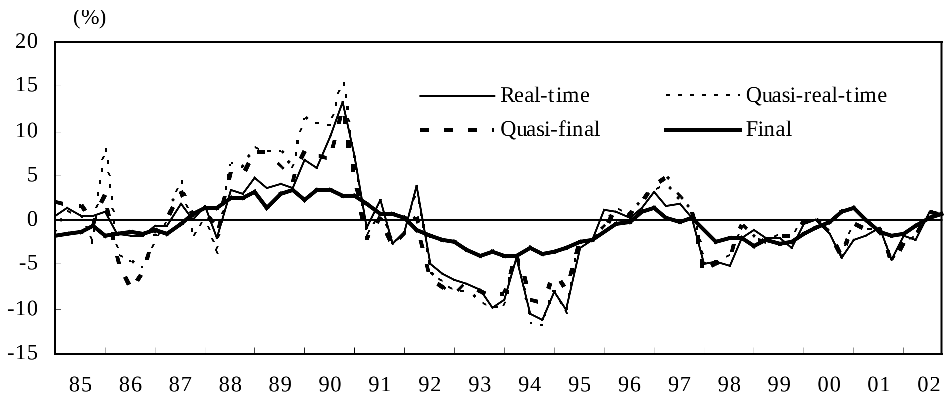
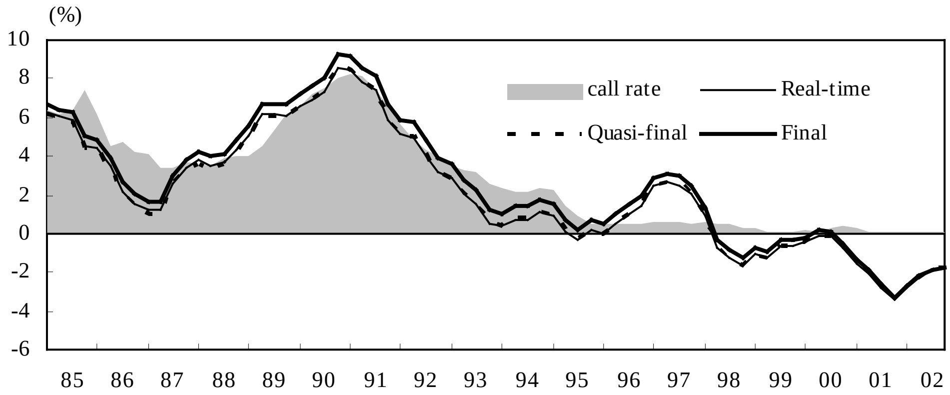
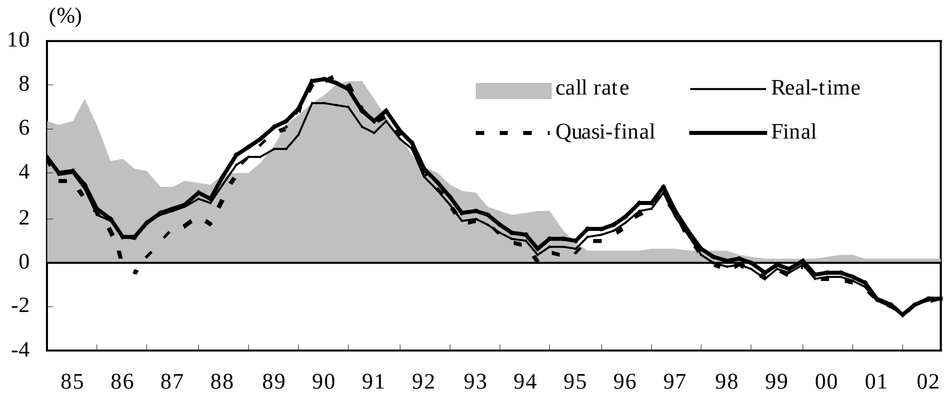


Figure 6: Original Taylor Rule (Non-GDP Types)

a. Prototype



b. Standard



c. TV-NAIRU

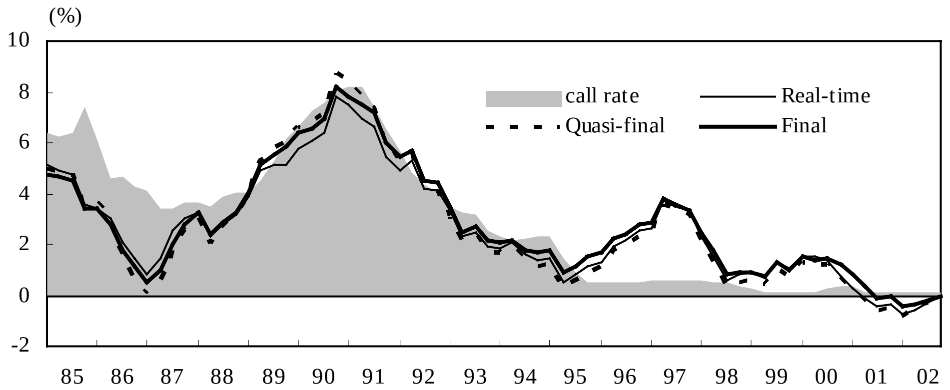
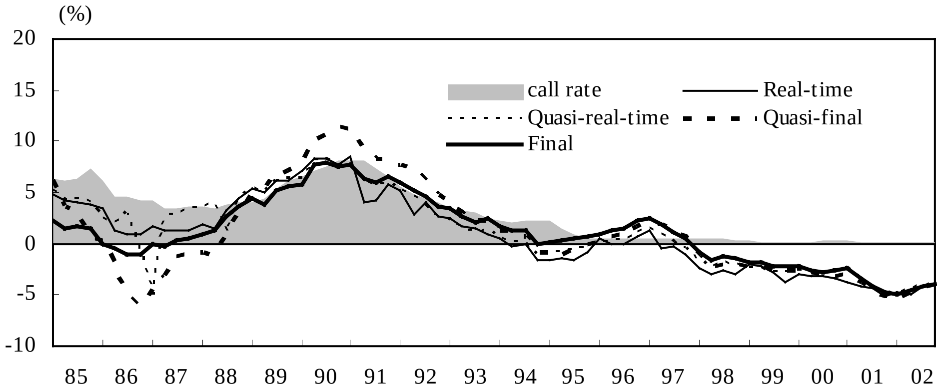
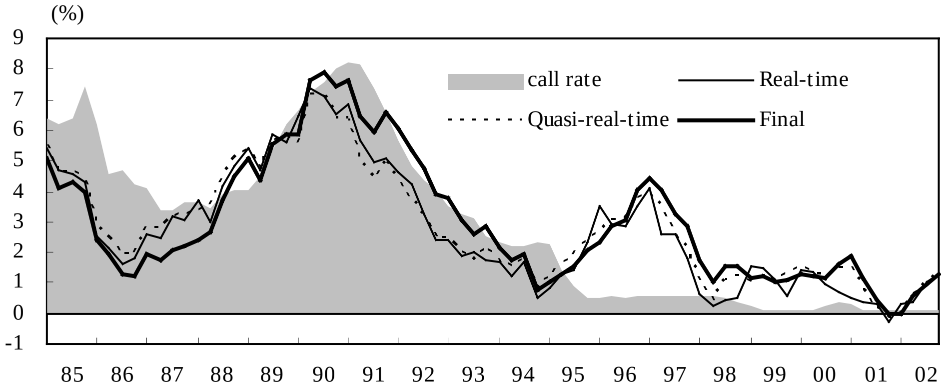


Figure 7: Original Taylor Rule (GDP Types)

a. Conventional



b. HP Filter



c. NAILO

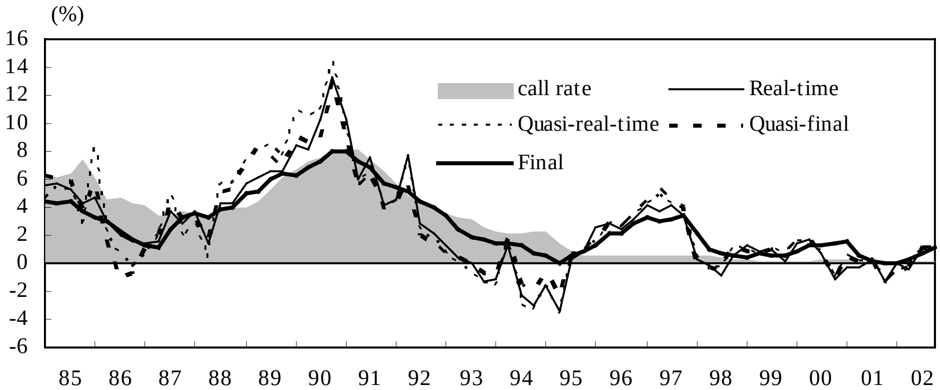
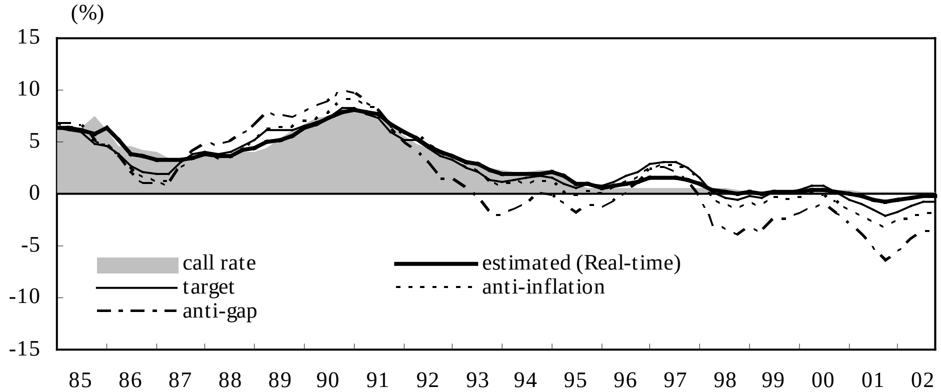
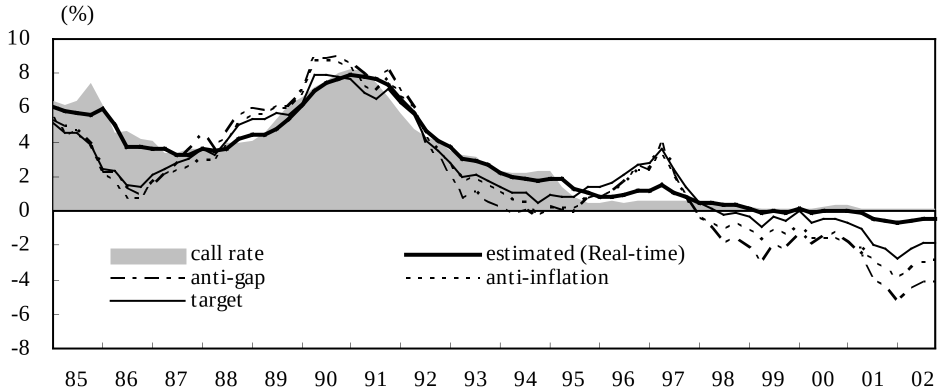


Figure 8: Modified Taylor Rule (Non-GDP Types)

a. Prototype



b. Standard



c. TV-NAIRU

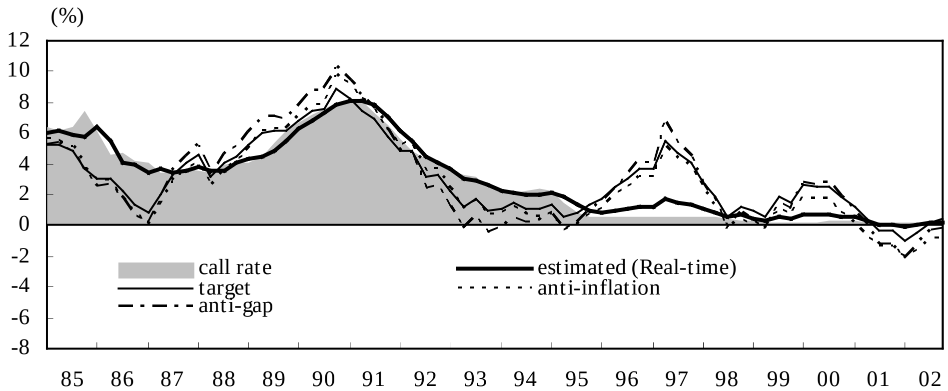
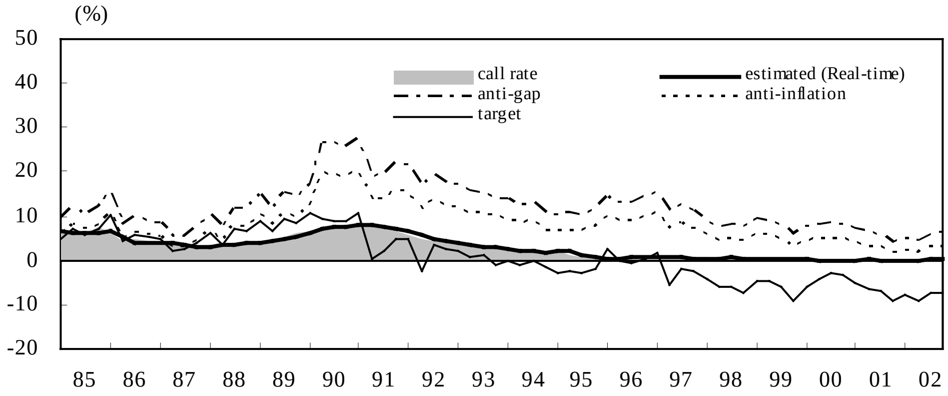
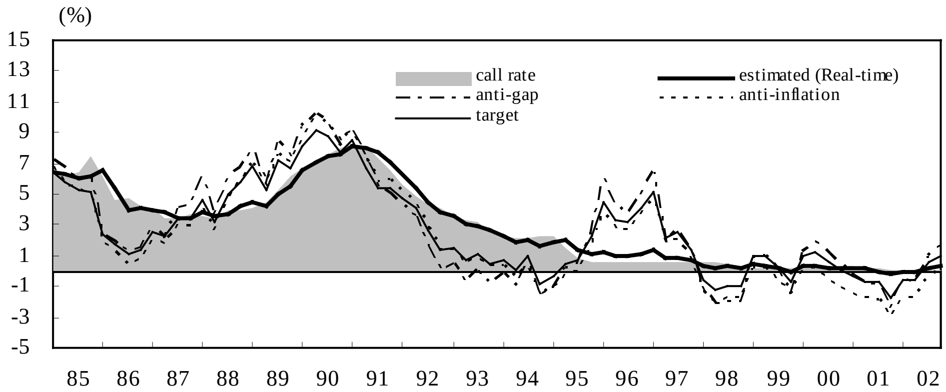


Figure 9: Modified Taylor Rule (GDP Types)

a. Conventional



b. HP Filter



c. NAILO

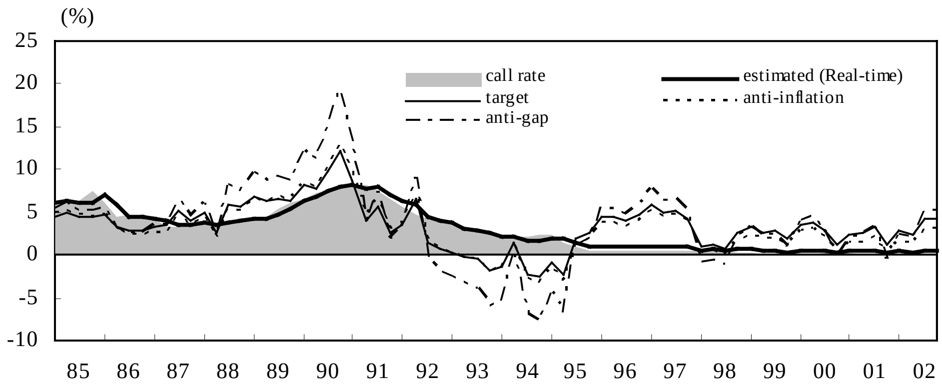


Figure 10: TANKAN

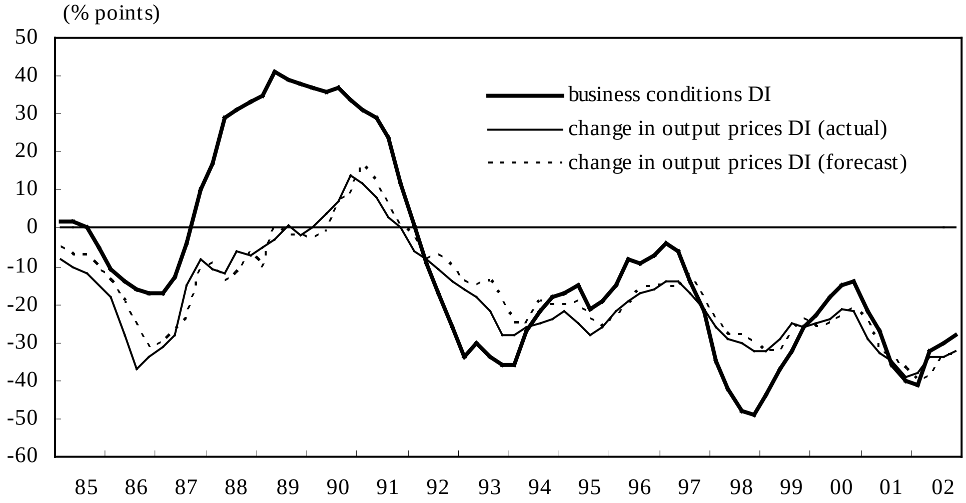
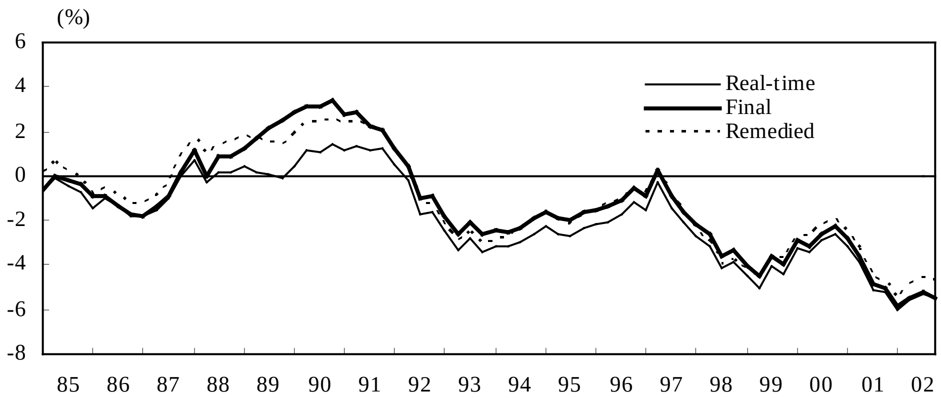


Figure 11: Remedied Real-Time Output Gap (Non-GDP Types)

a. Prototype

b. Standard



c. TV-NAIRU

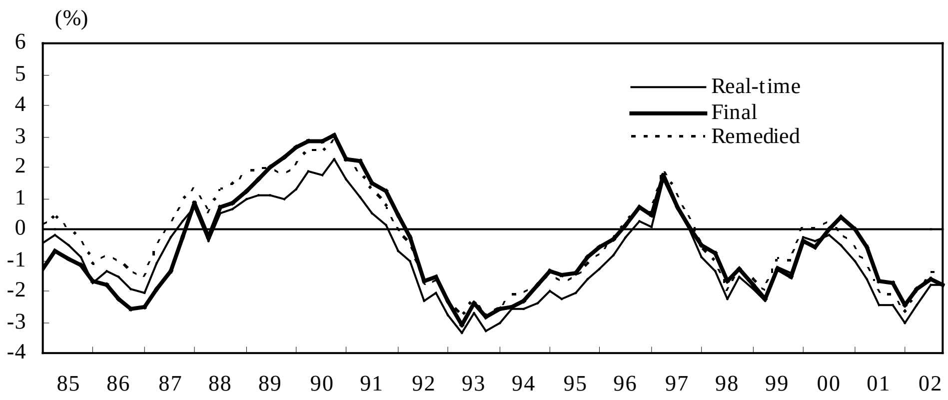
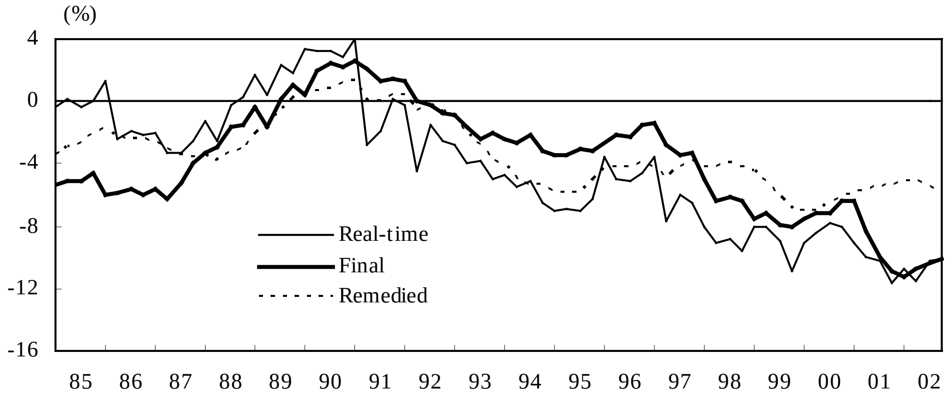
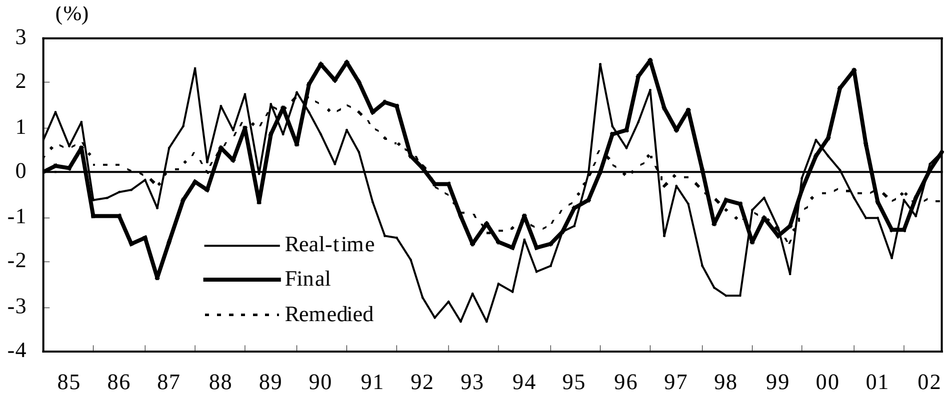


Figure 12. Remedied Real-Time Output Gap (GDP Types)

a. Conventional



b. HP Filter



c. NAILO

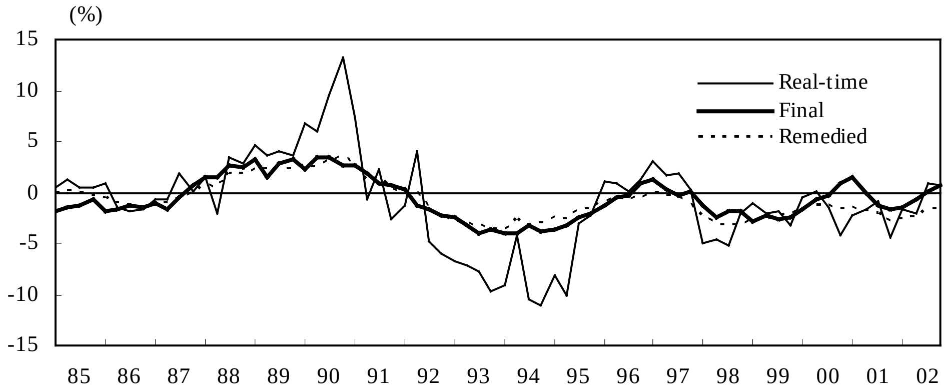
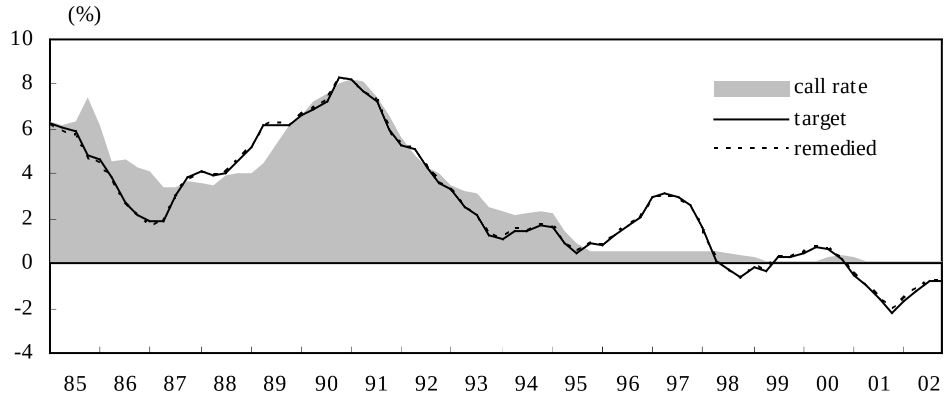
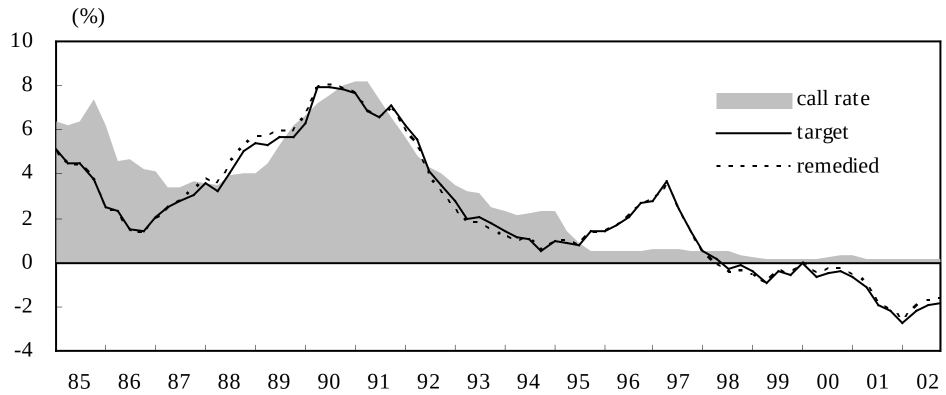


Figure 13: Remedied Taylor Rule (Non-GDP Types)

a. Prototype



b. Standard



c. TV-NAIRU

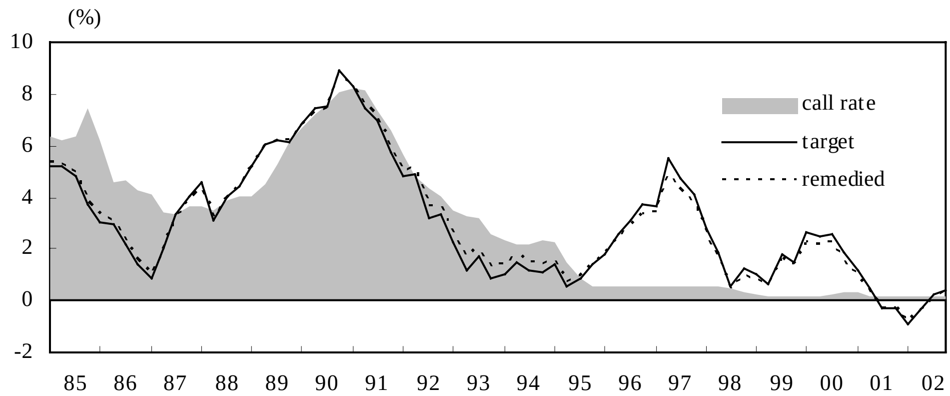
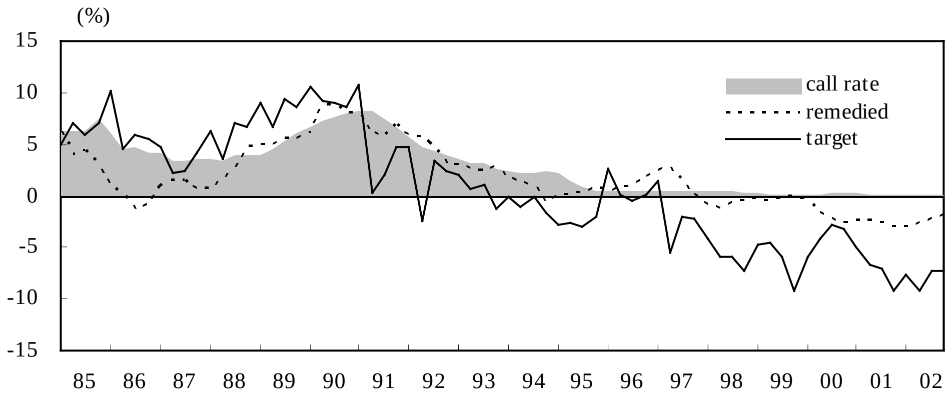


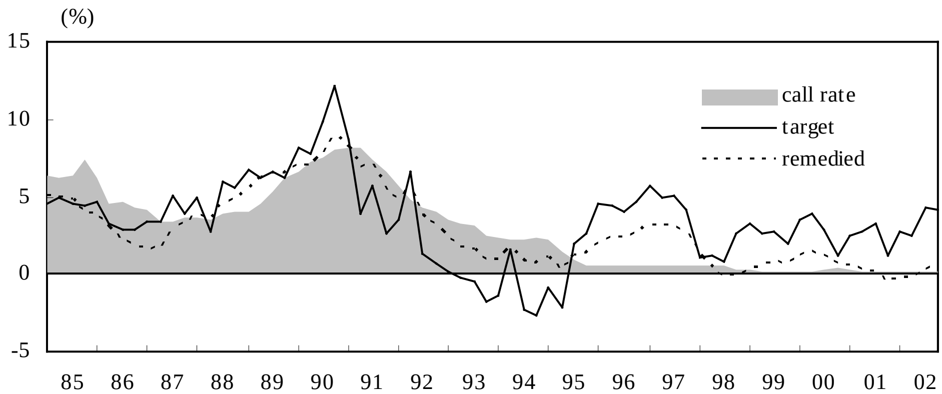
Figure 14: Remedied Taylor Rule (GDP Types)

a. Conventional



b. HP Filter

c. NAILO



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