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

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Abstract

This paper examines Bank of Japan methods for the estimation of output gap, especially in the perspective of real time estimation problem. After briefly reviewing the evolution of output gap estimation at the Bank, I discuss advantages and disadvantages of various output gap measures developed so far. First, I examine the usefulness of output gap for inflation forecasting and show that real-time output gap sometimes includes too much noise to improve inflation forecasting. Second, I investigate the implication of real-time estimation problem on the Taylor rule and evaluate the Bank's policy during the asset bubble period of the late 1980s through the early 1990s. Third, I exploit the TANKAN information to enhance the usefulness of real-time output gap in inflation forecasting and policymaking.

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

JEL Classification: E31, E32, E52, E58

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I. Introduction

The output gap is surrounded by a variety of uncertainties. 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 uncertainty depends on an estimation method of the output gap. Especially, I am interested in the six output gap measures that the Bank of Japan (BOJ) has developed for the preparation of an economic outlook and the formation of monetary policy. I review the history of output gap estimation at the Bank of Japan and present the construction of the six output gap measures briefly. Then, the paper compares these measures and discusses their advantages and disadvantages from the viewpoint of the vulnerability against the data-revision and data-arrival.

This paper quantifies what serious effects output gap uncertainty had 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 forecast is often far from satisfactory in a real policymaking process due to its large error. The paper estimates a generalized forecast function and shows to what extent forecast uncertainty exists. I show that the output gap is rather disturbing in inflation rate forecasting. There are some cases where it is better to get rid of the output gap measure from a forecast function at all.

Regarding monetary policy, I compare the original Taylor rule with the actual movement of the overnight call money rate. The paper shows that the BOJ policy from the late 1980s to the early 1990s was basically consistent with the Taylor rule prescription. The paper also investigates how the BOJ should have responded to the inflation rate and the output gap to get better results with the benefit of hindsight. The general result is that a better policy obtains by controlling the call money rate faster and responding the inflation gap and output gap more strongly.

This paper is also devoted to examining the usefulness of representative business cycle indicators for the reduction of uncertainty in the output gap estimate. Among various business cycle indicators published in Japan, some indicators are free from data revision (e.g., the *Short-term Economic Survey of Enterprises in Japan: TANKAN*). The paper discusses how to use additional information in order to avoid or ameliorate the 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 give brief introductions to their estimation methodologies. In section III, I present six measures of 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 policy from the late 1980s to the early 1990s is evaluated from the Taylor rule point of view and I discuss possible modifications to improve the rule as a policy reference. In section VI, a remedy on the real time measure of output gap by the TANKAN information is introduced and the implication on inflation forecasting and policymaking is discussed.

II. History of Output Gap Measures at the Bank of Japan

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

(1) The Prototype Output Gap

In the year of 1988, the BOJ staff was concerned with the question of why a stable inflation rate coexisted with an extremely high growth rate (figure 1). A note of the Bank's monthly bulletin issued in May 1989 claimed that the stability of inflation was attributable to a sharp increase in import. To quantify this effect, the first measure of output gap was developed. The measure is called the *prototype output gap* below.

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

$$y = a + s\ell + (1-s)k , \qquad (3.1)$$

where s is the income share of labor. a is the Solow residual and is interpreted total factor productivity. It 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

$$y^* = a + s\ell^* + (1-s)k^* . \qquad (3.2)$$

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

$$g = sg_\ell + (1-s)g_k . \qquad (3.3)$$

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

$$g^m = s_\ell g_\ell + s_k g_k + s_m g_m , \qquad (3.4)$$

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 import effect is not under discussion below).

Due to the limited availability of data, the production function approach is hard to be pursued literally. Especially in Japan, there is no direct data on capital utilization in the non-manufacturing sector. For this reason, the prototype output gap assumes away the capacity utilization rate in the non-manufacturing sector in the calculation of actual capital input, k.

(2) The Conventional Output Gap

After the bursting of the asset bubble in the early 1990s, the Japanese growth rate fell down substantially (figure 1). In face with the slowdown of economic activity, the Bank staff's next question was how much a potential growth rate had fallen. They were also faced 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 for the calculation of conventional output gap. The capital utilization rate is always assumed 100 percent in the non-manufacturing sector and the distorted Solow residual $\tilde{a}$ is obtained. Now assume that the productivity grows at a constant rate. Then, the true TFP a is obtained by regressing the distorted Solow on a linear trend.[1]

$$\tilde{a} = y_0 + y_1 T_t + h_t . \tag{3.4}$$

The true TFP is given by the fitted value, $\hat{y}_0 + \hat{y}_1 T$, while the capacity utilization rate in the non-manufacturing sector is by the regression residual, $\hat{h}$. Given the maximum input of labor and capital, equation (3.2) gives 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 experiment, however, various problems occurred in the conventional output gap. Particularly, the substantial decline 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 the fall in the regression residual of equation (3.4).[2]

(3) The Standard Output Gap

The critique toward the conventional output gap created new movements for more reliable measures of output gap. Clearly, the problem in the prototype and conventional output gap 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 in the help of various data source, including electricity consumption, capital excessiveness, and so forth. I call their measure the *standard output gap* below.

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

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[1] Originally, a kinked linear trend is assumed in the estimation of total factor productivity rather than equation (3.4), that is, $\tilde{a} = y_0 + y_1 T_t^1 + y_2 T_t^2 + h_t$. Nonetheless, equation (3.4) is assumed throughout this paper, since it is difficult to assume at what quarter the Bank staff found the kinks happen.

[2] The conventional output gap declined due to the decrease in the regression residual of equation (3.4). If the growth of total factor productivity slowed, a portion of the decline in the conventional output gap was attributed to structural change on the supply side of the economy. But, a trend shift was hard to be identified in real time. Particularly, the abrupt changes during 1998 -1999 also made the judgment of a trend shift very difficult.

detail. Figure 3.b depicts the electric power units for commercial use, EPU : the ratio of actual electricity consumption to contracted amount.[3] First, Kamada and Masuda regress it on a time trend and the production capacity BSI in the non-manufacturing sector (the *Business Outlook Survey* by Ministry of Finance, shown in figure 3.c).

$$EPU_t = c_0 + c_1 T_t + c_2 BSI_t + z_t . \tag{3.5}$$

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

$$\frac{\hat{c}_0 + \hat{c}_2 BSI_t}{\max(\hat{c}_0 + \hat{c}_2 BSI_t)} \tag{3.6}$$

Once the capacity utilization rate in the non-manufacturing sector is obtained, the actual input of capital service, k, is estimated correctly and equation (3.3) produces correct output gap. The resulted output gap is shown in figure 2.c. Furthermore, since the Solow residual is no more distorted by business cycle and reflects true total factor productivity, a, the maximum level of output is also calculated by equation (3.2) and the potential growth rate is also obtained.

(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 no connection with price movements per se. To gain implications for prices, the Bank staff estimates the NAIRU version of Phillips curve.[4] Since 1999, the output gap measure has declined steadily. Nonetheless, the inflation rate appeared relatively stable in terms of the consumer price index (excluding fresh food) in a quarter-to-quarter basis. This suggests the possibility that the NAIRU has declined over time, rather than staying at a specific level.[5]

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

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[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) is defined in terms of an unemployment rate. Here, I define the concept in terms of output gap.

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

$$p_t = p_t^e + b(g_t - g_t^n) + g \cdot x_t + e_t , \qquad (3.7)$$

where p is the inflation rate; p^e is the expected rate of inflation. For the latter, I use the following specification.

$$p_t^e = a\Sigma_{i=1}^{4} p_{t-i} / 4 + (1-a)\Sigma_{i=5}^{8} p_{t-i} / 4 . \qquad (3.8)$$

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

I assume a random walk process for the NAIRU. Namely,

$$g_t^n = g_{t-1}^n + n_t . \qquad (3.9)$$

A state space model is constructed with g^n as a state variable, equation (3.7) as an observation equation, and equation (3.9) as a transition equation. Then, the Kalman filter is applicable for the estimation of parameters, g^n, a and b.[6]

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

(5) The NAILO

Since the production function approach depends on plenty of data, measurement errors tend to accumulate in estimated output gap measures. In contrast, the time series method often requires

[6] Theoretically, there is no problem in estimating the variance of e in equation (3.7) and n in equation (3.9) 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 n 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 e and v with a variety of sample period, many cases are encountered where the variance of v, which determines the behavior of the NAIRU, is found not significantly different from zero. The approach of the current paper to deal with this problem is to choose the ratio of the variance of n to the variance of e 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 uses this method to estimate the variance of the NAIRU in the US.

a small number of data. Thus, measurement error problems are less severe than the production approach are faced with.

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

$$\Sigma_{t=1}^{T}(y_t - y_t^{hp})^2 + l\Sigma_{t=2}^{T-1}(\Delta y_{t+1}^{hp} - \Delta y_t^{hp})^2, \tag{3.10}$$

where Δ is a first difference operator. The output gap is defined as a percentage deviation of actual output from this potential output. A disadvantage of the HP filter output gap is its lack of theoretical backgrounds. For this reason, the HP filter output gap has played few roles in making an economic outlook and formulating monetary policy at the Bank.

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

$$p_t = wp_{t-1} + (1-w)p_{t-2} + f(y_t - y_t^n) + x_t. \tag{3.11}$$

Rearranging this gives

$$y_t - \{p_t - wp_{t-1} - (1-w)p_{t-2}\}/f = y_t^n - x_t/f. \tag{3.12}$$

The left hand side is the inflation-rate-adjusted output. y^n obtains by applying the HP filter on it. The problem is that parameters w and f are unknown as well as y^n. Hirose and Kamada (2003) present a procedure to determine w, f and y^n, simultaneously. Figure 2.f shows the NAILO-based output gap.

III. Real-Time Estimation of Japanese Output Gap

The measure of 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;[7] (ii) data accumulation alters the estimate of potential output over time. The latter is called the *end-of-sample problem* in particular.

The uncertainty created by data revision and accumulation may affect the behavior of a central bank. Thus, it is an important task to quantify the effects of uncertainty for a careful implementation of monetary policy. The four stages of output gap, 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 were known up to a point of time in the past. As for the *quasi-final output gap*, a structural model is estimated from a full sample, while data are revised and accumulated, as in the case of the quasi-real-time gap. The *final output gap* assumes that the whole set of data series were known up to now.

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 (3.7) with $g_t^n = \bar{g}^n$ for each of the prototype, the standard, and the conventional output gap.

(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, with regard to the non-GDP types, it is a general property for the real-time output gap to coincide with the quasi-final output gap.

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

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[7] 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 Account* experienced the transition from the 1968 system to the 93 system in 2000.

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 was observed during the period between the late 1980s and the early 1990s.[8] Nonetheless, as for the non-GDP types, the real-time estimation problem appeared small.

(2) GDP Types of Output Gap

The group of non-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 extensive revision of GDP data. As a result, real-time output gap deviates from quasi-real time output gap substantially.

As for the HP filter output gap, no structural models are estimated; thus quasi-final output gap coincides with quasi-real-time gap. For the other GDP types, however, quasi-final output gap deviates from quasi-real-time output gap. For the conventional output gap, a linear trend is estimated to extract the total factor productivity 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 remarkable is that the real-time output gap is far more volatile than quasi-real-time output gap. The large volatility of real-time output gap stems from the noise inherited from data used for the estimation. Especially, the first released GDP, from which the real-time output gap is calculated, depends mainly on demand side data, which are notorious for their sampling distortion.[9] To the contrary, the final GDP, from which the final output gap is calculated, depends on supply side data, which are less noisy and more reliable for their large sampling coverage.

It is also remarkable that the final output gap diverts from the other stages of output gap substantially. Particularly, the real-time output gap swings largely at the turning points of

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

[9] For instance, the private consumption component of GDP is based on the *Monthly Report on the Family Income and Expenditure Survey*, which is disturbed by personal factors of surveyed families that are far from representative for the whole economy.

business cycle. This shows 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 errors in the estimation of output gap. Around the middle of sample, a trend is easy to be identified, while it is quite uncertain at the end of sample.

The GDP figure is convenient in evaluating an economy's economic activity comprehensively, and thus economic policy will continue to be conducted by looking at the behavior of GDP statistics. However, the above argument shows that a trend of GDP is hard to be identified and there is a risk that monetary policy is affected too much by a wrong estimate of output gap.

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

This section investigates how informative the output gap is in forecasting inflation rates in future. From the main perspective of this paper, it is also interesting to see how seriously the real-time estimation problem affects the performance of inflation forecasting.

(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 the problem. In the context of inflation forecasting, when the GDP types of output gap are used, the performance of a forecast function estimated from the final output gap is questionable. What forecasters have in constructing a forecast function is not final output gap, but real-time output gap.

It can also happen that a forecasting function, whose performance is excellent in terms of in-sample fit, performs badly in terms of 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 terms of out-of-sample forecasting.

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

$$\bar{p}_{t+4} = g_0 + \Sigma_{i=0}^{n} g_{1i} p_{t-i} + \Sigma_{i=0}^{m} g_{2i} g_{t-i} + \bar{h}_{t+4}, \tag{5.1}$$

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

With regard to lag lengths in the right hand side of equation (5.1), I assume 4 quarters for n and m at most, taking into consideration the limitation of sample. I also assume that $n = m$ for convenience. Since there is no current GDP and thereby current output gap available until the next quarter, a forecasting function should be estimated under the restriction of $g_{2,0} = 0$. 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) posted an interesting proposition, showing theoretically that forecasting errors were smaller by focusing 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 by p_t^T and g_t^T, respectively. I assume that the inflation rate is free from revision; thus I have $p_t^T = p_t$. Then, equation (5.1) is rewritten as

$$\bar{p}_{t+4} = g_0 + \Sigma_{i=0}^{n} g_{1i} p_{t-i} + \Sigma_{i=0}^{m} g_{2i} g_{t-i}^{T} + \bar{h}_{t+4}. \tag{5.2}$$

In contrast, according to the KDP proposition, a forecaster can enhance forecast performance by using g_t^t instead of g_t^T. That is, the following forecast function may improve on equation (5.2).

$$\bar{p}_{t+4} = g_0 + \Sigma_{i=0}^{n} g_{1i} p_{t-i} + \Sigma_{i=0}^{m} g_{2i} g_{t-i}^{t} + \bar{h}_{t+4}. \tag{5.3}$$

Data revision is considered to be a kind of noise, as far as it cannot be forecast in real time. Therefore, by focusing on 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 doubts on the KDP proposition. KDP's critical assumption is the efficiency of real-time data. The assumption cannot be justified ex ante and should be supported empirically. Below, I consider the applicability of the KDP proposition in the case of the CPI inflation forecast in Japan.

(2) Forecasting Results

Table 1 shows root mean squared errors (RMSE) of inflation forecasting with each of the six measures of output gap applied to a forecast function. For comparison, I show the result in the case of a simple AR model without relying on any output gap measures, which is shown at the bottom of the table. In the *ordinary case,* I use only the most recent estimates of output gap (i.e., equation (5.2)), while I use all the older vintages in the *KDP case* (i.e., equation (5.3)). The *in-sample* RMSE is calculated from regression residual in the estimation of forecasting functions, while the *out-of-sample* RMSE is calculated from forecasting errors in the forecast of one-year-ahead inflation rates through the estimated forecasting function. The RMSE is calculated for the period of 1995-2001 for each case.

An optimal lag length is chosen according to the Akaike information criteria (AIC). I begin with the lag of four quarters because of the limitation of small sample, though it is desirable to start with a longer lag, say 12 quarters. Fortunately, however, the optimal lag length is 1 quarter, except for the out-of-sample RMSE for the KDP case of NAILO output gap. 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-pf-sample forecasting performance is much worse than in-sample fit performance appears. Notice that the standard output gap, although estimated in a very primitive way, shows an excellent out-of-sample forecasting performance as well as a good in-sample fit. As for the others, however, close fit of forecasting functions does not necessarily imply good performance in inflation forecasting.

Second, for three of six output gap measures, a simple AR process outperforms output-gap-based forecasting functions in inflation forecasting. With the AR model with a first lag as a benchmark, the forecasting functions with the TV-NAIRU, the conventional, and NAILO output gap fail to reduce their out-of-sample forecasting RMSE (the performance of HP filter gap is almost the same as the AR model). In other words, forecasting performance can be worse off by incorporating output gap measures into forecast functions.

Third, forecasting performance may improve by exploiting all the older vintage data rather than by relying solely on the most recent vintage data. Comparing with the ordinary case, the KDP method reduces out-of-sample forecasting RMSE in the cases of the conventional output gap as well as the HP filter output gap (almost intact for the NAILO output gap).

V. 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 evaluation of the monetary policy stance is based on the Taylor rule, which was formulated in Taylor (1993) originally and used frequently thereafter.

(1) Original Taylor Rule

Taylor's (1993) original specification is given by

$$i_t = r^* + p_t + a_p (p_t - p^*) + a_g g_t , \qquad (6.1)$$

where i is the short-term interest rate that is used as a policy instrument or the federal fund rate (FF rate) in the US; r^* is an equilibrium real interest rate; p^* is a target rate of inflation of monetary authority; a_p and a_g are parameters of policy responsiveness against the deviation of actual inflation rates from the target and against the output gap, respectively.

Taylor (1993) showed that the monetary policy conducted by the Board of Governors of the Federal Reserve System was approximated by equation (6.1). First, the potential output is defined as a linear trend fitted on real GDP during the period of 1984Q1-1992Q3; then the output gap is obtained as the percentage deviation of actual output from the potential. Policy parameters are given by $p^* = 2$, $a_p = a_g = 0.5$, and $r^* = 2$.

The original Taylor rule can deviate from actual interest rates mainly for four reasons: (i) discretionary monetary policy; (ii) specification of the Taylor rule; (iii) choice of the output gap; (iv) the problem of real-time output gap estimation. It is interesting to think about the first factor or why monetary authority takes discretionary action. I do not pursue this question, however, since it is beyond the scope of this paper. I refer readers to 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 (overnight call rate) depends on the following factors: (i) To what extent does the Japanese economy resembles the US economy; (ii) to what extent the two countries' policy goals look like; (iii) to what extent the two countries have learned their optimal policy rule. When investigating the Taylor's original specification, I accept his original setting except for $p^* = 0$. I use the CPI to measure inflation rates rather than Taylor's choice of the GDP deflator.[10]

With regard to the third factor, 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. As far as various output gap measures coexist and there is no consensus on which output gap should be substituted in the Taylor rule, no one can reach a final answer about whether the Bank of Japan followed the Taylor rule.

Finally, there is the problem of real-time output gap estimation. Corresponding to the four stages of output gap revision, I have four of 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 prevailed ex post, it is the best guide line and compared with actual call rate for purpose of evaluating monetary policy.

A difference between the final rule and the actual call rate is decomposed into two parts: a discretionary policy part between a real time rule and an actual call rate and a real-time-problem part between final and real-time rules. The latter part is decomposed further into three parts, depending on the four stages of output gap revision: a data revision part between real-time and quasi-real-time rules, a model-parameter revision part between quasi-real-time and quasi-final rules, a data accumulation part between quasi-final and final rules.

So far there have been no researches that distinguish between discretionary policy factors and real-time-estimation factors to discuss the Japanese monetary policy. However, the problem of real-time output gap estimation causes actual policy to deviate from the Taylor rule even when monetary authority follows it closely and should be extracted in evaluating an actual policy. In order to investigate policy stance, call money rate should be compared with a real time rule rather than a final rule.

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[10] The inflation rate he used was the percent change of the GDP deflator over the preceding four quarters, which he interpreted was a proxy of expected rate of inflation. Alternatively, I also used actual inflation rates observed one-year ahead, as in Clarida et al. (1998) as well as 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 a longer time series is available in the JCER survey than the *consensus forecast*. I do not discuss these alternatives, since the parameters of the Phillips curve could not estimated with the theoretically correct sign frequently.

(2) Policy Evaluation through the Original Taylor Rule

Here I evaluate the BOJ policy from the late 1980s to the early 1990s from the Taylor rule point of view. 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 critique is that monetary tightening during 1987-1990 and easing during 1990-1995 were both too small and too late. To the contrary, there is literature that claims that the Bank of Japan followed the Taylor rule on the whole" (e.g., Okina and Shiratsuka [2002]).

In figures 6 and 7, various Taylor rule prescriptions are depicted with overnight call money rates (shadowed area), based on the six measure of output gap for each stage of revision. Remarkably, the difference between the actual call rate and the final 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 was supposed to be the output gap measure the Bank used during this period.

There are several minor dispersions between the final rule and the actual call money rate even with the prototype output gap. For instance, as Okina and Shiratsuka (2002) discuss, the monetary easing might be too late during the period of 1992-1995. As Jinushi et al. (2000) point out, the introduction of the zero interest rate policy in February 1999 might be delayed. But these dispersions were not significant from the quantitative point of view.

Noteworthy is that the deviation of the actual call money 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 is not the real-time estimation problem that kept the BOJ policy away from the Taylor rule prescription. The discretionary factor (a difference between the real-time and final rules) explains why the BOJ policy deviated from the Taylor rule during this period.

The policy prescriptions based on the other output gap measures are nothing but imaginary experiments. Yet, close examination is valuable for the following reasons. Obviously, it is desirable to know the properties of the Taylor rule when various measures of output gap are applied. Furthermore, the Bank has not relied on the prototype output gap any more, because the measure is an insufficient business cycle indicator (it does not take into consideration the capacity utilization rate in the non-manufacturing sector).

Remark that the actual call money rate did not deviate from the final rule, whatever output gap measures are used for the Taylor rule. Particularly in the case of TV-NAIRU output gap, the Taylor rule was very close to the actual call money rate during 1988-1995. It is also remarkable that the Taylor rules with the GDP types of output gap (classical, 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 in the rule, the volatility of the real-time rule is so large that the Bank staff might hesitate to adopt the Taylor rule as a policy reference, especially when the Bank prefers controlling its instrument smoothly.

(3) Policy Evaluation through Estimated Taylor Rules

The consistency with the Taylor rule does not justify the BOJ policy by itself. Rather, the "lost decade" since the early 1990s suggests that the original Taylor rule should be modified or brand new guide line should be formulated instead.[11] Here I consider the question of what policy rule is optimal. There are two approached to follow. The first approach is to build up a macro econometric model that describes real economy and to find an optimal policy rule in terms of monetary authority's loss function. The second approach is to estimate a policy rule during the period when monetary policy functioned well.[12] For instance, Jinushi et al. (2000) defines a rule observed during the period of 1975-1985 as a "good rule." They use it as a benchmark when evaluating the BOJ policy during the creation and bursting of the asset bubble.

The two approaches, however, agree in saying that the monetary tightening during the late 1980 and the easing during the early 1990s were both too small and too late. It is beyond the scope of this paper to show whether this argument is true. Instead, this paper proceeds in the following way. First, I estimate the BOJ policy stance by fitting the Taylor rule into the sample data during the period of 1988-1995. Next, I consider how to modify the estimated policy stance to obtain a Taylor rule according to which the monetary tightening in the late 1980s and easing in the early 1990s were stronger and earlier than what they were.

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

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

I use the following extension of equation (6.1), which incorporates smooth control of the policy instrument.[13]

$$i_t = q i_{t-1} + (1-q) i_t^{target}, \qquad (6.2)$$
$$i_t^{target} = r^* + p_t + a_p (p_t^e - p^*) + a_g g_t. \qquad (6.3)$$

That is, actual call money rates are considered to adjust toward the estimated target rate (i^{target}) at the speed of $(1-q)$.

First, I think what modification is necessary for the Taylor rule to command appropriate timing of interest rate change. In figures 8 and 9, the thick lines are fitted values of equation (6.2), while the thin lines depict the target call rates, i.e., equation (6.3). The faster the adjustment speed, the closer the Taylor rule approaches to the target rate. With full adjustment speed ($q = 0$), the target rate (i^{target}) coincides with the Taylor rule prescription (i). In this limiting case, the Taylor rules are above actual call money rates during the period of 1987-1990 and are below actual rates during the period of 1991-1995, whatever output gap measures are used in the Taylor rule. This means that appropriate timing of policy change is obtained by making the adjustment speed faster.

Next, I consider how much a call money rate should be raised. A sufficient condition for stabilizing policy is that a coefficient on the inflation rate in equation (6.3) is greater than one (the Taylor principle). Table 2 shows that the policy reaction was evaluated to be destabilizing with some measures of output gap. In particular, when the standard output gap is used, the estimated Taylor rule is stabilizing ex ante (i.e., with real-time output gap), but is destabilizing ex post (i.e., with 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 money rate is depicted (dotted lines) when I raise the parameter value on the inflation rate by + 0.5 percent (anti-inflation policy). Qualitatively, the target rate rises up further during the period of 1987-1990 and falls down further during the period of 1991-1995.[14] The quantities are not so large, however. For comparison, I raise the

[13] Equations (6.2) and (6.3) are close to the one introduced by Clarida et al. (1998). A difference is that they use inflation rates observed actually in future, while I use the past inflation rate as a proxy of expected rate of inflation.

[14] A constant term is adjusted to cross out the effects of raising parameter values on the inflation rate.

parameter values on the output gap by + 0.5 percent (chain lines). Then, a similar reaction is obtained in the target rate, but with larger effects quantitatively.

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

VI. Remedies on Real-time Output Gap

In this section, I consider the possibility to remedy real time output gap for a policy use. In order to improve the real-time output gap, I require supplement data to have the following two properties. First, supplement data will be not revised in future. Even if revised, final revision should be completed within a few months. Second, supplement data should have no trend. If there are trends in supplement data, it creates another real-time estimation problem in the course of data accumulation.

(1) Improving Real-Time Output Gap

I use the *Short-Term Economic Survey of Enterprises* in Japan (*TANKAN* for short) as a supplement data. Real time GDP data is compiled mainly from demand side data, while final GDP data is from supply side data. The TANKAN compiles entrepreneur's business plan and sentiment and thus reflects much 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.

Among much information in the TANKAN, I choose the *business condition diffusion index* (DI). Figure 12 shows the behavior of the business condition DI, d^b. One of its desirable properties is that it is revision-free. It is controversial, however, whether the business condition DI is stationary or not. Below, I proceed under the assumption that the DI has no trend factor in its movement.

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

$$g_t^{2002Q4} = d_0 + d_1 \cdot g_t^t + d_2 \cdot \Sigma_{q=0}^{h} d_{t-k-q} /(1+h) + e_t^f \ , \qquad (7.1)$$

where g^{2002Q4} and g^t are final and real-time output gap, respectively. In estimation, I discarded some data at the end of sample to avoid the end-of-sample problem.

If real time GDP data exploited all information available, there would be no way for forecasting final GDP data by the business condition DI. As discussed above, however, the business condition DI may have additional information that is not reflected in real time GDP data. When the business condition DI includes additional information, the estimated value of d_2 is different from zero significantly. Note that as the sample extends to the current period, the real-time data approaches to the final data. This implies that the dispersion between the final gap and real-time gap shrinks away. For this reason, I discard the recent sample in the estimation of equation (7.1).

(2) Estimation Results

Table 3 presents the results when I estimated equation (7.1) by OLS. The business condition DI is statistically significant in every case except for one case, i.e., the TV-NAIRU type of real-time output gap. This is an interesting result, since the business condition DI has no further information than the TV-NAIRU type output gap has. An interpretation is that the time-varying NAIRU reflects structural changes occurring in the supply side of economy and covers the same information as the business condition DI has.

In general, with the GDP types of output gap, an estimated coefficient on the business condition DI is large, while small with the non-GDP types. For the non-GDP types of output gap, since the real-time output gap is very close to the final output gap, the coefficient on the real-time output gap is close to one. For the case of GDP types, a coefficient on the business condition DI is large and a coefficient on the real-time output gap falls short of 1. This suggests that the business condition DI is helpful for the ameliorating the real-time estimation problem in the GDP types of output gap.

In figures 11 and 12, I show the prediction of final output gap from real-time output gap and the business condition DI. The GDP types of output gap are remedied significantly by the business condition DI. Especially for the NAILO output gap, a remedy function shows excellent performance. During the period of 2000-2001, the remedy function predicts the final output gap precisely and ameliorates the real-time estimation problem in the NAILO gap. A remedy function, however, performs badly in the case of HP filter output gap measure. A possible reason is that since the HP-filter-based output gap is intrinsically lack of theoretical backgrounds, it is disturbed with too much noise to be remedied by supply side information.

(3) Remedy Effects on Inflation Forecasting and Policy Making

First, I investigate the effects of the TANKAN remedy on inflation forecasting. I choose the RMSE of out-of-sample forecasting 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 with the business condition DI.

$$g_{t-i}^{T} = r_{0i} + r_{1i} g_{t-i}^{t} + r_{2i} d_{t-i} + e_{t-i}^{T} . \qquad (7.2)$$

In estimation, I discarded some data at the end of sample to avoid the end-of-sample problem.

Through this relationship, I estimate eight-quarter-ahead final output gap and use the result in equation (5.3). In table 1, an output-gap-based forecasting function outperforms a simple AR model with four of six measures of output gap. In table 4, after the TANKAN remedy, an output-gap-based forecasting function outperforms an AR model with five measures (the NAILO case is added). But the remedy effect is not remarkable.

Next, I investigate the effects of the TANKAN remedy on the Taylor rule. In figures 13 and 14, I show the Taylor rule with the output gap during the period of 1988-1995 remedied by equation (7.1). As pointed out above, the remedy by the business condition DI is not large for the non-GDP types of output gap and thus has only small impacts on the Taylor rule. In contrast, for the GDP types, the business condition DI has a great possibility to remedy the real time output gap and has great impacts on the Taylor rule.

In comparison of figures 13 and 14 with figures 4 and 5, the most remarkable is the case of the NAILO output gap. Furthermore, when I used the real time output gap in the estimation of the Taylor rule, neither inflation rate nor output gap is found significant, as in table 2. When I use the remedied output gap, however, both are significant in the estimated Taylor rule, as in table 5.[15] In addition, the Taylor rule with the remedied NAILO output gap is far smoother than it is before remedy. These are preferable properties when policy makers use the NAILO-based Taylor rule as a policy reference in the formation of monetary policy in a real world.

VII. Conclusion

This paper has two purposes: the introduction of output gap measures developed at the Bank of Japan and the quantification of the real-time estimation problem. Their performance is evaluated from the viewpoint of inflation forecasting and policy making. I also consider the possible remedy to ameliorate the real-time estimation problem by the TANKAN information.

The evaluation on inflation forecasting is as follows. First, the performance of out-of-sample forecasting is far worse than expected from the excellent in-sample fit of forecast functions. Second, for three of six measures, a simple AR model outperforms an output-gap-based forecast function. For the other three measures, however, the forecast functions are disturbed by the information carried by the output gap measures. Third, the method of Koenig et al. (2003) (KDP) is not necessarily useful for inflation forecasting in Japan. For two of six output gap measures, the performance of forecast function deteriorates by the KDP method.

The evaluation as a policy reference is as follows. First, the BOJ policy from the late 1980s to the early 1990s was consistent with the Taylor rule on the whole. In particular, the critique that the Bank's response was too weak and too late is often based on the wrong evaluation in the affection of the real-time estimation problem. Second, a better policy might be obtained by raising the adjustment speed of the call money rate toward the target interest rate or by strengthening the policy responsiveness to the diversion of the inflation rate and the output gap, although the new policy may create bad by-products.

The remedy of output gap measures by the TANKAN information produce favorable

[15] To the contrary, in the case of the HP filter output gap is 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.

effects on the output gap measures. TANAKAN's business condition DI is helpful for forecasting final output gap from real-time output gap, with the result that the number of forecast functions that outperform a simple AR model increases. Furthermore, for the GDP types of output gap, large volatility in the real-time measure is reduced substantially by remedy functions, which enhances the usefulness of the Taylor rule in a process of policy formation.

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Table 1. Forecast Accuracy

Output Gap	$\eta = n$	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	0.254	0.376	2.013
	3	0.269	0.630	2.215	0.255	0.401	2.043
	4	0.258	0.659	2.253	0.259	0.395	2.068
NAILO	1	0.370	0.510	1.833	0.305	0.550	2.090
	2	0.361	0.479	1.824	0.293	0.526	2.079
	3	0.359	0.417	1.847	0.269	0.489	2.064
	4	0.354	0.398	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	0.602346 ***	2.572557 ***	0.45527 ***	1.283847 ***
		(0.101485)	(0.297133)	(0.075631)	(0.181901)
	final	0.590721 ***	2.321465 ***	0.464547 ***	1.20199 ***
		(0.104192)	(0.275071)	(0.075588)	(0.186197)
Standard	realtime	0.708379 ***	2.598355 ***	0.654703 **	1.468469 ***
		(0.103386)	(0.797601)	(0.264630)	(0.412476)
	final	0.692324 ***	2.812073 ***	0.876191 ***	0.798406 **
		(0.081531)	(0.547029)	(0.243980)	(0.411868)
TVNAIRU	realtime	0.769313 ***	3.150256 ***	1.041646 **	1.110097 **
		(0.075683)	(0.799651)	(0.378004)	(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	0.852137 ***	−2.075261	−0.528624	3.72948
		(0.118641)	(6.690195)	(1.451170)	(3.262933)
HP filter	realtime	0.823769 ***	1.798735 **	0.94283 *	1.963293 ***
		(0.079384)	(0.751842)	(0.484265)	(0.403641)
	final	0.775564 ***	1.665057	0.756567	1.588095 *
		(0.106802)	(1.197312)	(0.626407)	(0.816891)
NAILO	realtime	0.901467 ***	3.86506 *	0.59146	0.161511
		(0.098352)	(2.264392)	(0.524410)	(1.722226)
	final	0.653578 ***	2.510373 ***	0.597545 ***	1.275376 ***
		(0.105887)	(0.356296)	(0.124889)	(0.225023)

1. ***, ** and * indicate significance of an associate variable at 1, 5 and 10 percent levels.
2. standard errors are in ( ).

Table 3. Remedy Functions by TANKAN

dependent variable final gap	constant	realtime output gap	bussiness condition DI
non-GDP type			
Prototype	0.519447 ***	0.89829 ***	0.014616 ***
	(0.031036)	(0.026732)	(0.003379)
			[0, 0]
Standard	0.77218 ***	0.977558 ***	0.015707 ***
	(0.086136)	(0.052177)	(0.004117)
			[0, 0]
TVNAIRU	0.383834 ***	0.967523 ***	0.005324
	(0.079040)	(0.085753)	(0.004804)
			[0, 0]
GDP type			
Conventional	−2.129952 ***	0.395471 ***	0.053966 ***
	(0.384949)	(0.081933)	(0.014521)
			[6, 0]
HP filter	0.290946 **	0.301509 ***	0.023449 ***
	(0.118910)	(0.075227)	(0.004633)
			[4, 0]
NAILO	−0.140583	0.207286 ***	0.039099 ***
	(0.134610)	(0.038590)	(0.007008)
			[0, 2]

1. ***, ** and * indicate significance of an associate variable at 1, 5 and 10 percent levels.
2. standard errors are in ( ).
3. The entries of [ ] are k's and h's in equation (v).

Table 4. Forecast Accuracy after the Remedy

Output Gap	$n = m$	KDP Case		
		RMSE		AIC
		in sample	out of sample	
non−GDP type				
Prototype	1	0.236	0.334	1.414
	2	0.223	0.308	1.331
	3	0.217	0.361	1.356
	4	0.183	0.379	1.228
Standard	1	0.264	0.529	1.824
	2	0.254	0.494	1.825
	3	0.253	0.505	1.875
	4	0.249	0.539	1.941
TV−NAIRU	1	0.319	0.946	1.998
	2	0.309	1.014	2.030
	3	0.309	1.105	2.091
	4	0.304	1.122	2.063
GDP type				
Conventional	1	0.190	0.479	1.753
	2	0.212	0.412	1.692
	3	0.203	0.486	1.588
	4	0.195	0.476	1.485
HP filter	1	0.303	0.645	1.835
	2	0.235	0.525	1.601
	3	0.221	0.453	1.516
	4	0.224	0.476	1.518
NAILO	1	0.345	0.661	1.903
	2	0.338	0.700	1.904
	3	0.333	0.762	1.937
	4	0.319	0.714	1.905
AR	1	0.286	0.670	2.127
	2	0.274	0.652	2.143
	3	0.274	0.679	2.183
	4	0.271	0.697	2.220

Table 5. Estimated Taylor Rules after the Remedy

dependent variable call rate		adjustment speed	constant of target rate	realtime gap after remedy	inflation rate
non-GDP type					
	Prototype	0.601764 ***	2.264613 ***	0.446946 ***	1.299595 ***
		(0.100311)	(0.274934)	(0.073438)	(0.178590)
	Standard	0.710949 ***	2.16541 ***	0.610346 **	1.374871 ***
		(0.094846)	(0.597318)	(0.222186)	(0.387898)
	TVNAIRU	0.624366 ***	2.652662 ***	0.877132 ***	1.220085 ***
		(0.099159)	(0.317970)	(0.157171)	(0.199441)
GDP type					
	Conventional	0.802515 ***	7.384998 *	1.159416	−0.349724
		(0.093245)	(4.037991)	(0.727937)	(1.671230)
	HP filter	0.806352 ***	2.281058 **	2.043082 **	0.872428
		(0.085617)	(0.886718)	(1.070909)	(0.762024)
	NAILO	0.762954 ***	2.7999 ***	0.893214 ***	0.979511 **
		(0.100569)	(0.599732)	(0.290975)	(0.414199)

1. ***, ** and * indicate significance of an associate variable at 1, 5 and 10 percent levels.
2. standard errors are in ( ).

Figure 1. Output and Inflation in Japan

a. GDP Growth Rate

b. Inflation Rate

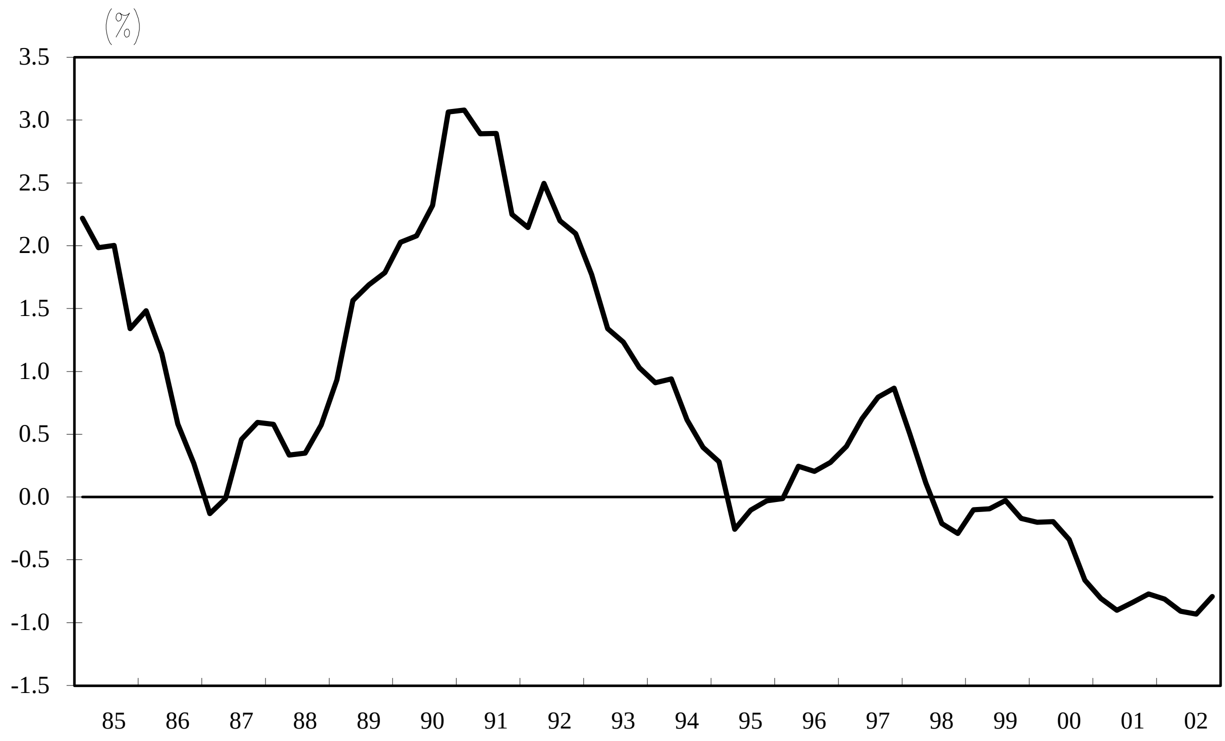


Figure 2. Measures of Output Gap at the Bank of Japan

a. Prototype

b. Conventional

c. Standard

Figure 2.(continued)

d. TV-NAIRU

e. HP filter

f. NAILO

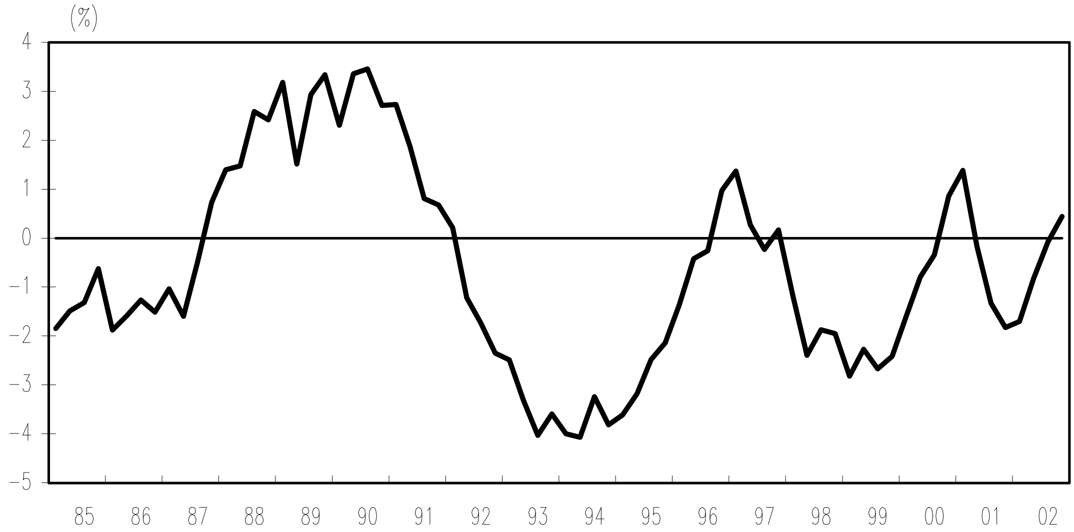
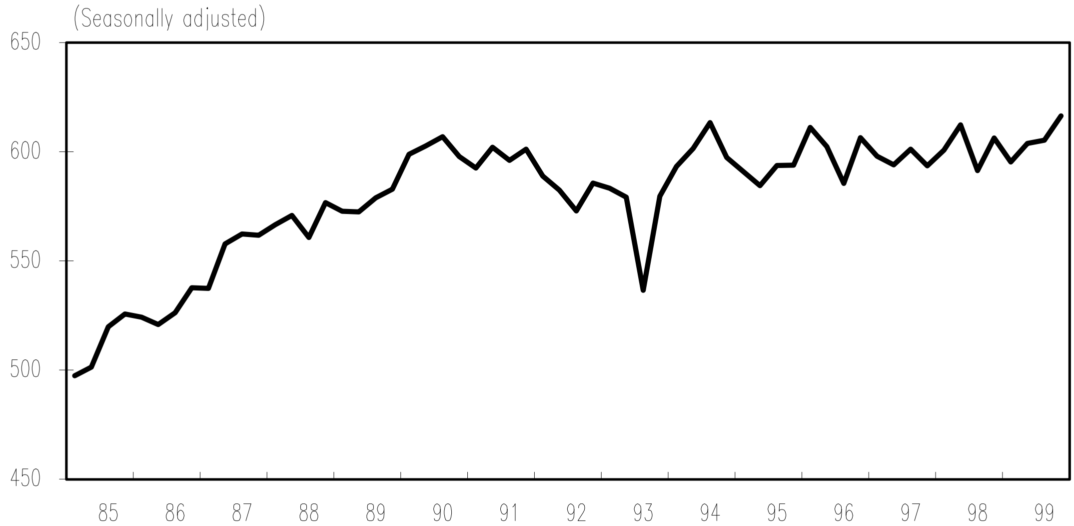


Figure 3. Data for Estimation of Standard Output Gap

a. Capacity Utilization in Non-Manufacturing Sector

b. Electoric Power Units for Commercial Power



c. Production Capacity BSI

Figure 4. Output Gap in Various Stages of Revision (non-GDP types)

a. Prototype

b. Standard

c. TV-NAIRU

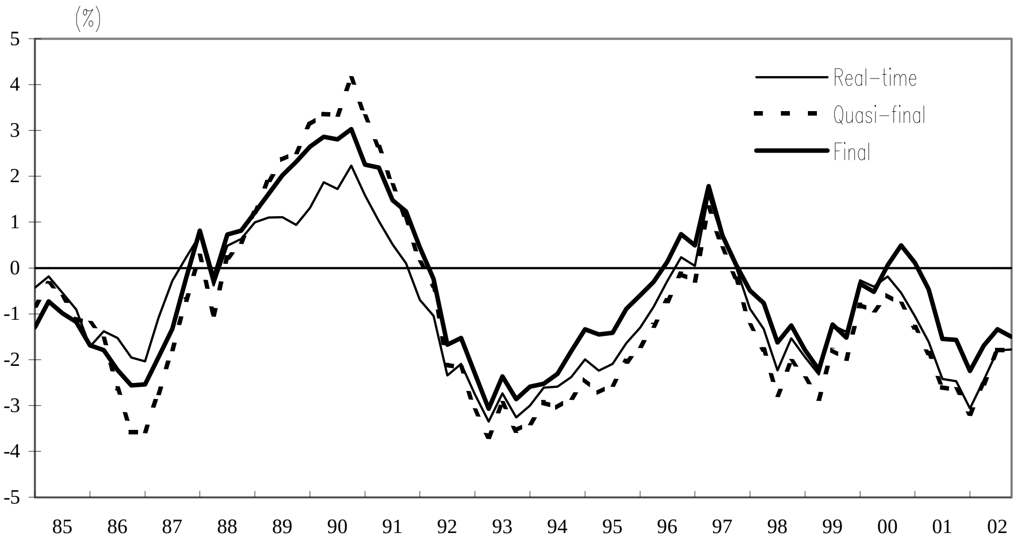
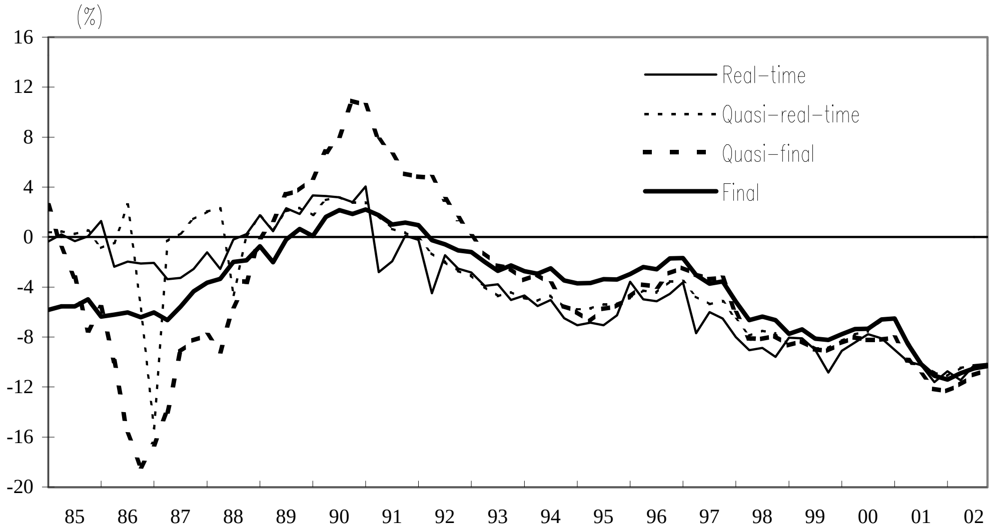


Figure 5. Output Gap in Various Stages of Revision (GDP types)

a. Conventional



b. HP filter

c. NAILO

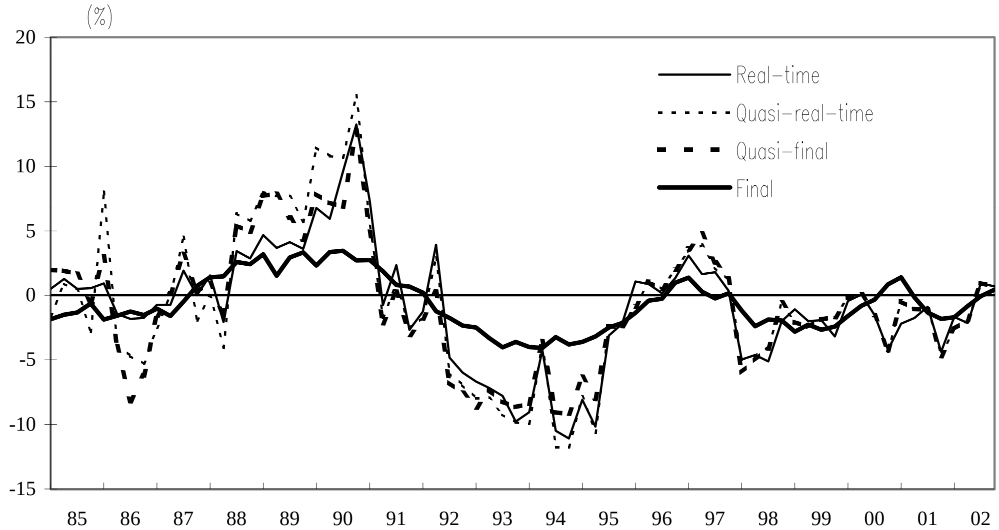
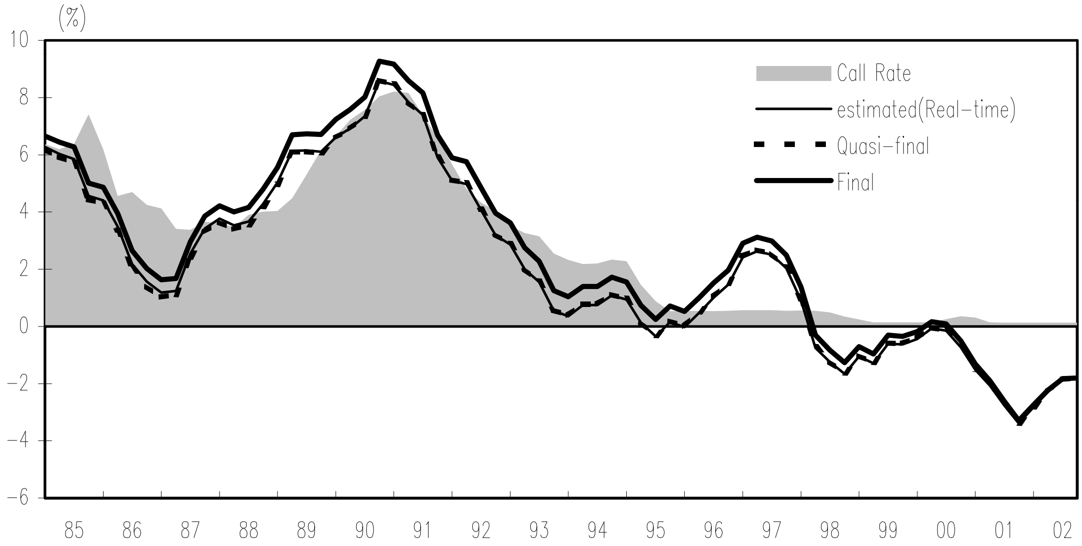
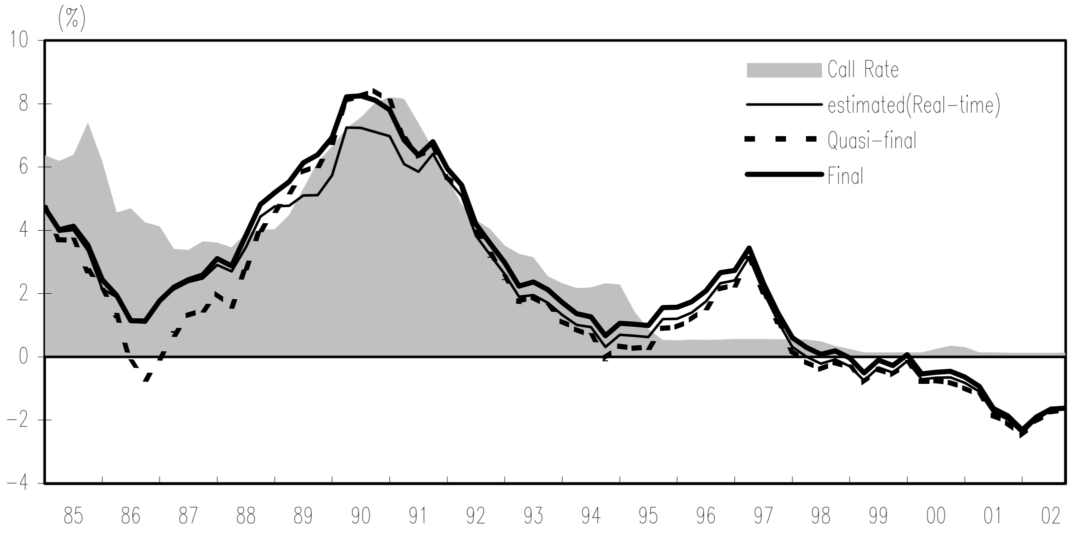


Figure 6. Original Taylor Rule (Non-GDP types)

a. Prototype



b. Standard



c. TV-NAIRU

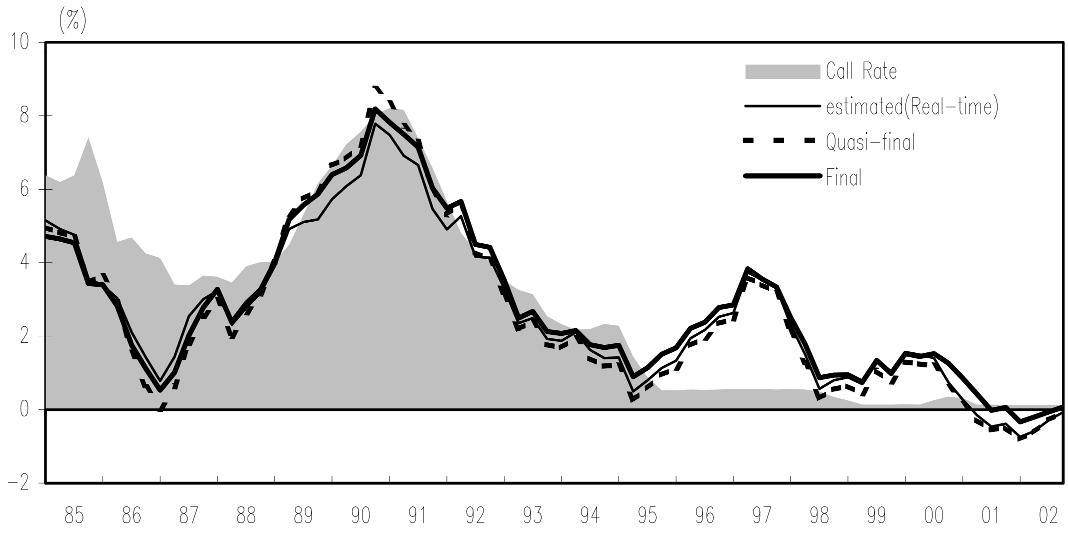
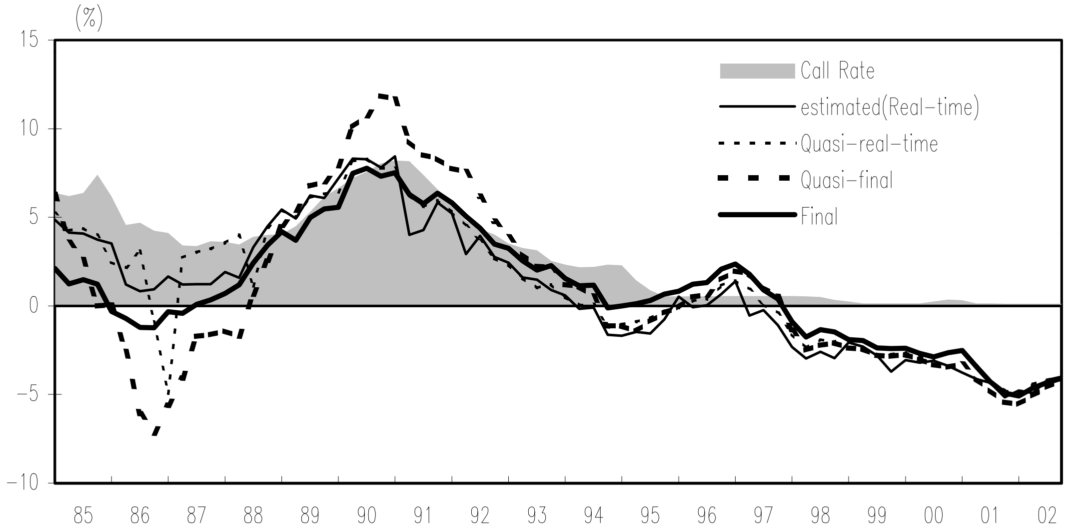
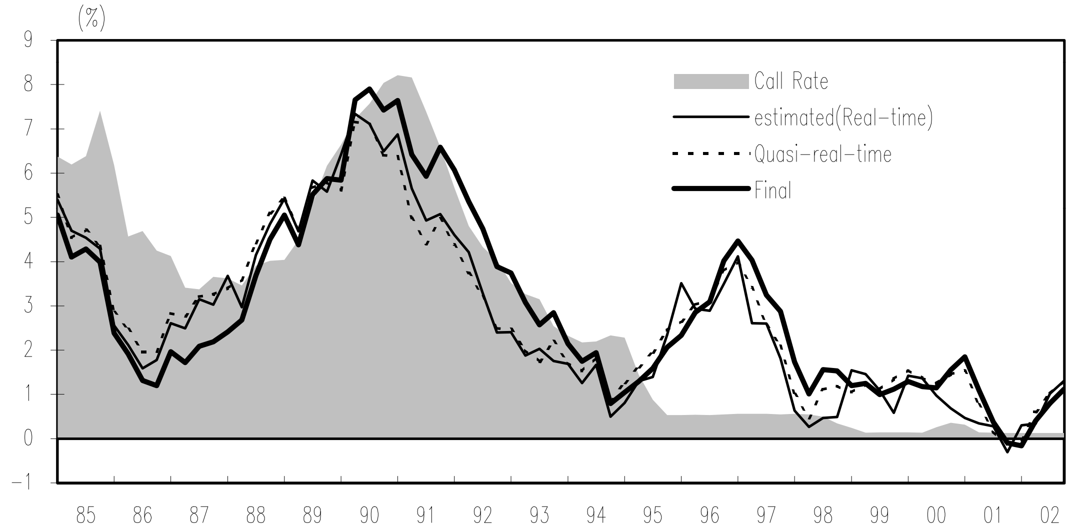


Figure 7. Original Taylor Rule (GDP types)

a. Conventional



b. HP filter



c. NAILO

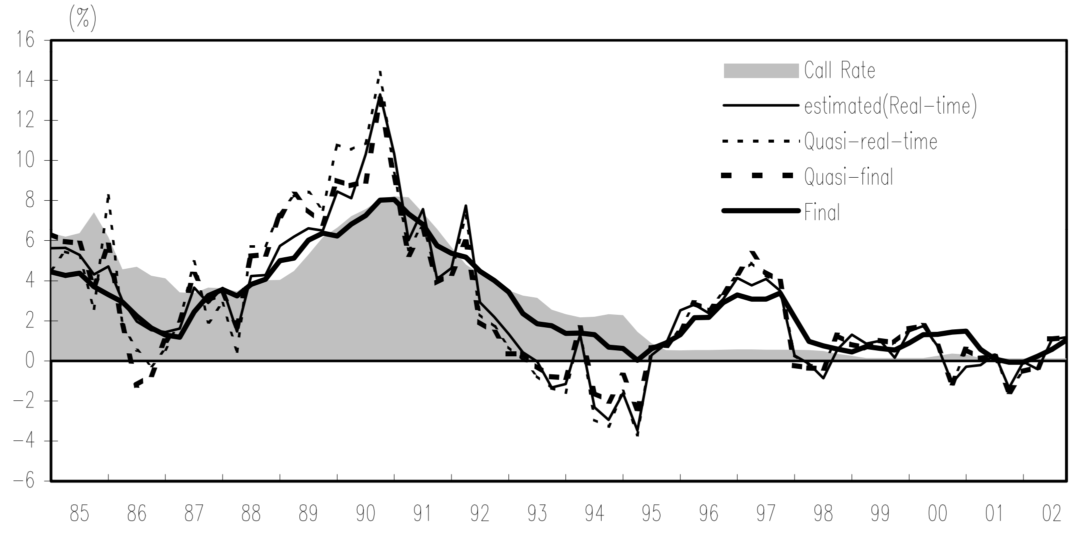
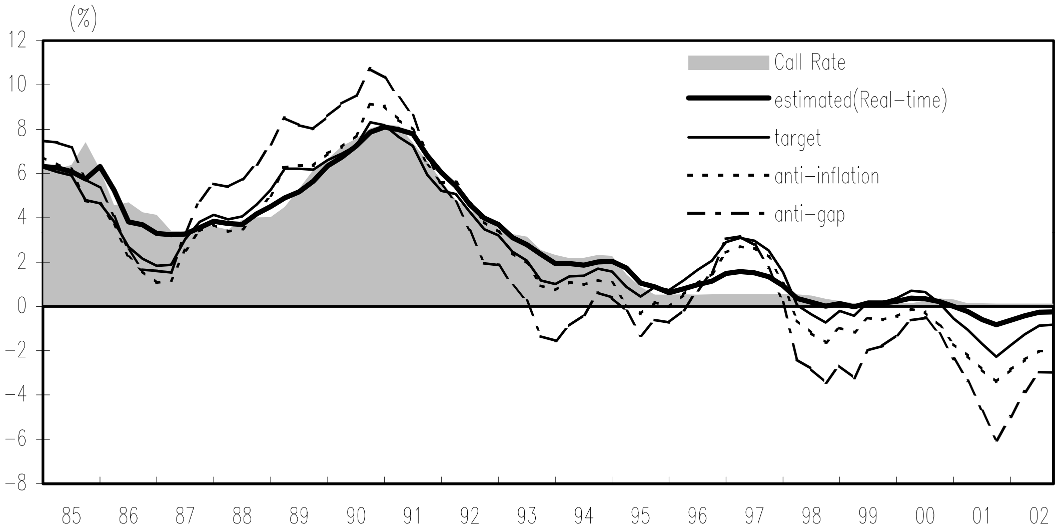
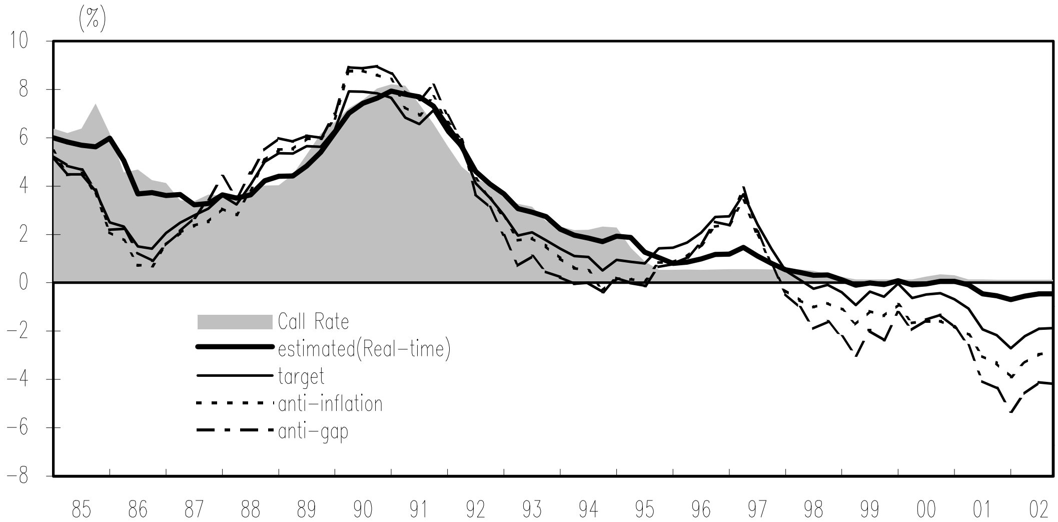


Figure 8. Modified Taylor Rule (Non-GDP types)

a. Prototype



b. Standard

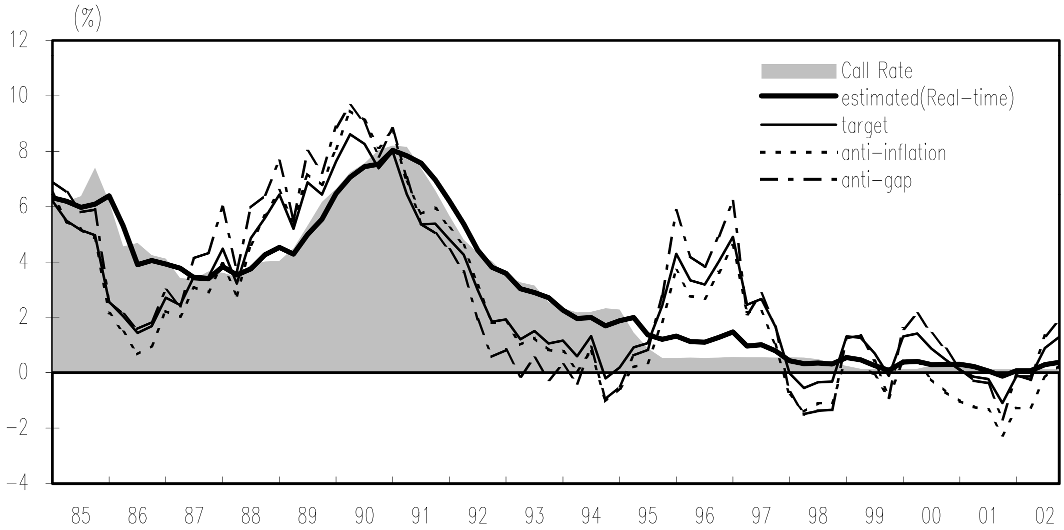


c. TV-NAIRU

Figure 9. Modified Taylor Rule (GDP types)

a. Conventional

b. HP filter



c. NAILO

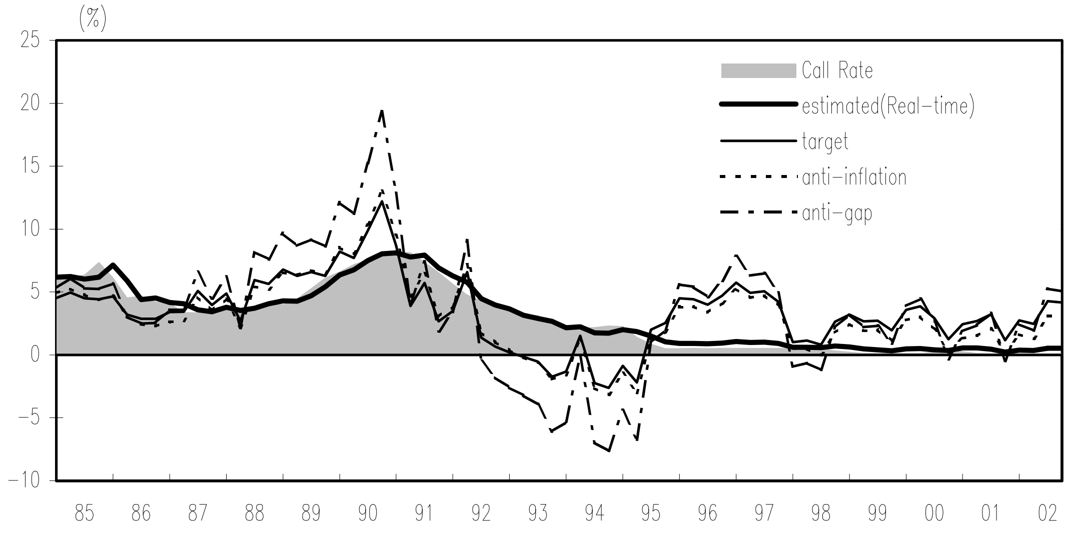


Figure 10. TANKAN – Business Condition D.I.

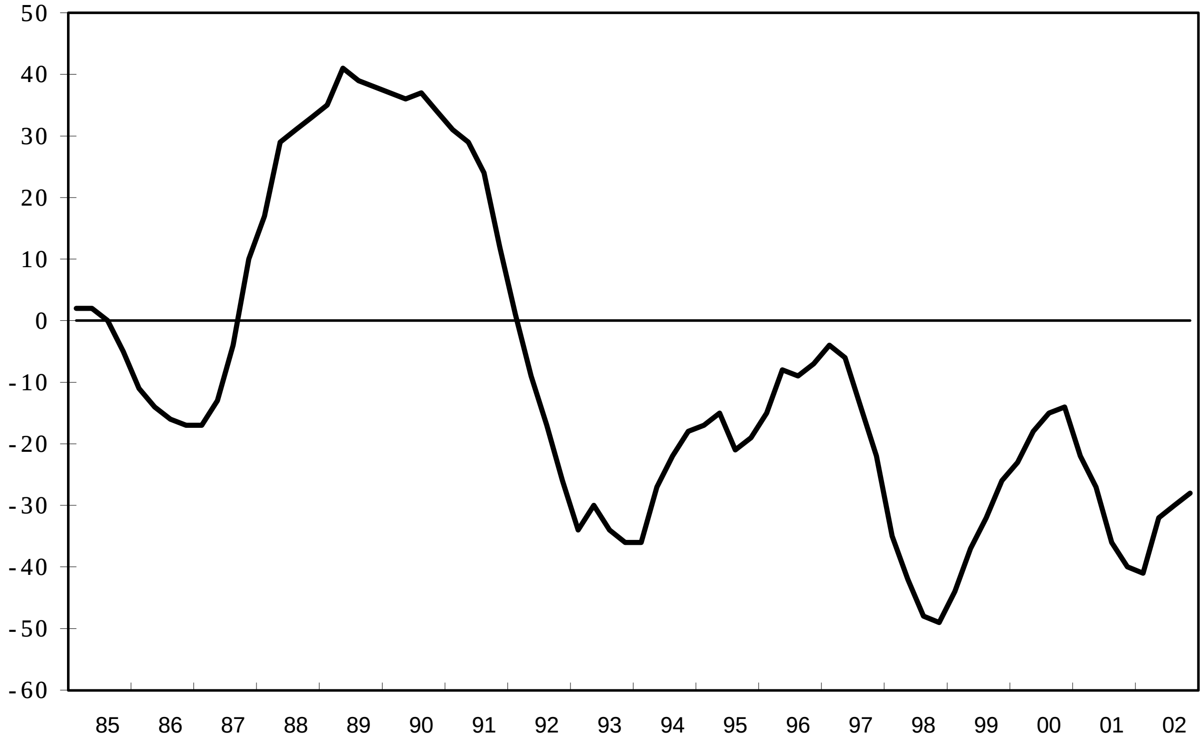


Figure 11. Remedied Real-Time Output Gap (Non-GDP types)

a. Prototype

b. Standard

c. TV−NAIRU

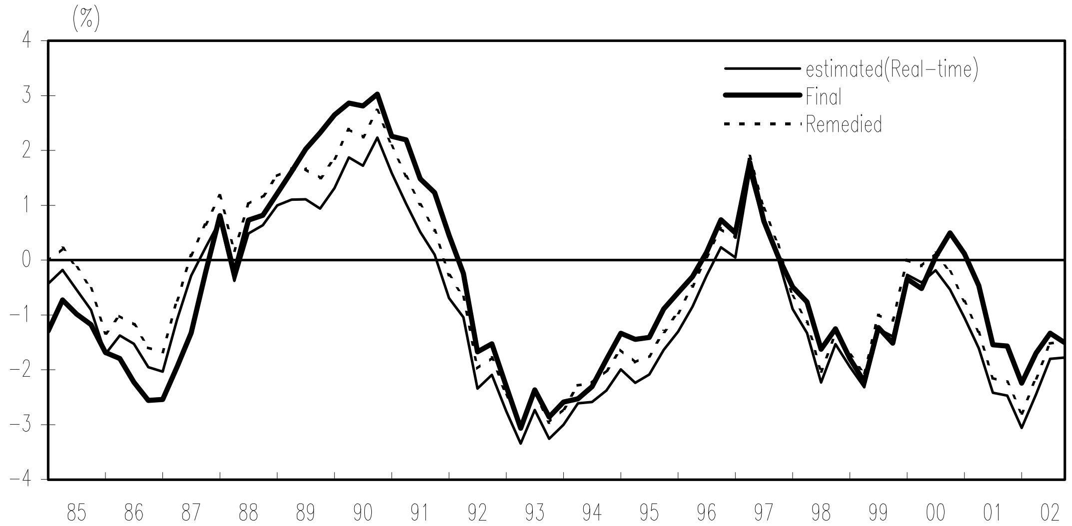


Figure 12. Remedied Real-Time Output Gap (GDP types)

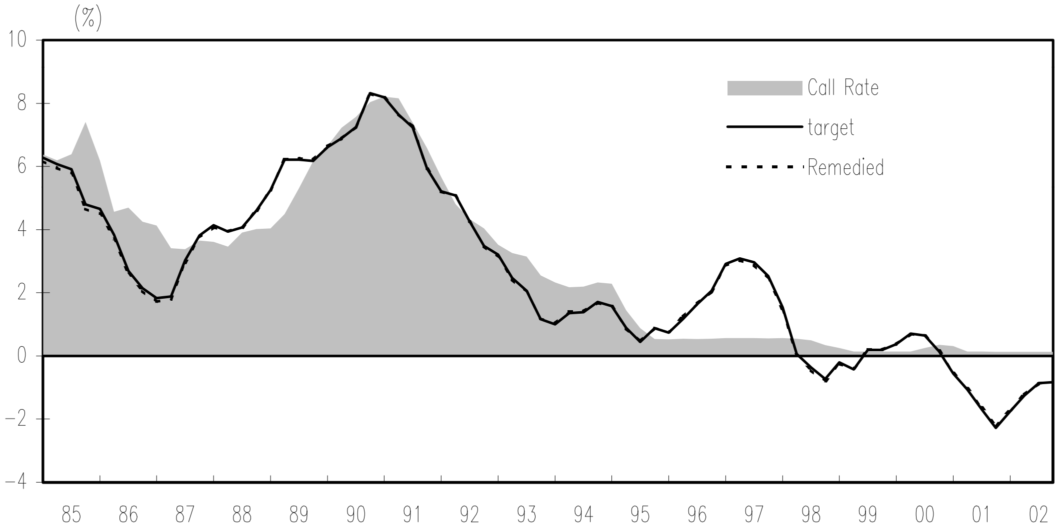
a. Conventional

b. HP filter

c. NAILO

Figure 13. Remedied Taylor Rule (Non-GDP types)

a. Prototype



b. Standard

c. TV−NAIRU

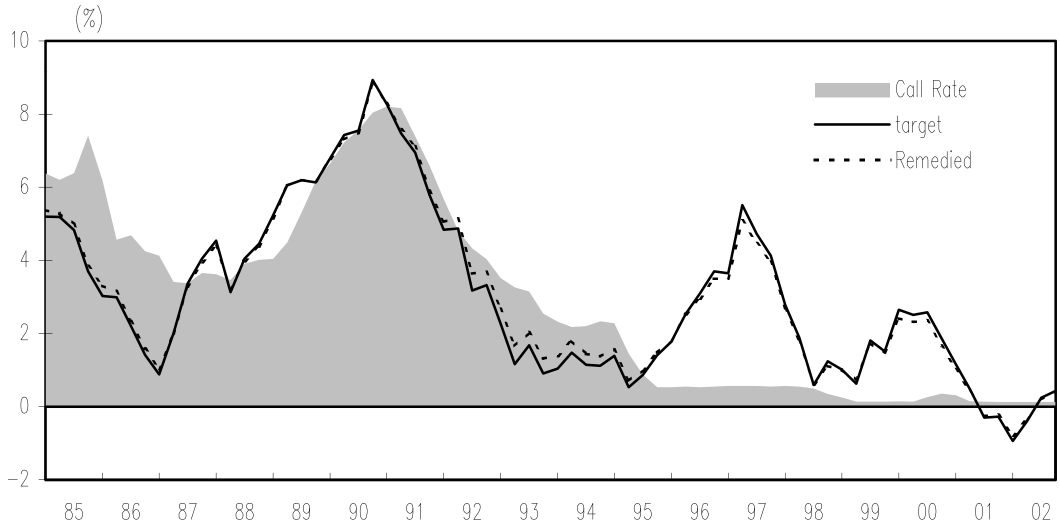
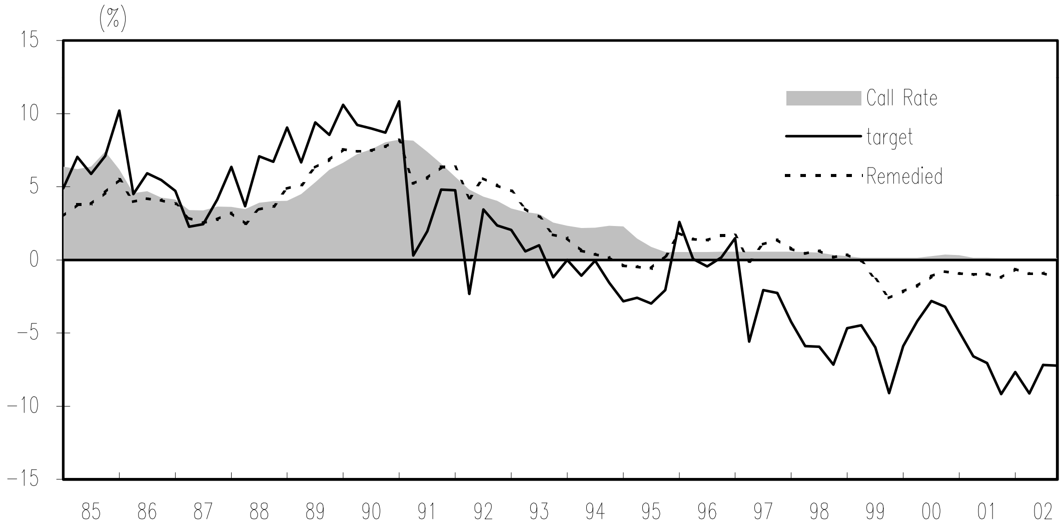
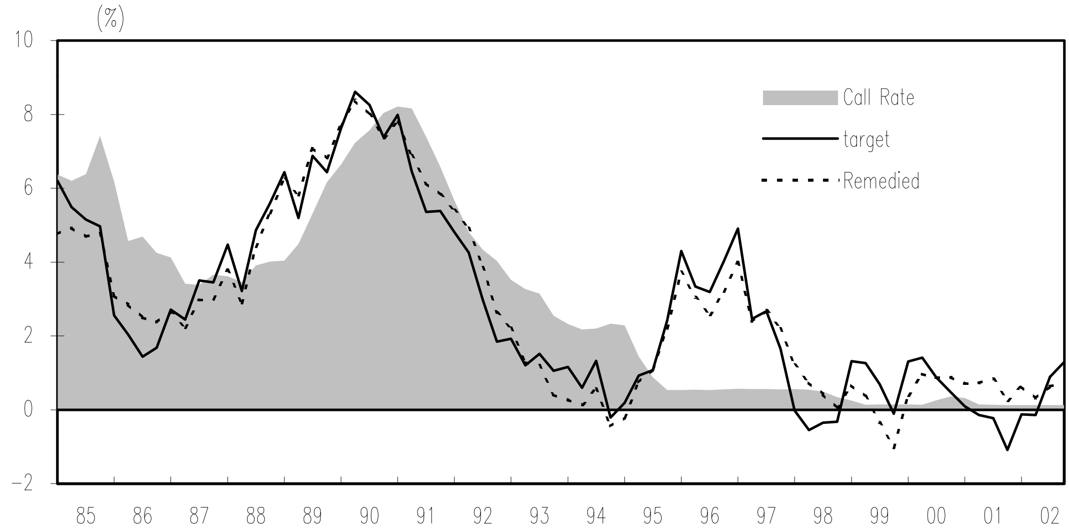


Figure 14. Remedied Taylor Rule (GDP types)

a. Conventional



b. HP filter



c. NAILO