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Abstract

This paper explains the new methodology for calculating Japan's output gap and potential growth rate, both of which are regularly estimated and released by the Research and Statistics Department of the Bank of Japan. We have revised the estimation method given: (1) the retroactive revision of Japan's GDP statistics; (2) the newly available capital stock data which is in line with the new 2008SNA guidelines and adjusted for economic depreciation; and (3) recent structural changes in the factor markets for labor and capital that should be reflected in these estimated trends.

Specifically, we have changed our estimation methodology in the following three ways: first, we have revised the estimation method of the "labor force participation rate gap," so as to reflect the recent sustained increase in the labor force participation rate starting around 2012 as a structural trend; second, we have revised the estimation method of the "hours worked gap," to identify the persistent decline in working hours over recent years as more of a structural development possibly due to changes in people's working styles; and third, we have revised the method for calculating the manufacturing "utilization gap," in order to reflect the economic depreciation of equipment and structures more appropriately.

Taking a look at the revised output gap, we find that the overall picture for most of the recent period remains unchanged. Furthermore, it turns out that the inflation-prediction power of the revised output gap is almost unchanged from the

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previous version. Meanwhile, the resulting potential growth rate shows a significant upward revision for the last few years, mainly reflecting a rise in the TFP growth rate associated with the revision of the GDP statistics. As a result, the potential growth rate in recent years is estimated to be in the range of 0.5-1.0 percent, which is comparable to that of the first half of the 2000s, prior to the global financial crisis.

1. Introduction

The output gap is the economic measure of the difference between total demand as an actual output of an economy and average supply capacity, smoothed out for the business cycle — namely potential GDP —, in the goods and services market of the nation. The potential growth rate is the annual rate of change in potential GDP. In factor markets, the output gap expresses the differential between the labor and capital utilization rates and their average past levels. The potential growth rate is the sum of the average growth of labor input and capital input, and the efficiency with which these factors are used, namely total factor productivity (TFP). The output gap and the potential growth rate are often used by central banks and international institutions to analyze and assess economic and price conditions. The estimation results of both are released quarterly by the Bank of Japan on the Bank's website¹ and current conditions and the outlook are assessed in the *Outlook Report*.

This paper explains the new methodology for calculating Japan's output gap and the potential growth rate, both of which are regularly released by the Research and Statistics Department of the Bank of Japan. We have revised the estimation method given: (1) the retroactive revision of Japan's GDP statistics in December 2016, which incorporates a revision of the benchmark year, as well as implementing the 2008SNA and the regular annual revision;² (2) the newly available capital stock data ("Quarterly Estimates of Net Capital Stocks of Fixed Assets" statistics) which is in line with the new 2008SNA guidelines and adjusted for economic depreciation; and (3) recent structural changes in the factor markets for labor and capital that should be reflected in these estimated trends. Specifically, we have changed our estimation methodology in the following three ways: first, we have revised the estimation method of the "labor force participation rate gap," so as to reflect the recent sustained increase in the labor force participation rate starting around 2012 as a structural trend; second, we have revised the estimation method of the "hours worked gap," to identify the persistent decline in working hours over recent years as more of a structural development possibly due to changes in people's working styles; and third, we have revised the method for calculating the manufacturing "utilization gap," in order to reflect the economic depreciation (obsolescence) of

¹ Analyzed data, *Output Gap and Potential Growth Rate*, are released, in principle, on the third business day in January, April, July, and October.

http://www.boj.or.jp/en/research/research_data/gap/index.htm/

² The GDP statistics were revised from the benchmark year of 2005 (1993SNA) to the benchmark year of 2011 (2008SNA) in the release of the quarterly estimates July-September 2016 (Second Preliminary). For details, see Cabinet Office (2016).

equipment more appropriately.

In section 2, we explain our basic principles in estimating the output gap and the potential growth rate, comparing with those of other institutions. Section 3 provides a detailed explanation of the revision. In section 4, we compare the revised output gap and potential growth rate with those of the previous methodology. Section 5 concludes.

2. Defining the Concept and Basic Principles

This section explains the basic principles behind the estimation method of the output gap as defined by the Research and Statistics Department of the Bank of Japan, and also that of Hara *et al.* (2006). We focus here on the differences in our own estimation and that of other institutions. We then clarify the estimation framework for the output gap which is calculated — in a method unique to the Bank of Japan — directly from the labor and capital utilization rate without using GDP statistics.³

2.1 Basic Concept of Output Gap and Potential Growth Rate

Output gap (gap_t) is defined as the differential between actual GDP (Y_t) and potential GDP (Y_t^*) as follows;

$$gap_t = \frac{Y_t - Y_t^*}{Y_t^*}$$

Rewriting the above as $1 + gap_t = Y_t/Y_t^*$ and taking the logarithm of both sides of the equation provides the following relationship:⁴

$$gap_t = y_t - y_t^* \tag{1}$$

where $x = \ln X$, hereinafter the same.

According to the production function in macroeconomics, GDP is obtained from the interrelations of three variables: (1) labor input (L_t); (2) capital input (K_t); and (3) the efficiency with which these factors are used, namely TFP (A_t). We assume the following relationship for convenience:

³ As will be discussed later on this paper, GDP statistics are not used in the sense that the output gap estimated by the Bank is not the differential of actual GDP and potential GDP. Strictly speaking, however, the labor share (α), which is used for the weighted average of utilization gap of each production factor, is based on GDP statistics.

⁴ Here, use the relationship that $\ln(1 + z) \approx z$ if z is close to zero, to calculate the left-hand side of equation (1).

$$Y_t = A_t L_t^\alpha K_t^{1-\alpha} \quad (2)$$

This is called the "Cobb–Douglas production function," which is the most general formularization of the production function in macroeconomics. Taking the logarithm of both sides of the equation provides the following relationship:

$$y_t = a_t + \alpha l_t + (1 - \alpha)k_t \quad (3)$$

Under the assumption of the Cobb–Douglas production function, it is known that elasticity α of labor input to GDP equals labor share in equilibrium. Therefore, using equation (3), it is easy to calculate the change in a_t , TFP growth or the growth rate of A_t , from the observed change in y_t , l_t , k_t , which is the growth rate of Y_t , L_t , K_t .

The same formularization of production function can be applied to potential GDP, i.e., aggregate average supply capacity obtained by smoothing out the business cycle.

$$Y_t^* = A_t^* L_t^{*\alpha} K_t^{*1-\alpha} \quad (4)$$

Taking the logarithm of both sides of the equation provides the following relationship:

$$y_t^* = a_t^* + \alpha l_t^* + (1 - \alpha)k_t^* \quad (5)$$

Here, a change in equation (5) gives the potential growth rate and then subtracting equation (5) from (3), we obtain:

$$y_t - y_t^* = (a_t - a_t^*) + \alpha(l_t - l_t^*) + (1 - \alpha)(k_t - k_t^*) \quad (6)$$

Combining equations (1) and (6), we arrive at the output gap as follows:

$$gap_t = \alpha(l_t - l_t^*) + (1 - \alpha)(k_t - k_t^*) + \varepsilon_t \quad (7)$$

where $\varepsilon_t \equiv a_t - a_t^*$ is defined as TFP noise including measurement errors. Ignoring the TFP noise, the output gap simply becomes the weighted sum of the labor input gap and the capital input gap.

The output gap and potential GDP can be estimated in two ways. The first method calculates the potential GDP first, and then the output gap is the differential between the potential GDP and actual GDP. Specifically, average inputs of labor (l_t^*), capital (k_t^*), and TFP trend (a_t^*) are estimated from observed data; then potential GDP (y_t^*) is given in equation (5); and finally, the output gap is obtained by subtracting the potential GDP (y_t^*) from actual GDP (y_t). This is a widely-used method which has been adopted by a

number of central banks and international institutions. In terms of Japan's output gap and potential growth rate, the estimation data released by the Japanese Cabinet Office, the IMF, and the OECD are all based on this method (Charts 1 and 11).

The second method calculates the output gap first, using the labor input gap and capital input gap. More specifically, we adopt a procedure in which we start with an estimation of the labor input gap ($l_t - l_t^*$) and the capital input gap ($k_t - k_t^*$) from observed data relating to production factors; we then calculate the output gap by taking the average of these two gaps weighted by labor share α ; and finally we obtain the potential growth rate (year-on-year change in y_t^*) by computing the weighted average of average labor and capital input growth rate (year-on-year change in l_t^* , k_t^*), and the TFP trend growth rate (year-on-year change in a_t^*) which is estimated separately,⁵ according to equation (5). This method is the one adopted by the Research and Statistics Department of the Bank of Japan.

The significant point of the difference between the first and second method is that in the second, we use utilization of production factor data instead of GDP statistics (note that GDP statistics are not used until the potential GDP is estimated). Generally speaking, the following two points should be considered in relation to GDP statistics: (1) GDP statistics are released later than statistics relating to utilization of labor and capital;⁶ and (2) GDP statistics contain measurement errors and thus are frequently and drastically revised retroactively in the regular annual revision of the Quarterly Estimates (QE) and the revision of the benchmark year.⁷ Based on these two points, the Research and Statistics Department of the Bank of Japan has adopted the approach which estimates the output gap directly using data relating to utilization of production factors in order to grasp the pressure on price change precisely and in real time. Using this method it is not necessary to wait until the release of the GDP statistics⁸ and the estimation of the output gap is not affected by any retroactive revision of the GDP

⁵ The Bank defines the estimation methodology of the TFP trend growth rate (changes from the previous year of a_t^*) as follows: first, calculate year-on-year growth rate of the actual TFP (changes from the previous year of a_t) on a quarterly basis using equation (3), and then apply HP filter ($\lambda = 1600$) to the growth rate of actual TFP.

⁶ The first and the second preliminary of the Quarterly Estimates of GDP (QE) are released about one and a half months and two and a half months after the end of the quarter, respectively. However, most data relating to usage of capital and labor such as the unemployment rate are released by one month after the quarter ends.

⁷ For the international comparison on the revision of the GDP statistics, see Zwijnenburg (2015).

⁸ Furthermore, it is possible to nowcast the output gap for a certain quarter, even at any point during the quarter, with monthly indices relating to production factors.

statistics (the influence of GDP retroactive revision appears in TFP change exclusively and only the potential growth rate is revised⁹). In this paper, this basic approach remains unchanged.

2.2 Labor Input Gap and Capital Input Gap

In the following section, we describe the measurement method of the labor input gap and the capital input gap adopted by the Research and Statistics Department of the Bank of Japan.

Labor Input Gap

Labor input (man-hours), which is given by multiplying the 'number of workers' by 'total working hours per worker,' can be decomposed as follows:¹⁰

Labor input

= Number of workers × Total working hours per worker

$$= \text{Population aged 15 or over} \times \frac{\text{Labor force}}{\text{Population aged 15 or over}} \times \frac{\text{Number of workers}}{\text{Labor force}} \times \text{Total working hours per worker}$$

$$= \text{Population aged 15 or over} \times \text{Labor force participation rate} \times \text{Employment rate} \times \text{Total working hours per worker}$$

As shown in the above equation, labor input (L_t) is described as the multiplication of (1) population aged 15 or over (F_t); (2) labor force participation rate (P_t); (3) employment rate (E_t); and (4) total working hours per worker (H_t).

$$L_t = F_t P_t E_t H_t \quad (8)$$

The same relationship holds in potential labor input (L_t^*), which smooths out the business cycle. Notice that the population aged 15 or over does not vary in accordance with the business cycle.

⁹ The degree of revision of GDP growth rate itself is not equal to that of the potential growth rate as potential growth rate is calculated using trend value, which has smoothed out the actual TFP growth rate instead of the rate itself, as mentioned above.

¹⁰ Employment rate here is defined as number of workers divided by labor force, i.e., 1 – unemployment rate. On the other hand, the rate in Labour Force Survey conducted by Ministry of Internal Affairs and Communications is defined as number of workers divided by the population aged 15 or over.

$$L_t^* = F_t P_t^* E_t^* H_t^* \quad (9)$$

Taking the logarithm of both sides of equations (8) and (9), and the difference between them, we obtain:

$$l_t - l_t^* = (p_t - p_t^*) + (e_t - e_t^*) + (h_t - h_t^*) \quad (10)$$

As shown in the above equation, labor input gap ($l_t - l_t^*$) is calculated as the sum of labor force input gap ($p_t - p_t^*$), employment rate gap ($e_t - e_t^*$) and hours worked gap ($h_t - h_t^*$).

Capital Input Gap

Capital input (K_t) is calculated by multiplying the actual capital stock (\bar{K}_t) by the utilization rate (U_t).

$$K_t = U_t \bar{K}_t \quad (11)$$

In the same way, potential capital input (K_t^*) is equal to the multiplication of actual capital stock (\bar{K}_t) and average utilization rate (U_t^*).

$$K_t^* = U_t^* \bar{K}_t \quad (12)$$

Taking the logarithm of both sides of equation (11) and (12), and taking the difference between them, we obtain:

$$k_t - k_t^* = u_t - u_t^* \quad (13)$$

As shown in the above equation, the capital input gap ($k_t - k_t^*$) is none other than the differential between actual utilization rate and average utilization rate, namely the utilization gap ($u_t - u_t^*$).

The aggregate capital input gap can be written as follows:

$$u_t - u_t^* = \beta_M (u_t^M - u_t^{M*}) + \beta_N (u_t^N - u_t^{N*}) \quad (14)$$

Here, $u_t^M - u_t^{M*}$ and $u_t^N - u_t^{N*}$ are the utilization gap in manufacturing and nonmanufacturing, respectively, and β_M , β_N denote the weights of tangible fixed assets in manufacturing and nonmanufacturing industries in capital stock.

Because of the difficulty in estimating them, we assume that the utilization rate of intangible fixed assets, accumulation of research and development (R&D) investment and software investment do not vary in accordance with the business cycle and are

constant; in other words the utilization gap of intangible fixed assets is zero at any time.

3. Key Points of this Revision

As mentioned above, the Research and Statistics Department of the Bank of Japan calculates the output gap directly from the labor and capital utilization rate. In this revision, the following three items were revised: (1) the labor force participation rate gap; (2) the hours worked gap; and (3) the utilization gap in manufacturing. The estimation methods for the employment rate gap and the utilization gap in nonmanufacturing were not revised in essence.¹¹ The details of the recent revision are as follows (Chart 2).

3.1 Revision of the Labor Force Participation Rate Gap

Looking at the developments of the labor force participation rate over the relatively long-term, there are kinks in the trend due partly to demographical effects including population aging and changes in people's life and work styles; typically, these changes in the trend occur at the same time as when the business cycle changes. For example, since the end of 2012 and in the wake of the economic recovery, the labor force participation rate has clearly increased, reflecting the increasing number of (1) dual-income households and (2) elderly continuing to work on in their old age.

Until now, the trend of the labor force participation rate had been estimated as a variable trend using (1) Hodrick-Prescott (HP) filter by gender and age group and then (2) averaging by the population in each group as weights (Chart 3). However, doing so meant that, in order to identify kinks such as that observed around 2012 as turning points in the trend, it was necessary to wait until a considerable amount of time-series data became available. It would be misleading if these upward movements were not identified as a trend and the labor force participation rate gap were instead estimated as a remarkably positive value because the rise in the labor force participation rate after 2012 would be identified as a cyclical increase.

For this reason the approach was revised and, following the methodology of the Congressional Budget Office of the United States (CBO, 2001), a piecewise linear regression, which allows for sharp kinks in the trend in each peak of the business cycle, was adopted.¹² Specifically, we have conducted a regression analysis on labor force

¹¹ For the details of estimation methods for the employment rate gap and the utilization gap in nonmanufacturing, see Annex 1.

¹² In this method, troughs of the business cycle are not considered as breakpoints and thus there are

participation rate by gender and age segments (15-year intervals) on a linear trend which allows kinks at the peak of the Reference Dates of Business Cycle (RDBC) (Chart 4).¹³

$$P_t^i = \alpha_0^i + \alpha_1^i T_{1980.1Q} + \alpha_2^i T_{1985.2Q} + \alpha_3^i T_{1991.1Q} + \alpha_4^i T_{1997.2Q} + \alpha_5^i T_{2000.4Q} \\ + \alpha_6^i T_{2008.1Q} + \alpha_7^i T_{2012.1Q} + \varepsilon_t^i$$

where P_t^i is the labor force participation rate and i denotes group. Note that T_c equals zero until time c , which is the peak of the business cycle, and is a linear time trend after time c . The potential labor force participation rate is calculated by taking the average of the trend of labor force participation rate by gender and age segments derived from this regression equation, weighted by each group population.

In contrast to the previous method, this piecewise linear trend makes it possible to identify structural changes as turning points in a trend in a more timely manner.¹⁴ For example, the increase in the labor force participation rate in recent years can be identified as a 'structural increase' due to the allowance of kinks in the trend at the peak of RDBC from 2012/Q1, without waiting until a considerable amount of data has been compiled as would be the case with the previous method (Chart 5).

Note that the piecewise linear trend has the following issues: (1) as trend kinks cannot be recognized without going through 1-cycle of RDBC (economic expansion and recession), the recognition of possible structural changes in labor force participation rate during the cycle can be somewhat delayed; and (2) some time lag may be needed between recognizing a peak in the business cycle and reflecting the peak with regard to the trend in the labor force participation rate. Regarding the latter issue, it is possible to shorten the time lag by setting the trend kinks provisionally according to the same timing that the Indexes of Business Conditions shows a phase change without waiting for the official announcement of RDBC by the Cabinet Office.¹⁵

no kinks in 1-business cycle from one peak to the next peak. In other words, phase of recessions has the same trend with that of economic recovery in certain business cycles. Note that although this method allows kinks in the trend for peaks in business cycle, the trend does not always have to have a kink at a peak if the changes in the trend are not estimated statistically significant. For example, estimated trends from 1991/Q1, which is the peak of the business cycle, do not change from the earlier ones.

¹³ In practice, the model is re-estimated when data are revised for a quarter.

¹⁴ For the theoretical differences between HP filtering trend and piecewise linear trend, see Annex 2.

¹⁵ For example, the peak of the business cycle in RDBC was announced in the following way: (1) 2012/Q2 was provisionally settled in August 2013; and following this (2) 2012/Q1 settled in July 2015. However, the Indexes of Business Conditions shows a 'phase change,' which implies "there

3.2 Revision of the Hours Worked Gap

In the previous method prior to this revision, the measurement of trends in hours worked per worker took into account: (1) working time regulations which were in effect from the end of 80s to early 90s, such as the introduction of the five-day working week; and (2) population aging as a factor exerting downward pressure on the trends.¹⁶ However, the structural decline in working hours over recent years has not been sufficiently captured by this method, and this led to a relatively large negative gap in hours worked (Chart 6). The total working hours per worker in recent years has continued to decline gradually, due to an increase of married women and elderly in working shorter hours and the redressing of long working hours through work-style reforms, albeit with economic recovery. Therefore, as part of this revision, in order to capture the decline in actual working hours over the past few years as a structural rather than a cyclical decline, we have modified the method used to derive trends in hours worked. Specifically, we decided to calculate potential hours worked by taking an average of the variable trends, extracted in total working hours of full-time and part-time workers respectively by HP filter, weighted by the ratio of part-time workers (Chart 7).¹⁷ Unlike the labor force participation rate, however, it is acceptable to allow gradual trend changes derived by HP filter because no kinks in the trend are observed.

Although the hours worked gap is slightly negative at present, this revision has reduced the negative value following the global financial crisis when compared to the previous method. Even if new data are added in the future, the downward trend in potential hours worked would continue with the structural decline in total working

was a peak in the business cycle during the last few months," in September 2012 preliminary results released in November 2012; in these cases, it is possible to set the turning point at 2012/Q2 provisionally without waiting for the official announcement of RDBC.

¹⁶ Specifically, a declining linear trend was adopted for scheduled working hours of full-time workers until the end of the 1990s when working hours had been reduced due to revisions of the working time regulations in accordance with amendments to the Labor Standards Act, and after that the trend remained flat. The trends in scheduled working hours of part-time workers were derived using the results of the regression by linear trend and ratio of population aged 55 or over (trends in overtime working hours of both full- and part-time workers are flat as long-term average). Aggregate potential hours worked was calculated by taking the average of potential hours worked of full- and part-time workers respectively derived from this calculation weighted by the ratio of part-time workers.

¹⁷ The total hours worked is calculated by adding up scheduled and overtime working hours of full- and part-time workers which are seasonally adjusted respectively. Note that in the case of scheduled working hours, irregular spikes are eliminated from the original series, namely the trend-cycle (TC) component for X-12-ARIMA. The data is extrapolated with the year-on-year rate change in scheduled and overtime working hours separately before 1992 when the working hours of full- and part-time workers were not released.

hours per worker due to the development of ongoing work reforms.

3.3 Revision of the Utilization Gap in Manufacturing

In order to estimate the utilization gap in manufacturing, the Research and Statistics Department of the Bank of Japan previously used the operating ratio index, which was defined as the production index divided by the production capacity index. While the production capacity index reflects the disposal of physical equipment such as the retirement of equipment, the economic depreciation (obsolescence) of technology is hardly taken into consideration.¹⁸ It has been pointed out that if this was taken into account, potential production capacity in manufacturing would be assessed as lower, and thus the utilization rate would be higher (Chart 8).

While until now, the Research and Statistics Department of the Bank of Japan has partly adjusted the downward trend of the operating ratio by using the capacity utilization DI in the *Tankan*,¹⁹ the estimation method of utilization rate in manufacturing has changed reflecting the newly available depreciation-adjusted capital stock data ("Quarterly Estimates of Net Capital Stocks of Fixed Assets" statistics).²⁰ Specifically, by referring to the utilization rate estimation method developed and published by the Federal Reserve (Gilbert, Morin, and Raddock, 2000), the trend-adjusted capacity is defined as the fitted value of the following regression excluding the time trend; the dependent variable is the production capacity index (Cap_t), and the independent variables are the tangible fixed capital of manufacturing, which is estimated based on the "Quarterly Estimates of Net Capital Stocks of Fixed Assets" statistics at the end of previous time period (\bar{K}_{t-1}^M),²¹ and the time trend.²²

¹⁸ When production machinery are shut down due to scheduled maintenance or malfunction, it must be reported as a decline in production capacity.

¹⁹ Regarding the capacity utilization DI in the *Tankan*, economic obsolescence seems to be taken into account because the DI is based on the firms' subjective judgment for capacity deficiency. Until the revision, the downward trend of operating ratio could be somewhat adjusted using this DI as a proxy.

²⁰ The Cabinet Office conducted the survey "Private Investment and Retirement of Fixed Assets," which examines the acquisition/sale/abandonment of new/used capital, and years of use of capital since mid-2000s. The Cabinet Office started to release real capital stock on a quarterly basis, namely "Quarterly Estimates of Net Capital Stocks of Fixed Assets" which takes into account the changes in economic value after 1994 until the most recent in addition to the estimation of economic depreciation of each type of machinery based on average used years and resale prices.

²¹ The "Quarterly Estimates of Net Capital Stocks of Fixed Assets" statistics do not provide the subdivided stock series such as by industries or type of capital. Therefore, using the "Net Capital Stocks of Fixed Assets classified by Institutional Sectors and Economic Activities" in the annual estimates of GDP statistics, the tangible fixed capital of manufacturing is obtained from the fixed capital of private non-residential investment. It should be noted that, as the "Quarterly Estimates of

$$\ln(Cap_t) = \beta_0 + \beta_1 \ln(\bar{K}_{t-1}^M) + \beta_2 Trend + \varepsilon_t$$

Finally, the downward-trend-adjusted utilization rate in manufacturing is calculated by dividing actual production index by the trend-adjusted capacity index, and the % deviation from its long-run average (constant) is defined as the utilization gap in manufacturing.

Taking a look at the revised utilization gap in manufacturing, these changes result in an upward revision of the gap, mainly for the period after the global financial crisis (Chart 9). It is assumed that the level of tangible fixed capital of the manufacturing declines rather than that of production capacity index, as capital obsolesces more quickly mainly due to IT-related developments and emerging economies catching up.

4. Difference between the Output Gap and the Potential Growth Rate Before and After the Revision

In this section, we compare the estimates of the output gap and the potential growth rate before and after the revision.

4.1 Difference between the Output Gap Before and After the Revision

Taking a look at the revised output gap, we find that there are no significant changes in the graph and the timing of peaks and troughs also remain roughly unchanged, compared to the previous method (Chart 10). Looking in more detail, for the first half of the 2000s, these changes result in a slight downward revision of the output gap, while for the period following the global financial crisis they result in a slight upward revision. However, the upward revision for the last two years or so is relatively small, due to the fact that the upward revision of both capital input and hours worked gap is offset by the downward revision of the labor force participation rate gap.

Next, comparing the revised output gap with those of other institutions, while they

Net Capital Stocks of Fixed Assets" is available only after 1994, data up to 1994 are extrapolated by using the JIP database, which had been used until the revision.

²² With the advances in information and communications technology, the pace of obsolescence of capital has increased year by year. As a result, the production capacity has deviated upward comparing to the capital stock. The time trend captures this upward trend in the production capacity. Therefore, the trend-adjusted capacity index is defined as follows: $\beta_0 + \beta_1 \ln(\bar{K}_{t-1}^M)$. In practice, production capacity in use is obtained by dividing the production index by the operating ratio index instead of the Index of Production Capacity released by the Ministry of Economy, Trade and Industry, directly.

are quite similar in the long-term, some differences can be observed for specific periods (Chart 11). This indicates that there are discrepancies in the measurement of the output gap that reflect differences in the data used and the estimation method; in this sense, these discrepancies demonstrate the uncertainty in estimating the output gap.

Finally, comparing the relationship between the output gap and the CPI (all items less fresh food and energy) before and after this revision (Chart 12), there are no big changes as a whole in the Phillips curve, derived as a simple linear regression of both variables, while there are slight differences in the curve depending on the period. In order to assess how the performance of the Phillips curve has changed by the revision of the output gap more precisely, we estimate a 'hybrid Phillips curve' including forward looking and adaptive inflation expectations in addition to the output gap before and after revision as independent variables. The estimation results suggest that: (1) the standard error of new estimates is similar to that of the old one at the year-on-year rate change of around 0.3%; and (2) the error derived from the dynamic prediction for one-year ahead within in-sample data is also almost unchanged before and after the revision (Chart 13).

4.2 Difference between the Potential Growth Rate Before and After the Revision

Looking at the revised potential growth rate shows that, immediately after the global financial crisis, it dropped temporarily to about 0 percent, due mainly to the drop in capital input (Chart 14). However, it subsequently improved, mainly due to the increase in capital stock including research and development (R&D) as the economy recovered,²³ as well as the increase in the number of potential workers, particularly among women and the elderly. As a result, the potential growth rate in recent years is estimated to be in the range of 0.5-1.0 percent, which is more or less comparable to that of the first half of the 2000s, prior to the global financial crisis.²⁴

Comparing the potential growth rates before and after this revision shows that, while in the period after the global financial crisis the changes result in a downward revision

²³ Following the comprehensive revision of the GDP statistics, the real year-on-year growth rates of GDP in Japan in recent years have been revised upward due mainly to private non-residential investment. This upward revision in private non-residential investment leads to the increase in capital stocks.

²⁴ While decline in the growth rate in the medium to long-term observed in many advanced economies after the financial crisis is called "secular stagnation," according to the estimation results, such secular stagnation does not seem to be observed in Japan before and after the crisis. However, it could be said that since the late 1990s as a result of facing the zero lower bound on interest rates and a decrease in the working-age population ahead of other advanced economies Japan has suffered low growth and low inflation, and consequently Japan's economy has been mired in stagnation.

of the potential growth rate mainly due to the downward revision of both capital and labor inputs, the changes also result in a rather large upward revision over recent years, reflecting a rise in the TFP growth rate associated with the comprehensive revision to the GDP statistics²⁵ (Chart 15) and a rise in the capital stock growth rate as well as the recent rise in the labor force participation rate recast as more of a structural development.

5. Conclusion

This paper explains the new methodology for calculating Japan's output gap and potential growth rate, which are released regularly by the Research and Statistics Department of the Bank of Japan. We have revised our estimation method given: (1) the retroactive revision of Japan's GDP statistics; (2) the newly available capital stock data in line with the new 2008SNA guidelines and adjusted for economic depreciation; and (3) recent structural changes of the factor markets for labor and capital that should be reflected in these estimated trends.

Specifically, we have changed our estimation methodology in the following three ways: first, we have revised the estimation method of the labor force participation rate gap, so as to reflect the sustained increase in the labor force participation rate since around 2012 as a structural trend; second, we have revised the estimation method of the hours worked gap in order to identify the persistent decline in working hours over recent years as more of a structural development, possibly due to changes in people's working styles; and third, we have revised the method for calculating the manufacturing utilization gap in order to reflect the economic depreciation of equipment more appropriately.

This revision reflects the structural change of the labor market, which has become clear in the last few years and which affects the labor input gap and the fast pace of capital stock obsolescence, which affects the capital input gap; however, taking a look at the revised output gap, we found the overall picture for the most recent period remains unchanged. Furthermore, the inflation-prediction power of the new output gap remains almost unchanged from the previous one.

Meanwhile, the revised potential growth rate showed a subsequent improvement, mainly due to the increase in capital stock including research and development (R&D)

²⁵ Box 2 of the April 2017 issue of the Bank's *Outlook Report* analyses developments in Japan's TFP in recent years by industries.

as the economy recovered, as well as an increase in the number of potential workers, particularly among women and the elderly. The potential growth rate showed a significant upward revision for the last few years, mainly reflecting a rise in the TFP growth rate associated with the comprehensive revision of the GDP statistics. As a result the potential growth rate in recent years, which was in the range of 0-0.5 before the revision, is now estimated to be in the range of 0.5-1.0 percent, which is comparable to that of the first half of the 2000s, prior to the global financial crisis.

Annex 1: Employment Rate Gap and Utilization Gap in Nonmanufacturing

The estimation methods for the employment rate gap and the utilization gap in nonmanufacturing are not revised in essence. However, we have put in place some minor revisions, diverging from the method described in Hara *et al.* (2006), including a change in the statistics used. The following is a detailed explanation of the current estimation methods of these gaps.

A.1.1 Employment Rate Gap (Annex Chart 1)

As the employment rate is equal to $1 - \text{unemployment rate}$, trend employment rate is defined as $1 - \text{trend unemployment rate}$.²⁶

The trend unemployment rate is estimated from the unemployment-vacancy (UV) analysis, the method for identifying the structural and cyclical parts of the unemployment rate based on the relationship of unemployment and vacancy. In this analysis, under the assumption that labor demand and supply balances when the unemployment rate is equal to the vacancy rate, the structural unemployment rate is defined as the level of the unemployment rate at which, based on the empirical relationship, the number of unemployed would equal the number of vacancies.²⁷ In practice, the analysis subdivides by age group and merges them into the structural unemployment rate using the number of labor force as weight.²⁸

A.1.2 Utilization Gap in Nonmanufacturing (Annex Chart 2)

The capacity utilization DI ²⁹ in the *Tankan* is used to estimate the utilization in

²⁶ Labor demand declines and unemployment emerges during economic downturns, but this is not the only cause of unemployment. For example, unemployment emerges from a mismatch when there is a noticeable difference between the conditions offered by employers and those desired by job seekers. Moreover, because actual hiring and job-seeking activities take some time, there are always some individuals who remain unemployed while they are in transition from one job to another (frictional unemployment). Such mismatch and frictional unemployment may be considered as structural unemployment in the sense that it remains even when economic conditions improve.

²⁷ The analysis is based on the empirical relationship between the unemployment rate and vacancy rate in 1990-93 when the negative correlations of these rates were relatively clear. Specifically, structural unemployment is defined as the unemployment rate at the intersection of the following two slopes; the first, a straight line from each plot point with the slope derived from the empirical relationship mentioned above; and the other, a 45 degree line.

²⁸ Therefore, the structural unemployment rate defined here differs from the concept of the Non-Accelerating Inflation Rate of Unemployment (NAIRU), and does not show a direct relationship with prices or wages.

²⁹ The extrapolated value using the employment condition DI in the *Tankan* is used in the data up to 1990/Q3 as the capacity utilization DI is not available. Note that the Business Outlook Survey, the previous data source explained in Hara *et al.* (2006), is not used at present.

nonmanufacturing because actual capacity utilization data does not exist. In that estimation, in order to convert the DI into a comparable utilization to that of manufacturing, the utilization in manufacturing adjusted on a downward-bias ($u_t^{M,adj}$) is regressed on the capacity utilization DI of nonmanufacturing, all enterprise sizes (DI_t), and the fitted value of the estimation is used as the utilization in nonmanufacturing.

$$u_t^{M,adj} = \gamma_0 + \gamma_1 DI_t + \varepsilon_t$$

The gap is defined as the % deviation from its constant long-term averages.³⁰

³⁰ The error term in the estimation (ε_t) represents the difference between the behavior of the utilization in manufacturing and that in nonmanufacturing, depending on the economic conditions. For example, when the economy expands on account of domestic demand but exports and production is relatively weak, compared to that in manufacturing, the utilization in nonmanufacturing shows a typical trend of improvement. In these circumstances, the error term (ε_t) is continuously negative, being serially correlated.

Annex 2: HP Filtering and ℓ_1 Filtering

This is a brief explanation of the Hodrick-Prescott (HP) filtering, used in the calculation of the hours worked gap, and the ℓ_1 trend filtering, similar to the piecewise linear regression used in the labor participation rate gap.

A.2.1 HP Filtering

The Hodrick-Prescott (HP) filtering, proposed by Hodrick and Prescott (1997), is a statistical method of extracting trends from data.

In this equation, let y_t be the time series data at time t ; this can be broken down into two components: τ_t , the trend, and c_t , the cycle.

$$y_t = \tau_t + c_t \quad t = 1, \dots, T$$

Then, the following minimization problem of loss function yields the HP trend series.

$$\min_{\{\tau_t\}} \left[\sum_{t=1}^T (y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1} ((\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1}))^2 \right]$$

The first term in the equation above, the cycle of the original data, ensures that the dispersion between trend and original data is as small as possible. The second term is a second-order difference of the trend, which makes the trend as smooth as possible. The loss function is the weighted average of these two terms. The parameter λ represents how much weight is attached to each term. When λ is large, it means quite a penalty is added on to the second term, and the trend becomes smoother. On the other hand, when λ is close to 0, the trend becomes more similar to the original series.

The minimization problem explained above could be solved analytically. Let D , $T - 2 \times T$ matrix, as a second-order difference matrix as follows.

$$D = \begin{bmatrix} 1 & -2 & 1 & & & \\ & 1 & -2 & 1 & & \\ & & \ddots & \ddots & \ddots & \\ & & & 1 & -2 & 1 \end{bmatrix}$$

Then, τ_t^{HP} , the HP trend series, is determined as the linear function of the original data:

$$\tau_t^{HP} = (I + \lambda D^T D)^{-1} y_t \quad (I \text{ is an identity matrix})$$

A.2.2 ℓ_1 Filtering

The ℓ_1 filtering, similar to the HP filtering, is another statistical method of extracting trends from data. This method has been proposed recently by Kim, Koh, Boyd, and Gorinevsky (2009).

The name of ' ℓ_1 ' comes from the fact that the trend uses ℓ_1 norm, i.e., $p = 1$ case of the L^p norm.³¹

$$\text{norm}^p = \sqrt[p]{|x_1|^p + \dots + |x_n|^p}$$

Since the method of ℓ_1 filtering is similar to that of HP filtering, comparison could be helpful to understand the method.

Let y_t be the time series data at time t , which can be broken down into two components: τ_t , the trend, and c_t , the cycle.

$$y_t = \tau_t + c_t \quad t = 1, \dots, T$$

Then the following minimization problem of loss function yields the ℓ_1 trend series.

$$\min_{\{\tau_t\}} \left[\sum_{t=1}^T (y_t - \tau_t)^2 + \lambda \sum_{t=2}^{T-1} |(\tau_{t+1} - \tau_t) - (\tau_t - \tau_{t-1})| \right]$$

Similar to the HP filtering, the first term of the equation above represents the cycle of the original series. The second term, the second-order difference of the trend, differs from that of the HP filtering; in HP filtering, it is squared, i.e., ℓ_2 norm, function, but in ℓ_1 filtering, it is an absolute value, i.e., ℓ_1 norm, function. Bearing in mind that this second term represents the second-order difference of the trend, it becomes 0 when the trend is linear. From the above, qualitative interpretation of this minimization problem becomes as follows: (1) the trend is basically linear; and (2) the trend has a kink, i.e., the second term of the function becomes non-zero, when dispersed from the original data, i.e., the first term of the function, becomes large enough. These procedures yield the optimal piecewise linear regression trend which minimize the loss function.

It should be noted that the above minimization problem does not have an analytical

³¹ The concept of 'norm' is the generalized idea of length of vector on the plane. L^2 norm denotes $\sqrt{x_1^2 + \dots + x_n^2}$; it is so-called Euclid distance, the length in the general sense. L^1 norm denotes $|x_1| + \dots + |x_n|$; it is the sum of the absolute value of each term and the so-called Manhattan distance.

solution; therefore, the ℓ_1 trend is obtained by numerical approximation.

The concept of the piecewise linear regression applied to the labor force participation rate gap is similar to the ℓ_1 trend filtering, but it differs from the ℓ_1 trend in whether the point of refraction is determined ex-ante or not. In the case of ℓ_1 filtering, points of refractions may change when new data are added and re-estimated. Since the piecewise linear regression applied to the labor force participation rate gap determines the points of refractions ex-ante, these points remain unchanged, and the judgment of each past economic condition does not change ex-post.

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Estimation Methods of the Output Gap and Potential Growth Rate

(1) Various Estimates for Japan's Output Gap and Potential GDP

	Estimation order	Framework of the estimation	Details of the estimation method	Data availability
Cabinet Office	Calculates potential GDP first	Production function approach	Trend labor force participation rate and trend hours worked are based on HP filtering. Trend unemployment rate is structural unemployment rate based on the UV analysis. Capital input is based on the "Quarterly Estimates of Net Capital Stocks of Fixed Assets." For details, see Cabinet Office (2011, 2017).	Website of the Cabinet Office (8 times a year)
IMF			Data and methods are flexibly revised given the economic conditions. In IMF(2015), the following approach is used: trend labor force participation rate is based on the cohort analysis by gender and age group. Trend unemployment rate is the Non-Accelerating Inflation Rate of Unemployment (NAIRU). For details, see De Masi (1997), IMF (2015, 2017).	World Economic Outlook (twice a year)
OECD			Trend labor force participation rate and trend hours worked are based on HP filtering. Trend unemployment rate is NAIRU. Capital service is used in order to take the heterogeneity of rental price into consideration. For details, see Giomo <i>et al.</i> (1995), Cotis <i>et al.</i> (2005), Beffy <i>et al.</i> (2006), and OECD (2016).	Economic Outlook (twice a year)
Bank of Japan			Calculates output gap first	See text

(2) Estimates of Output Gap and Potential GDP in Other Countries and Regions

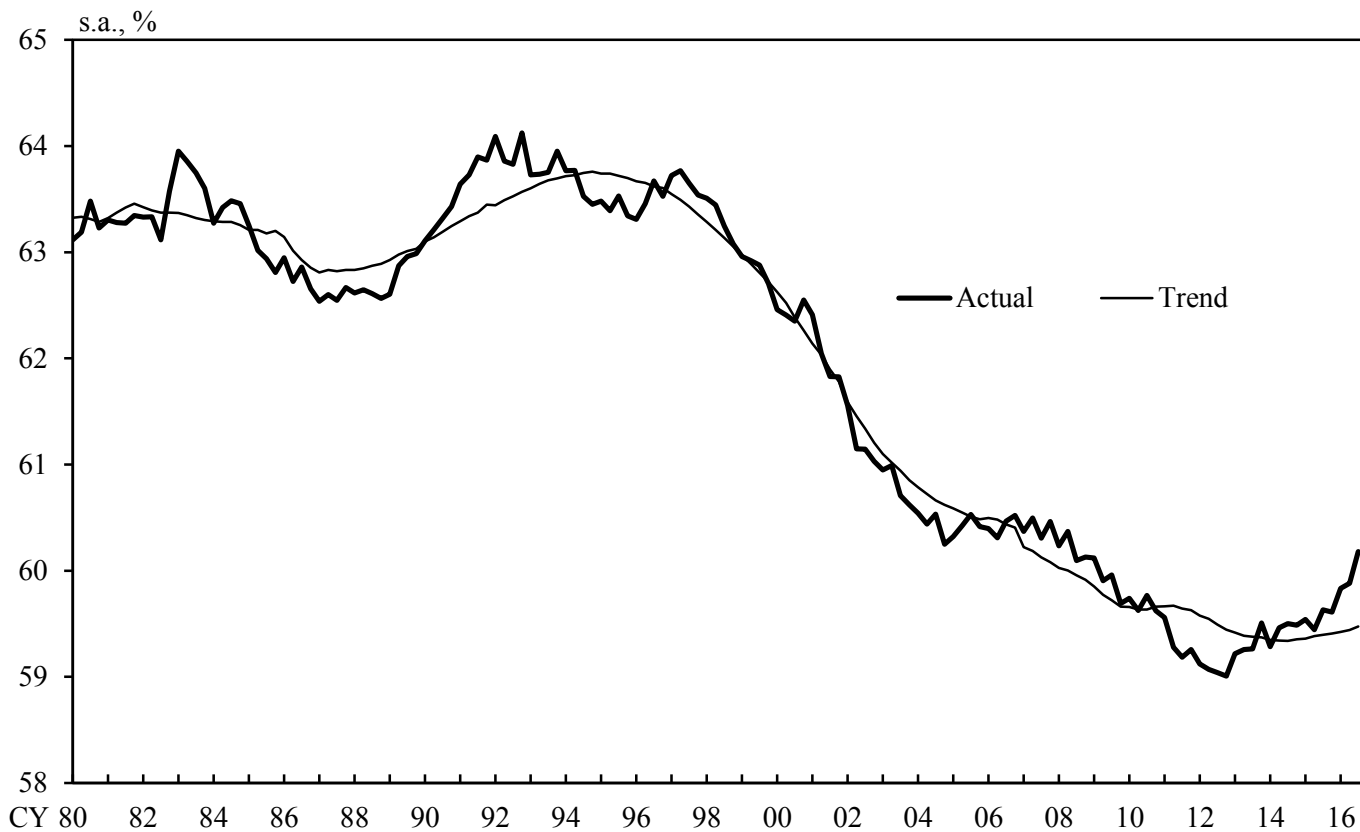
	Estimation order	Framework of the estimation	Details of the estimation method, etc.
FRB, US	---	Model approach	FRB/US, the large scale economic model, uses estimates of trends derived from the multivariate state-space model. In the model, the potential GDP is defined based on the production function. For details, see Roberts (2014), Brayton <i>et al.</i> (2014).
CBO, US	Calculates potential GDP first	Production function approach	Trend labor force participation rate, trend hours worked are based on piecewise linear regression. Trend unemployment rate is NAIRU. Capital service is used in order to take the heterogeneity of rental price into consideration. For details, see CBO (2001).
European Commission, Europe			Trend labor participation rate, trend hours worked are based on HP filtering. Trend unemployment rate is Non-Accelerating Wage Rate of Unemployment (NAWRU). For details, see Havik <i>et al.</i> (2014).
OBR, UK	Several methods are used in order to analyze the economic condition. Some are methods which measure potential GDP first, such as the production function approach or HP filtering approach. Some are methods which measure output gap first, such as the principal components analysis. For details, see OBR (2017).		

Output Gap: Key Points of the Revision

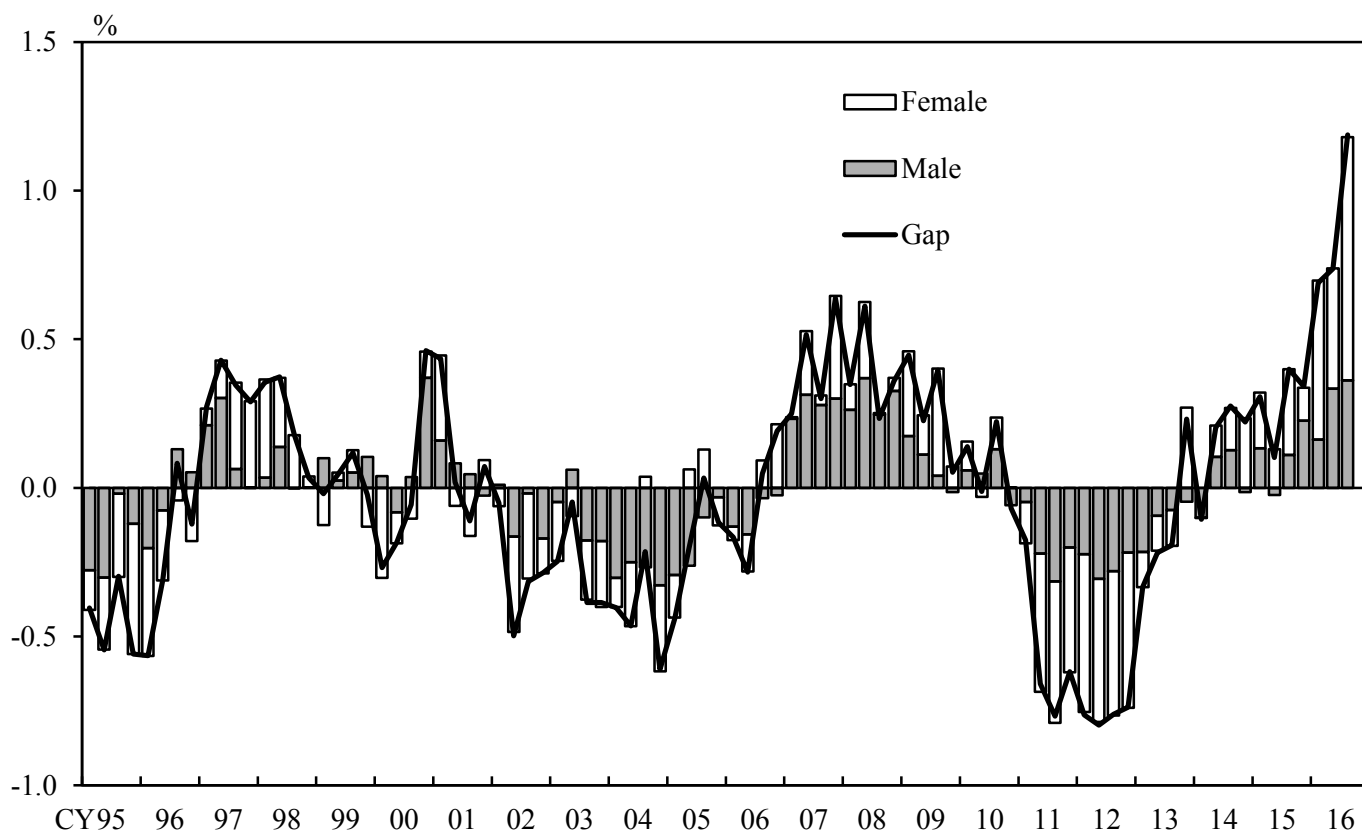
	Before revision	After revision
Labor Input Gap		
Labor Force Participation Rate Gap	Calculated based on HP filter trend by gender and age group	Calculated using a piecewise linear regression which allows breakpoints in the trend for each business cycle and by gender and age group
Hours Worked Gap	Calculated based on trends taking into account proportion of part-time employees and major working time regulations	Extracted the variable trends in total hours worked of full-time and part-time workers respectively using an HP filter as the average weighted by the proportion of part-time workers
Employment Rate Gap	Estimated based on the structural unemployment rate using UV analysis (Unrevised)	
Capital Input Gap		
Utilization Gap in Manufacturing	Differential between the utilization ratio of the IIP whose downward bias is adjusted using the production capacity DI from the Tankan survey and the past average of the utilization ratio itself	Differential between the utilization ratio of the IIP whose downward bias is adjusted using the Quarterly Estimates of Net Capital Stock of Fixed Assets and the past average of the utilization ratio itself
Utilization Gap in Nonmanufacturing	Differential between the production capacity DI from the Tankan survey adjusted comparable with the utilization gap in manufacturing and the past average of the utilization ratio itself (Unrevised)	

Labor Force Participation Rate Gap: Before Revision

(1) Actual Labor Force Participation Rate and Its Trend



(2) Labor Force Participation Rate Gap

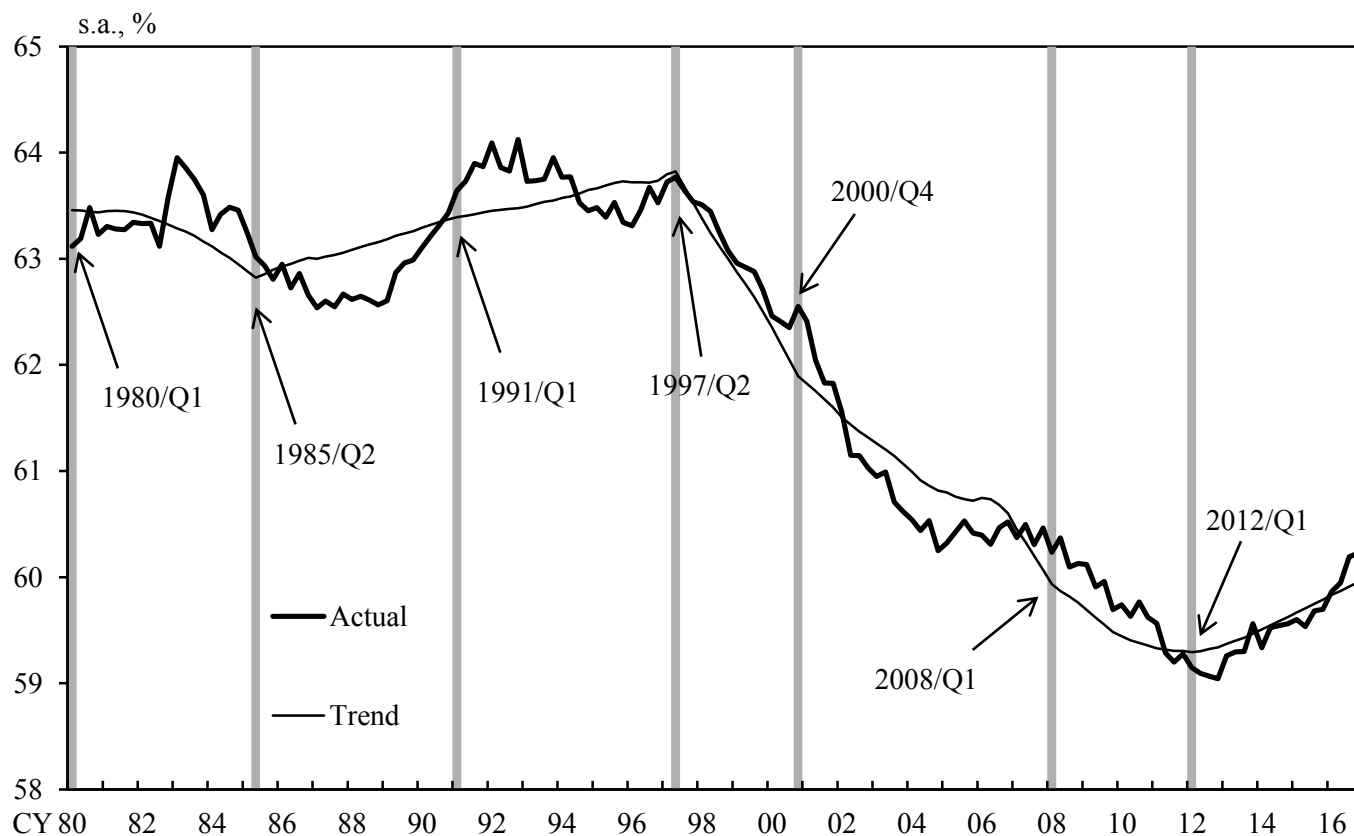


Note: Figures are as of January 2017.

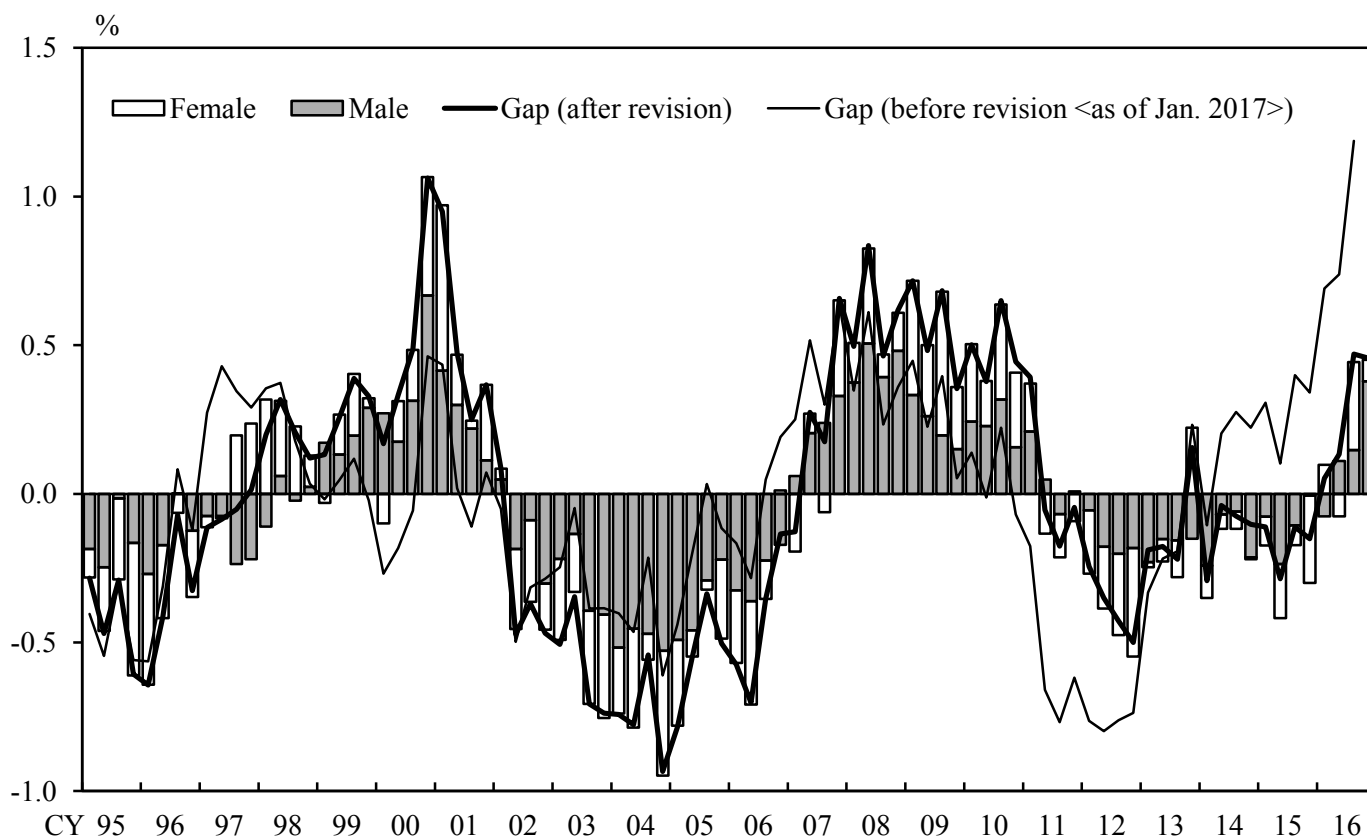
Source: Ministry of Internal Affairs and Communications.

Labor Force Participation Rate Gap: After Revision

(1) Actual Labor Force Participation Rate and Its Trend



(2) Labor Force Participation Rate Gap

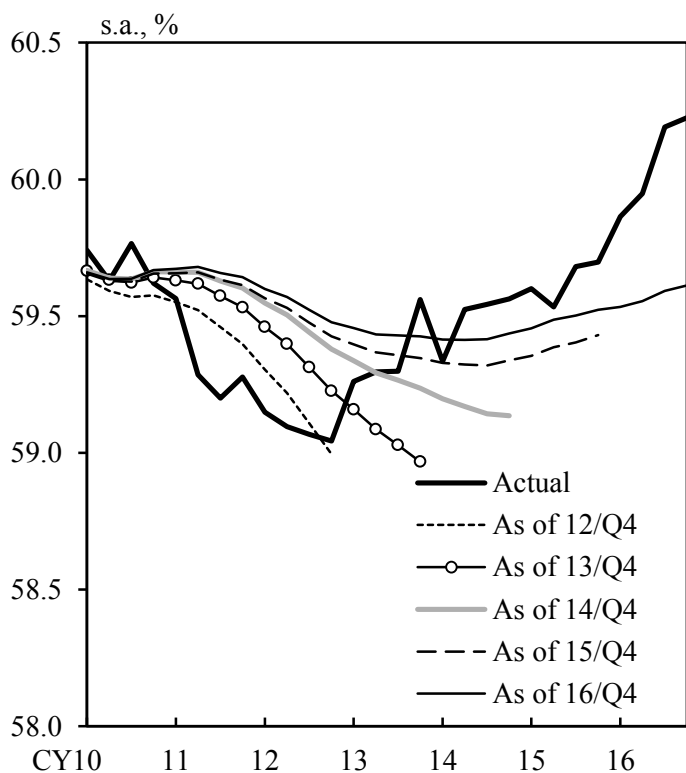


Note: The vertical lines in (1) indicate peaks of the Reference Dates of Business Cycle released by the Cabinet Office.
Sources: Ministry of Internal Affairs and Communications; Cabinet Office.

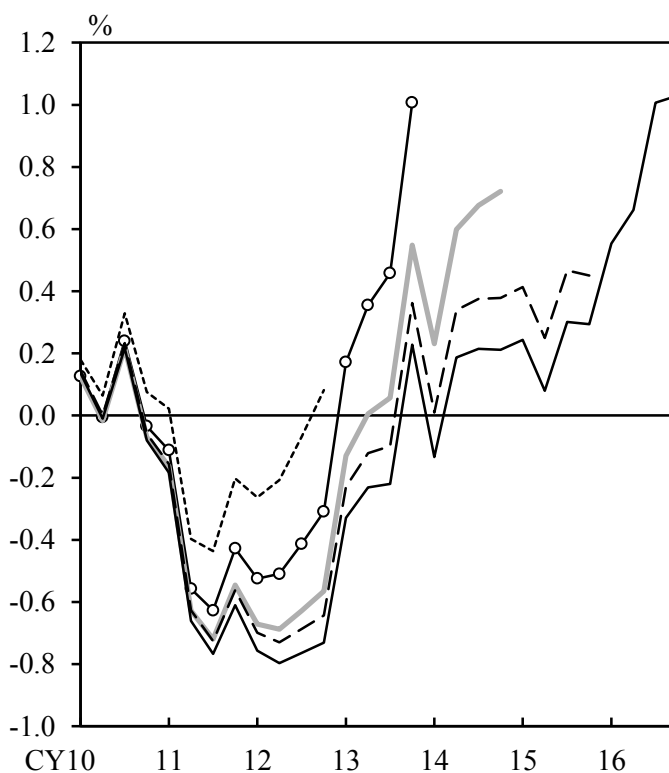
Patterns of Revisions in Labor Force Participation Rate Gap

(1) Before Revision

(a) Actual and Its Trend

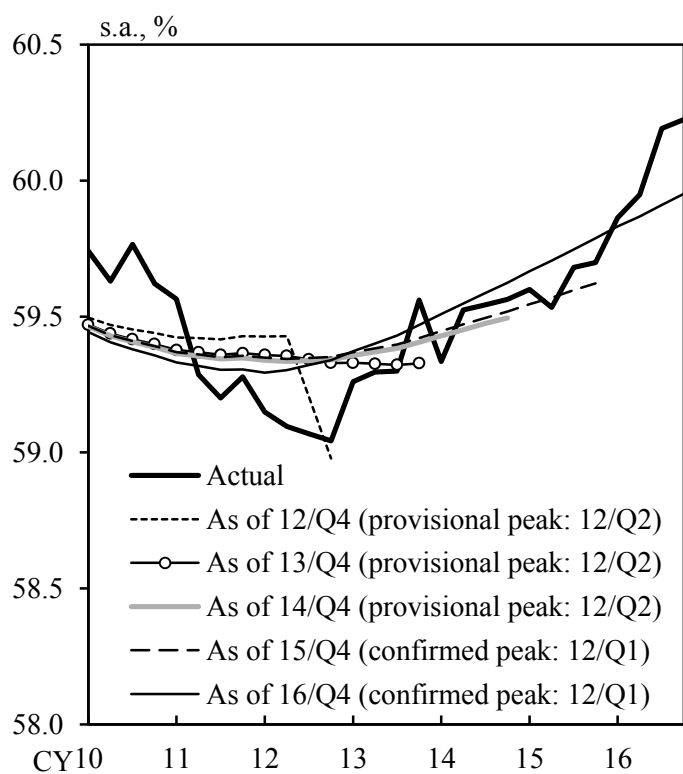


(b) Gap

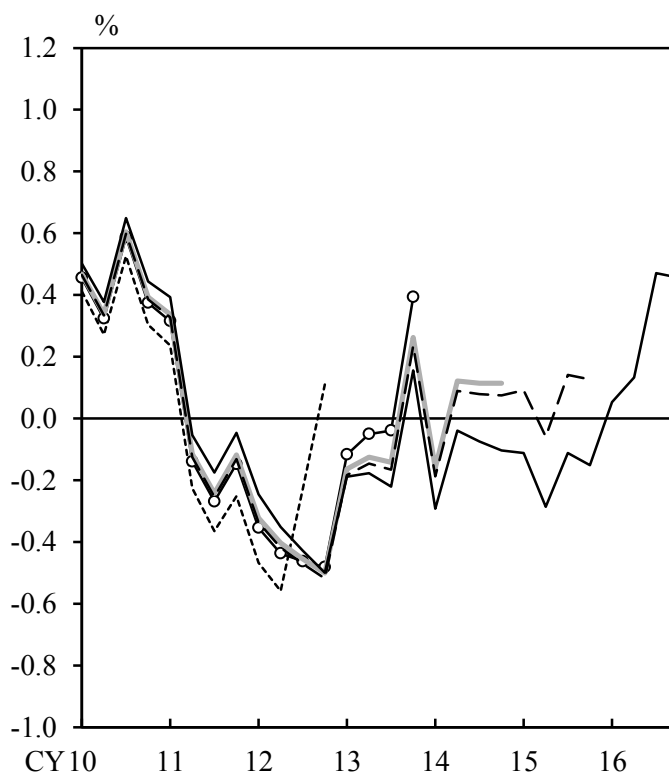


(2) After Revision

(a) Actual and Its Trend



(b) Gap



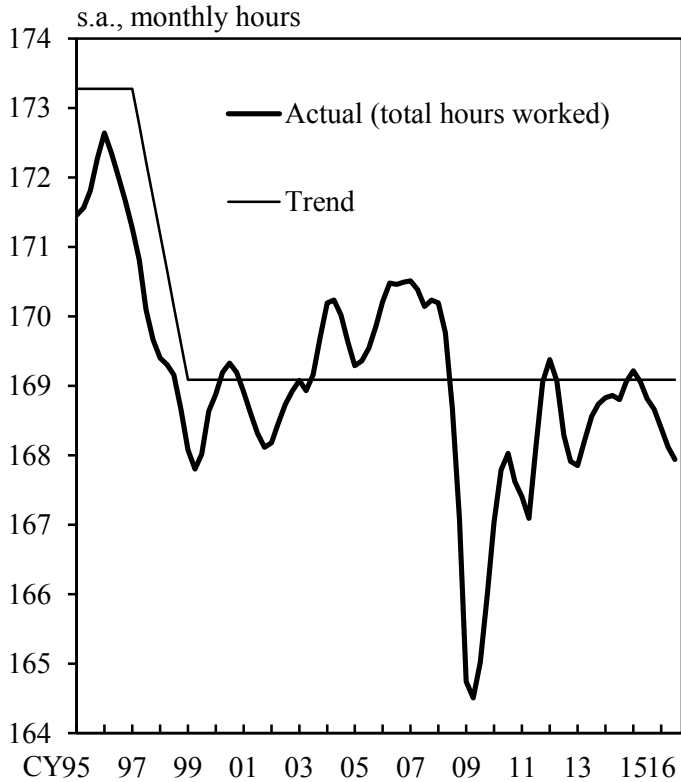
Note: With the latest data, the turning points of the business conditions are determined using information available in each estimation period. Specifically, we decided that 2012/Q2 was the turning point provisionally before July 2015 based on the assessment of Indexes of Business Conditions and the Reference Dates of Business Cycle provisionally settled in August 2013. After the Reference Dates of Business Cycle was confirmed in July 2015, the tuning point changed to 2012/Q1.

Sources: Ministry of Internal Affairs and Communications; Cabinet Office.

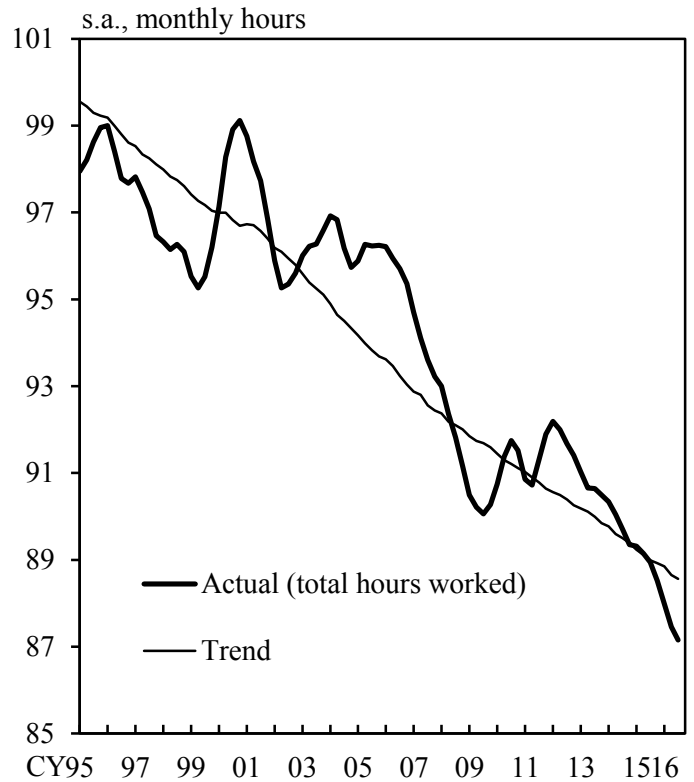
Hours Worked Gap: Before Revision

(1) Hours Worked: Actual and Its Trend

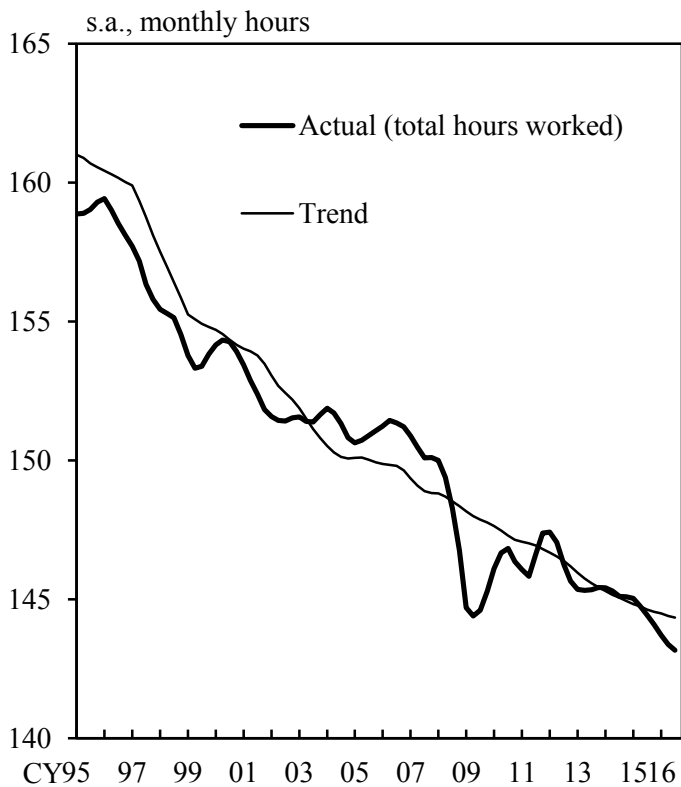
(a) Full-time Employees



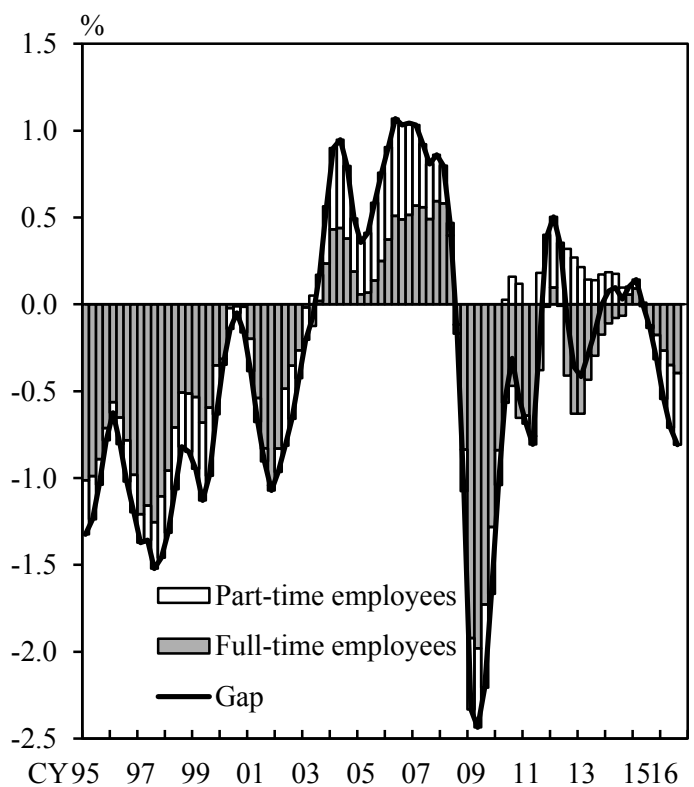
(b) Part-time Employees



(c) All Employees ((a)+(b))



(2) Hours Worked Gap



Notes: 1. Figures are as of January 2017.

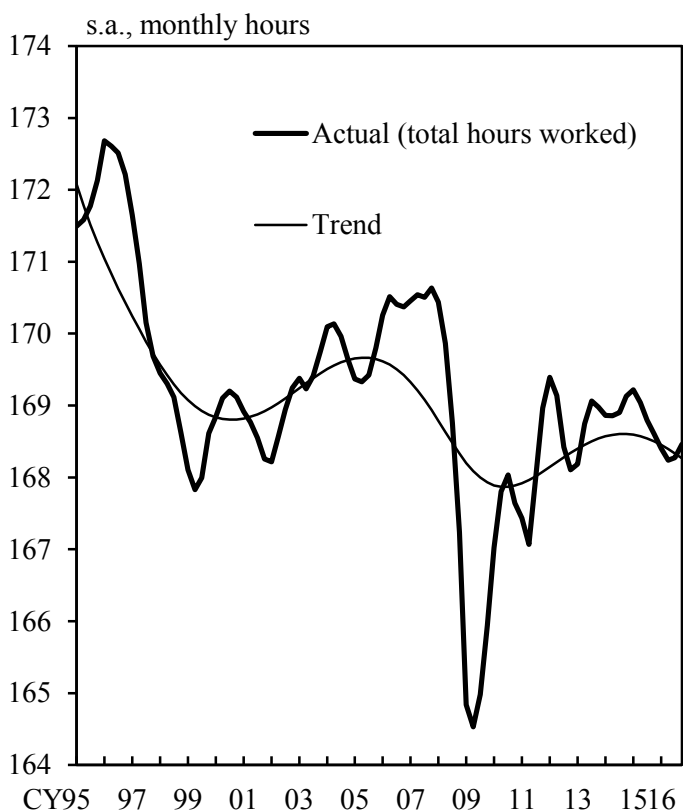
2. Actual hours worked are seasonally adjusted, and irregular spikes were eliminated from the original series.

Source: Ministry of Health, Labour and Welfare.

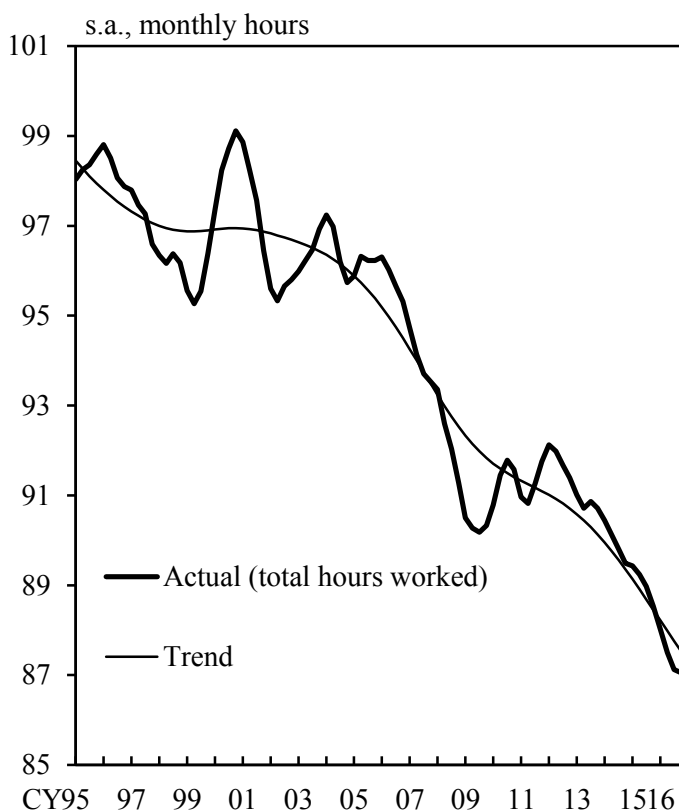
Hours Worked Gap: After Revision

(1) Hours Worked: Actual and Its Trend

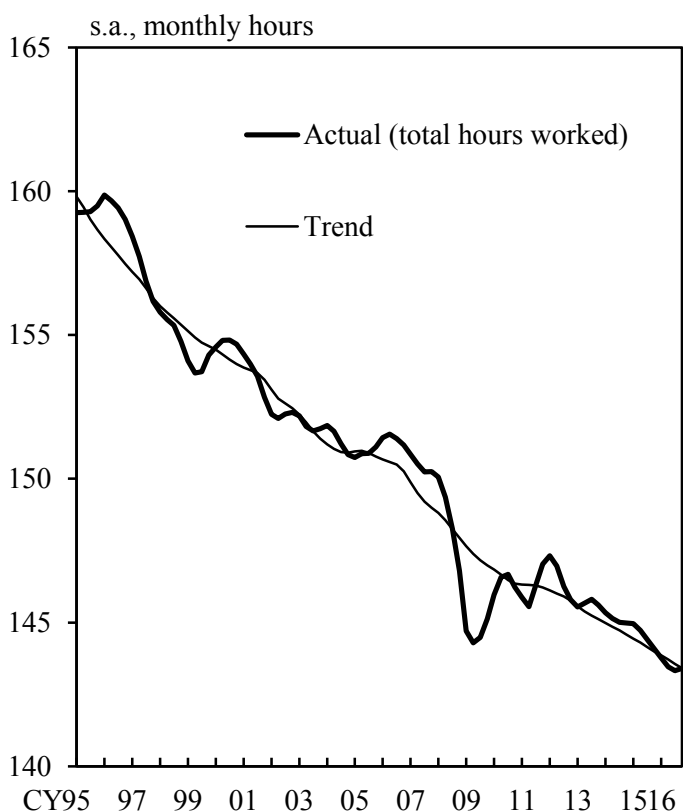
(a) Full-time Employees



(b) Part-time Employees



(c) All Employees ((a) + (b))



(2) Hours Worked Gap

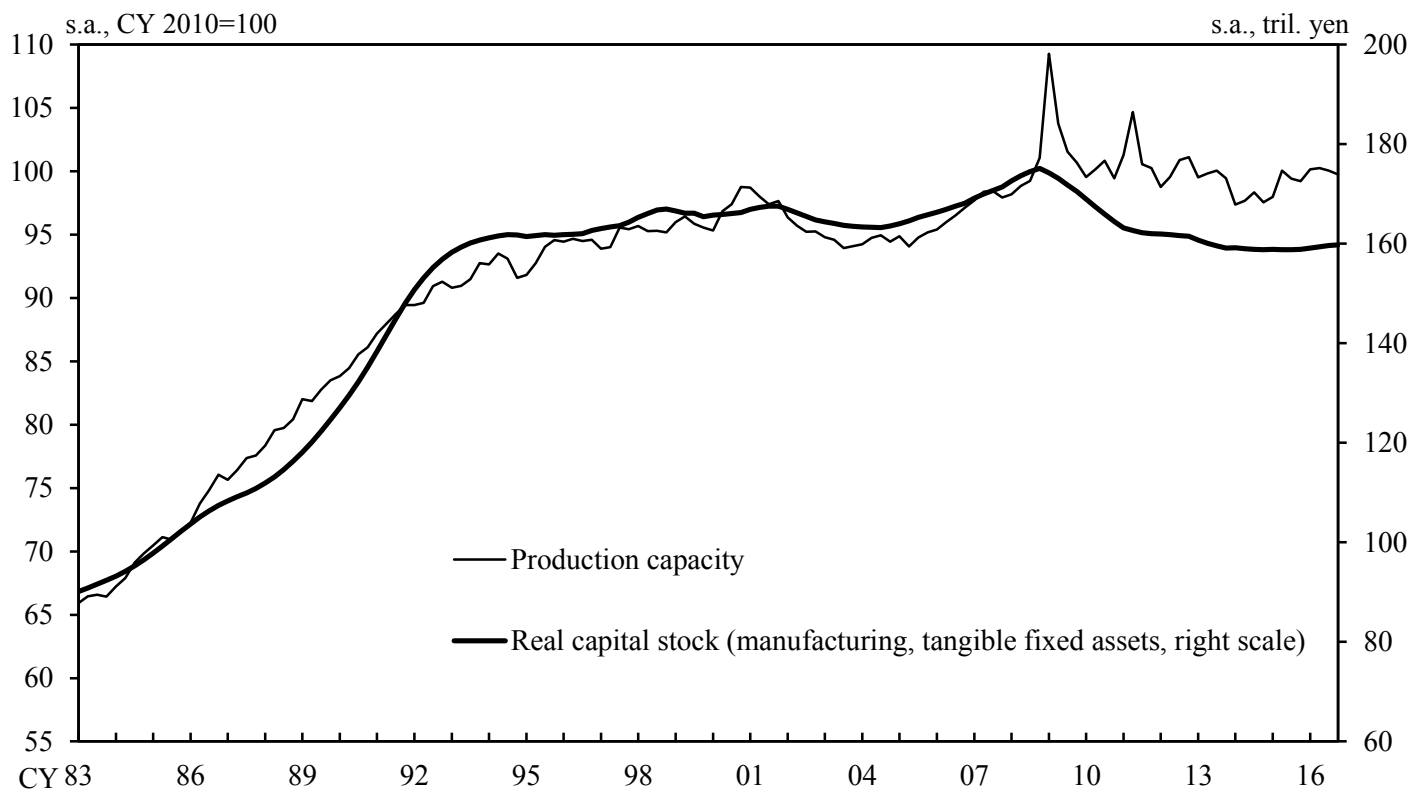


Note: Actual hours worked are seasonally adjusted, and irregular spikes were eliminated from the original series.

Source: Ministry of Health, Labour and Welfare.

Bias of Production Capacity and Operating Ratio

(1) Production Capacity and Real Capital Stock



(2) Index of Operating Ratio



Notes: 1. Production capacity in (1) is obtained by dividing the production index by the operating ratio index.

2. Real capital stock in (1) is estimated by the Research and Statistics Department, Bank of Japan using the "Quarterly Estimates of Net Capital Stocks of Fixed Assets" and the "Net Capital Stocks of Fixed Assets classified by Institutional Sectors and Economic Activities."

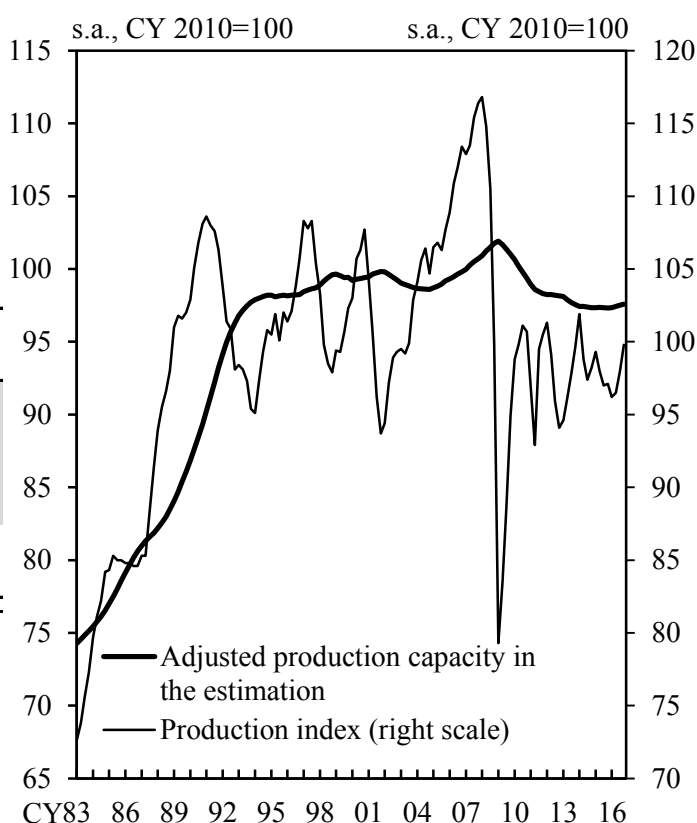
Sources: Cabinet Office; Ministry of Economy, Trade and Industry; Research Institute of Economy, Trade and Industry.

Adjusting Utilization Gap in Manufacturing

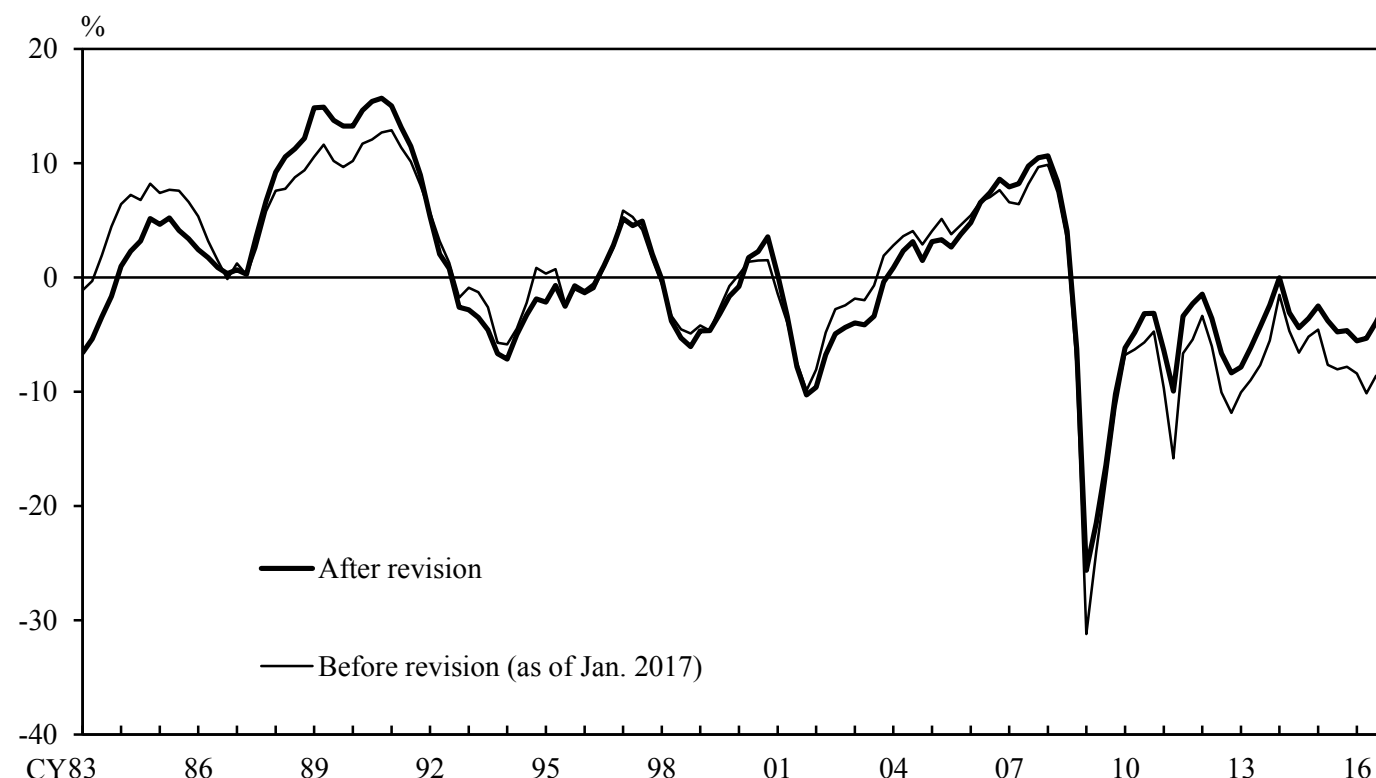
(1) Estimation

Estimated Model		
$\ln(Cap_t) = \beta_0 + \beta_1 \ln(\bar{K}_{t-1}^M) + \beta_2 Trend + \varepsilon_t$		
Estimation Results		
Dependent variable: Production capacity($\ln(Cap_t)$)		
Independent variables:	Coefficient	<i>t</i> -value
β_0 Constant	-1.114	-1.215
β_1 Capital stock ($\ln(\bar{K}_{t-1}^M)$)	0.470 ***	6.166
β_2 Time trend (<i>Trend</i>)	0.001 ***	12.845
Estimation period	1994/Q1 ~ 2016/Q4	
Adjusted R ²	0.67	
S.E. of regression	1.02	

(2) Adjusted Production Capacity



(3) Utilization Gap in Manufacturing



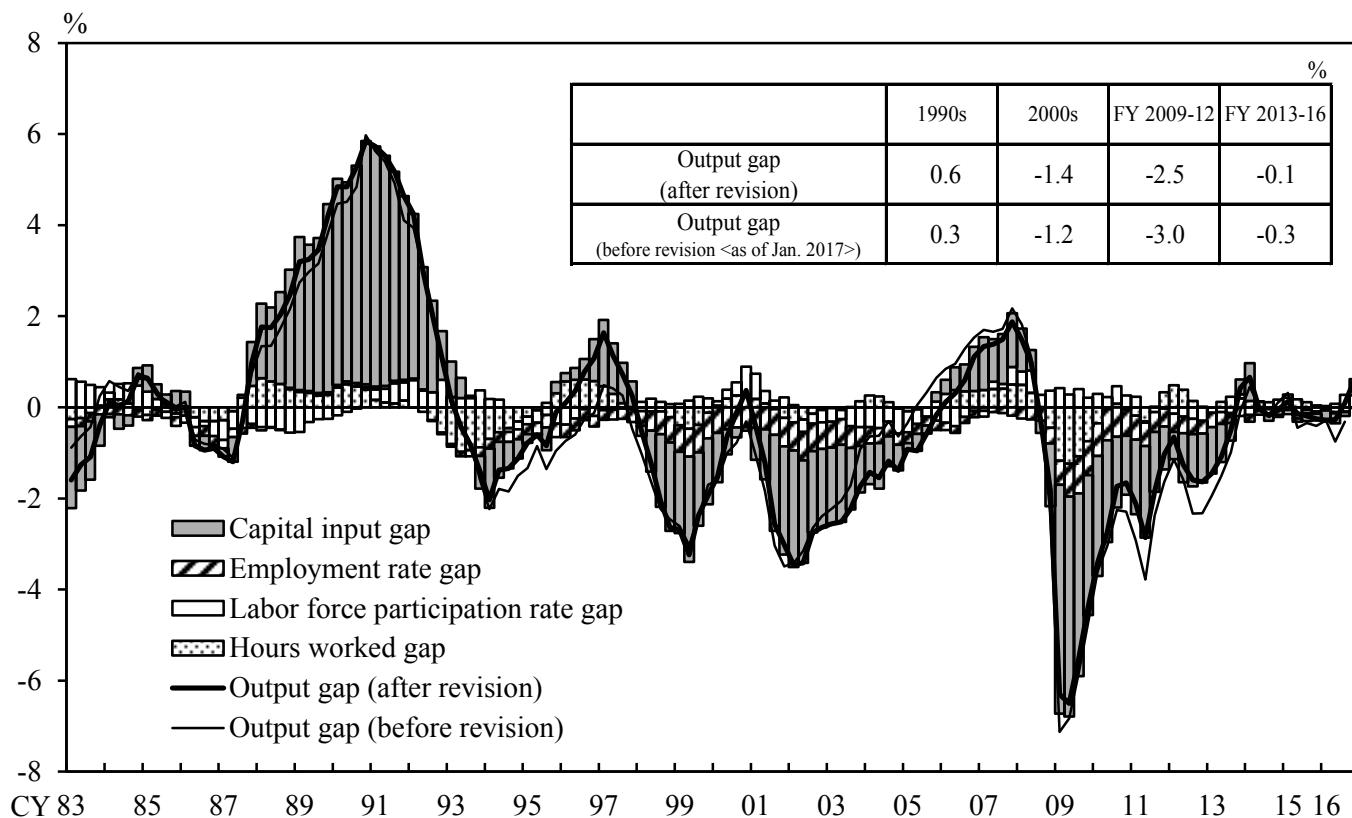
Notes: 1. *** in (1) denotes statistical significance at the 1% level. S.E. of regression is for production capacity (Cap_t).

2. Figures as of Jan. 2017 in (3) are up to 2016/Q3.

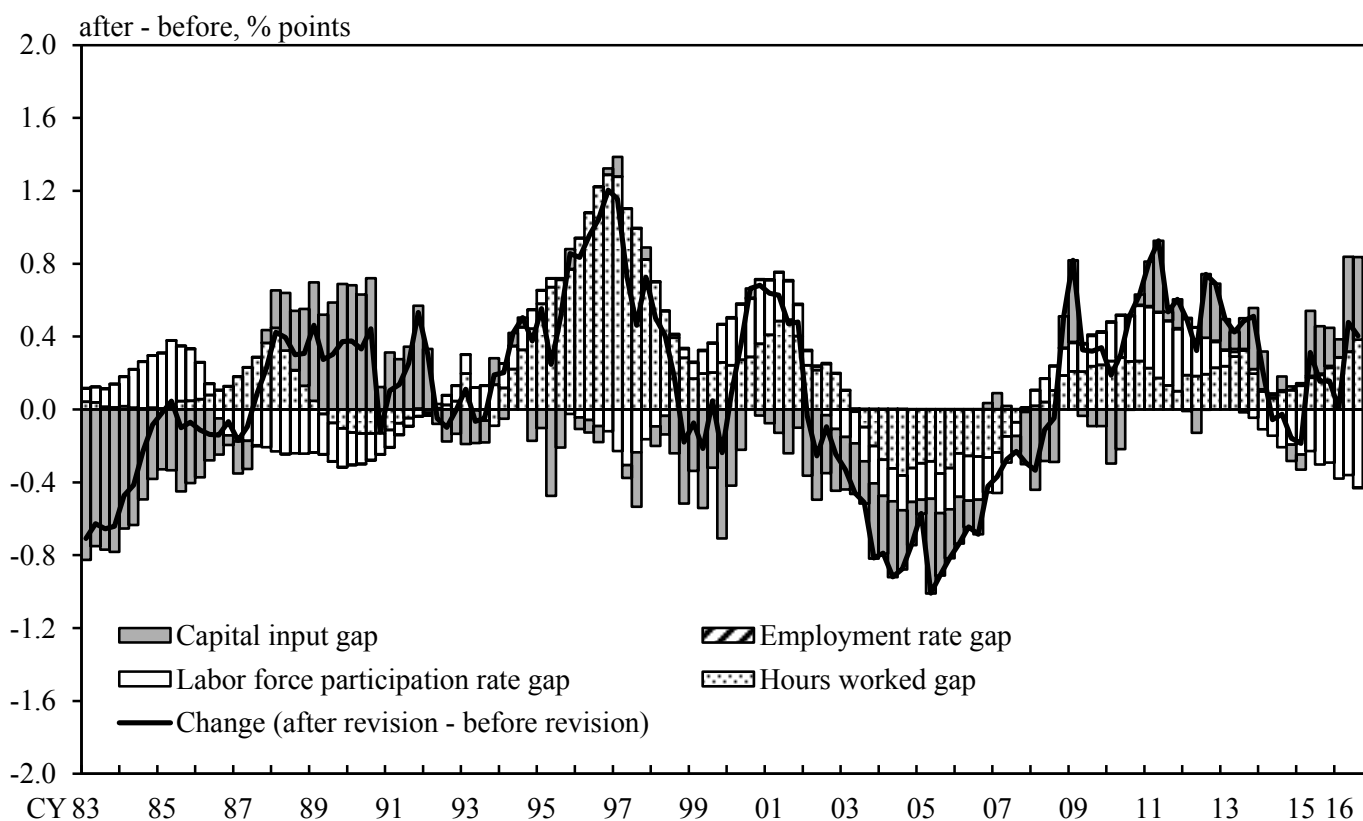
Sources: Cabinet Office; Bank of Japan; Ministry of Economy, Trade and Industry; Research Institute of Economy, Trade and Industry.

Revision of the Output Gap

(1) Output Gap



(2) Difference between the Output Gap Before and After the Revision

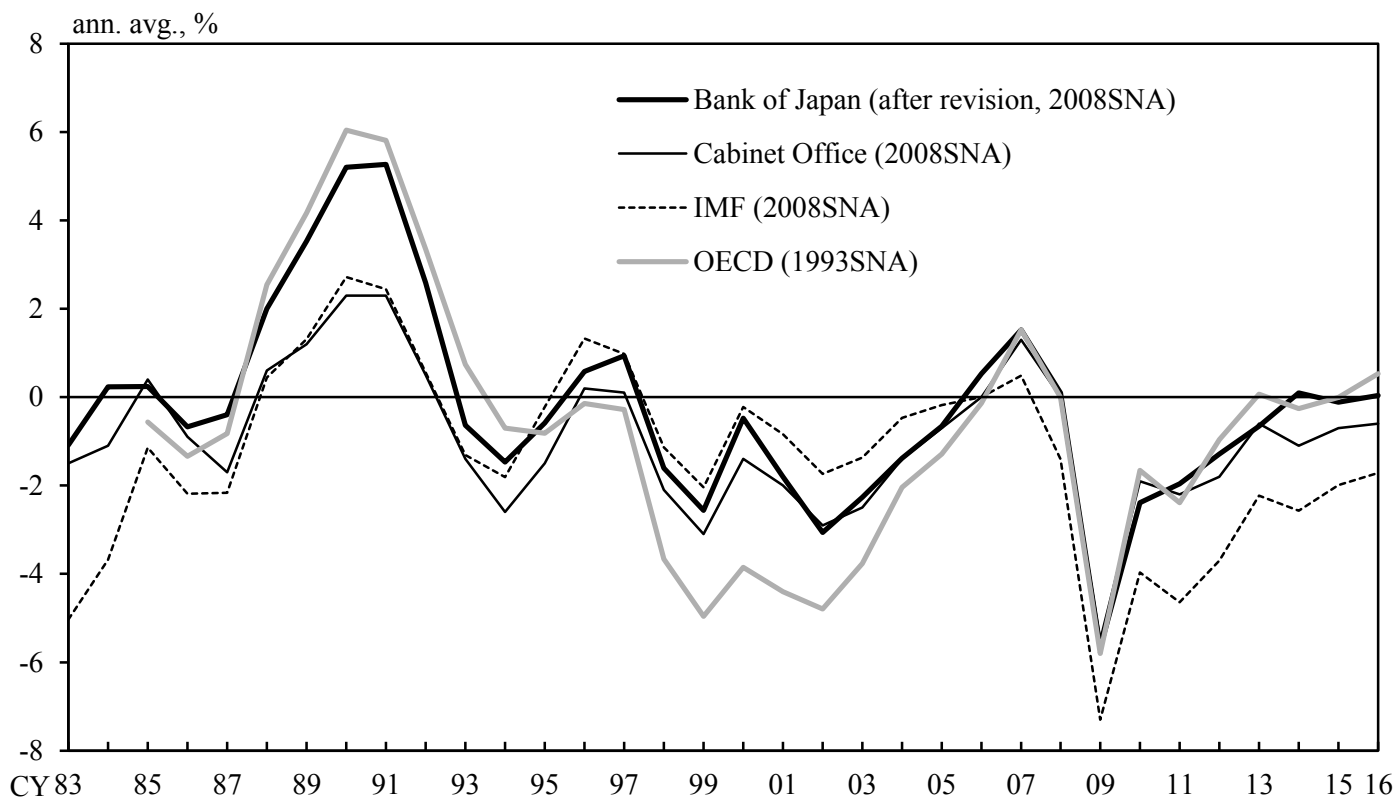


Note: Figures as of Jan. 2017 are up to 2016/Q3.

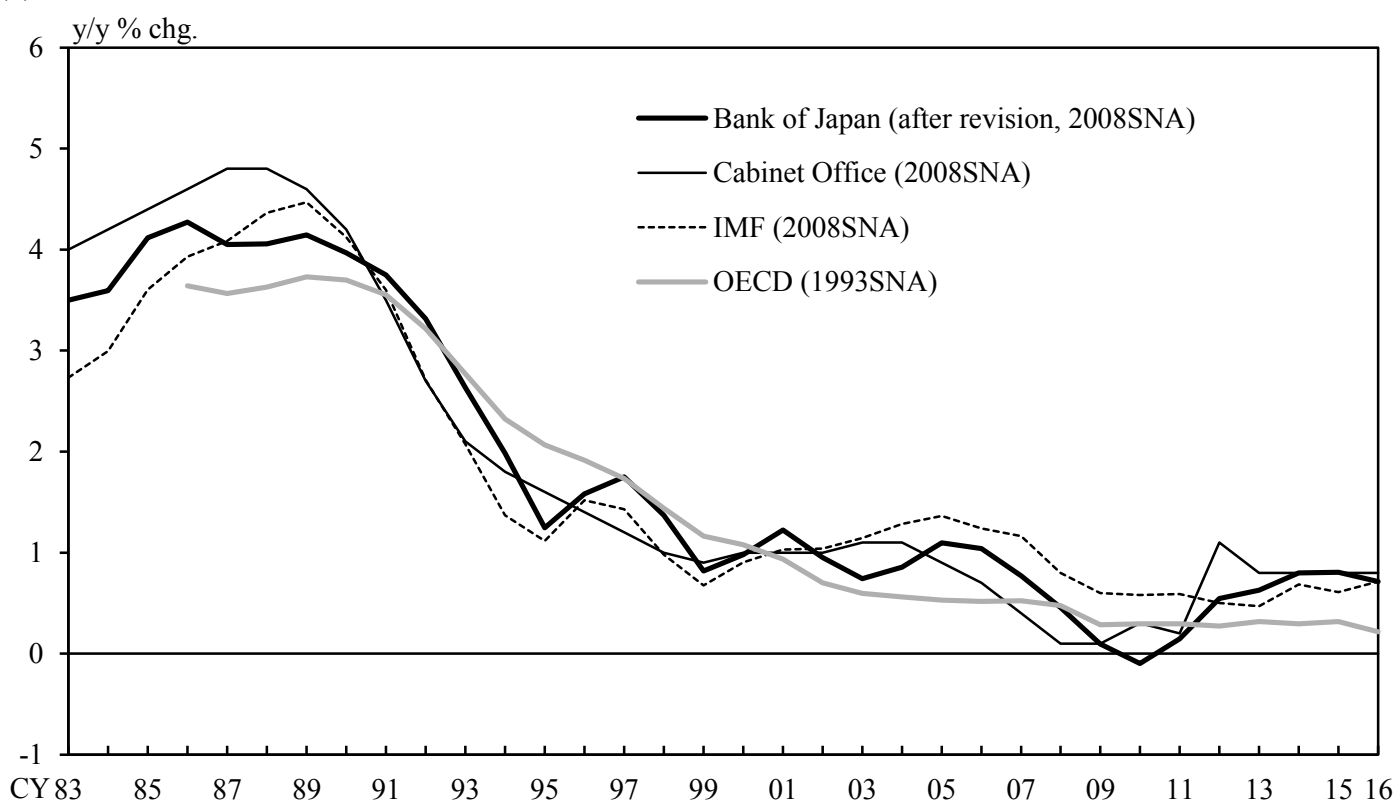
Sources: Cabinet Office; Bank of Japan; Ministry of Internal Affairs and Communications; Ministry of Health, Labour and Welfare; Ministry of Economy, Trade and Industry; Research Institute of Economy, Trade and Industry.

Various Estimates of Japan's Output Gap and Potential Growth Rate

(1) Output Gap



(2) Potential Growth Rate

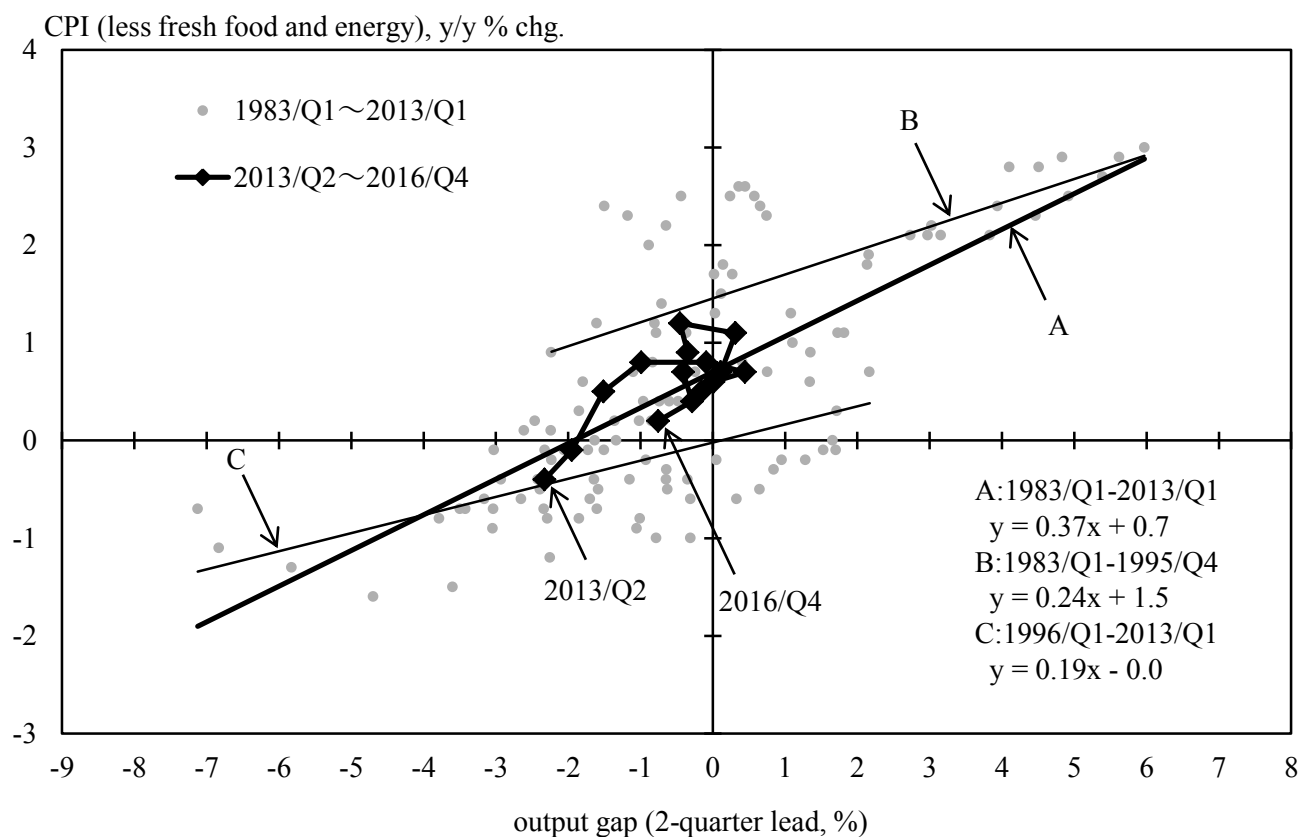


Note: Figures for the IMF are based on the April 2017 "World Economic Outlook." Figures for the OECD are based on the November 2016 "Economic Outlook." Figures for the OECD do not reflect the comprehensive revision of the SNA statistics, and those for 2016 are projections. For details, see Chart 1.

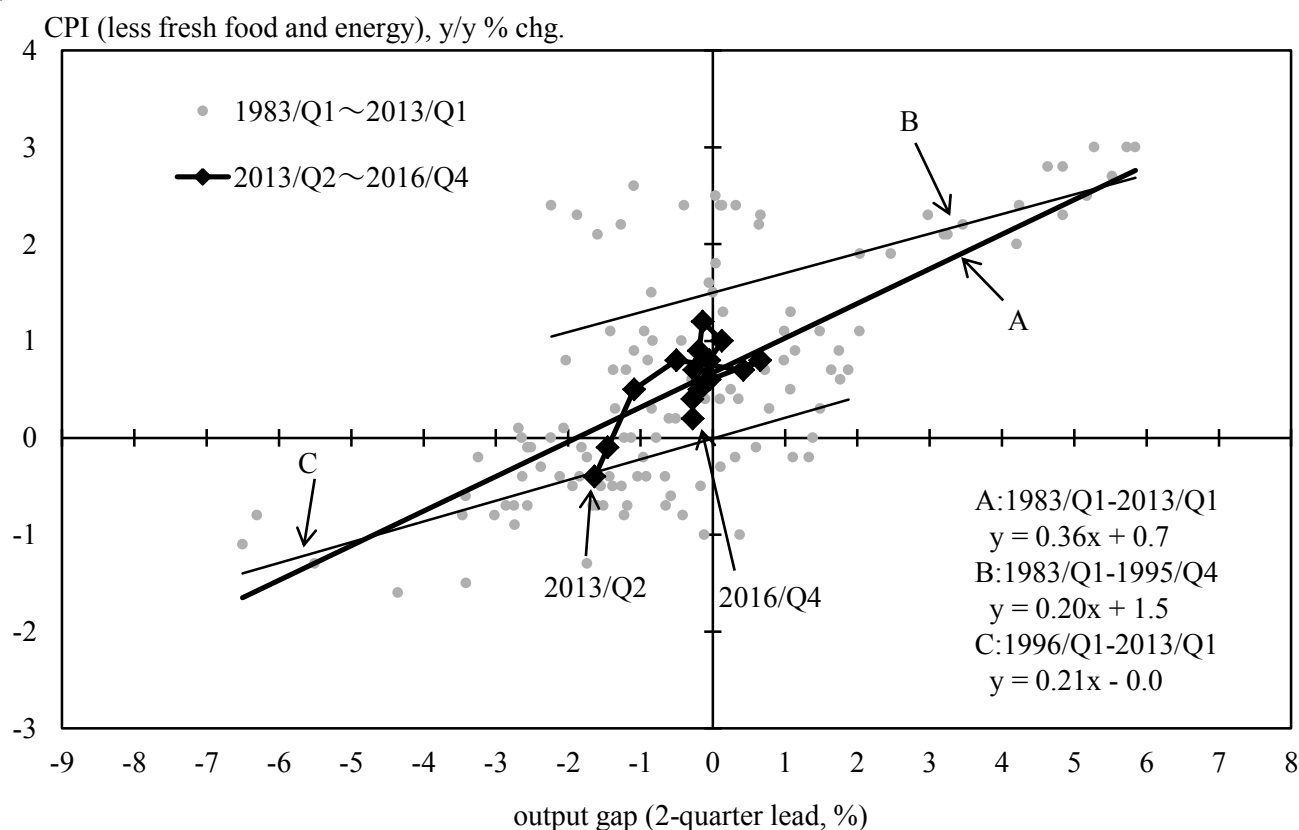
Sources: Cabinet Office; IMF; OECD, etc.

Phillips Curve (CPI All Items Less Fresh Food and Energy)

(1) Before Revision <as of Jan. 2017>



(2) After Revision



Note: Figures for the CPI are adjusted to exclude the estimated effects of changes in the consumption tax rate.
Sources: Ministry of Internal Affairs and Communications; Cabinet Office, etc.

Performance Comparison of Old and Revised Output Gaps: Phillips Curve

(1) Estimation Results of Phillips Curve Specification

CPI less fresh food, energy, and house rent,
 $=\beta_0$
 $+\beta_1 \times$ (medium to long-term inflation expectations,
 $+\beta_2 \times$ (CPI less fresh food, energy, and house rent_{t-1})
 $+(1-\beta_1-\beta_2) \times$ (CPI less fresh food, energy,
 and house rent_{t-2})
 $+\beta_3 \times$ (Output gap_t)
 $+\Omega \times$ (dummy variables for special factors)

Estimation Results

	Old	New
β_0	-0.39 ***	-0.41 ***
β_1	0.34 ***	0.34 ***
β_2	0.52 ***	0.52 ***
β_3	0.10 ***	0.10 ***
Adjusted R ²	0.78	0.78
S.E. of regression	0.32	0.32

(2) Forecast Error (after CY2005)

	MAE (Mean Absolute Error)		RMSE (Root Mean Squared Error)	
	Before Revision	After Revision	Before Revision	After Revision
1-period-ahead	0.16	0.16	0.19	0.19
2-period-ahead	0.26	0.24	0.31	0.30
3-period-ahead	0.37	0.35	0.44	0.42
4-period-ahead	0.48	0.45	0.55	0.52
Mean	0.32	0.30	0.37	0.36

Notes: 1. The estimation period is 1990/Q1-2016/Q3.

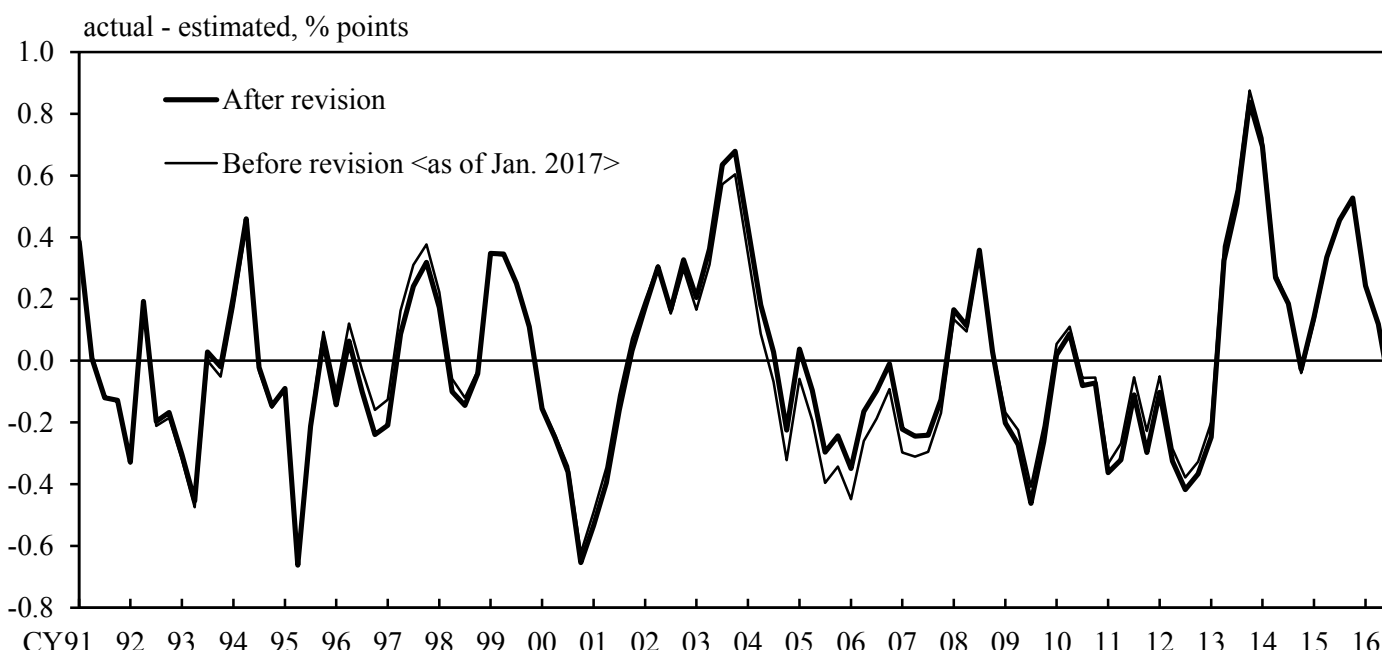
2. CPI less fresh food, energy, and house rent is quarter-on-quarter % change basis, seasonally adjusted. Figures for medium to long-term inflation expectations are the expectations for the CPI 6 to 10 years ahead and are based on the "Consensus Forecasts." In the estimations, dummy variables are included in order to control for the estimate effects of special factors such as the introduction of a subsidy for high school tuition.

3. With regard to medium to long-term inflation expectations, output gap, and dummy variables, perfect foresight is assumed.

4. S.E. of regression, MAE, and RMSE are year-on-year % change basis. *** denotes statistical significance at the 1% level.

5. Figures for the CPI are adjusted to exclude the estimated effects of changes in the consumption tax rate.

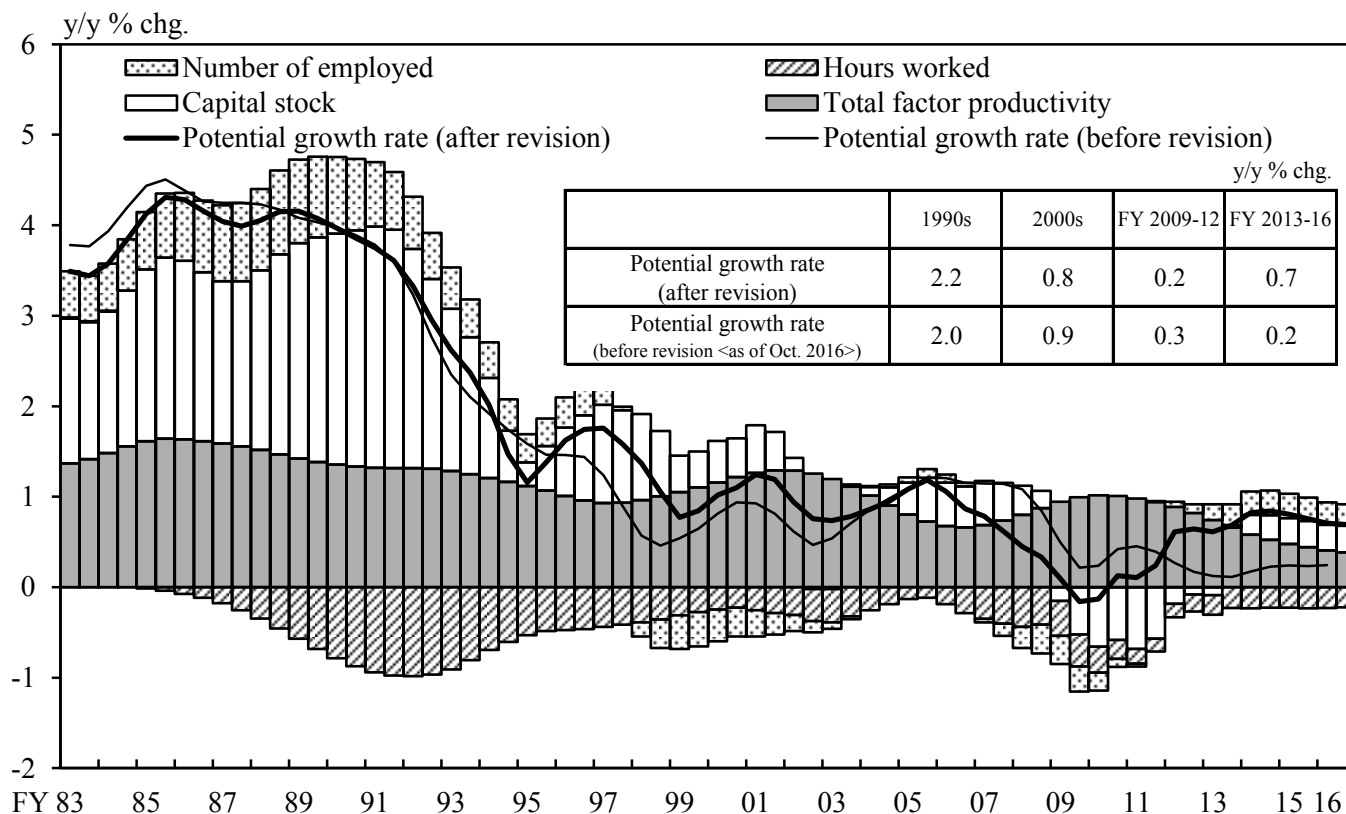
(3) Estimation Errors (year-on-year % change basis)



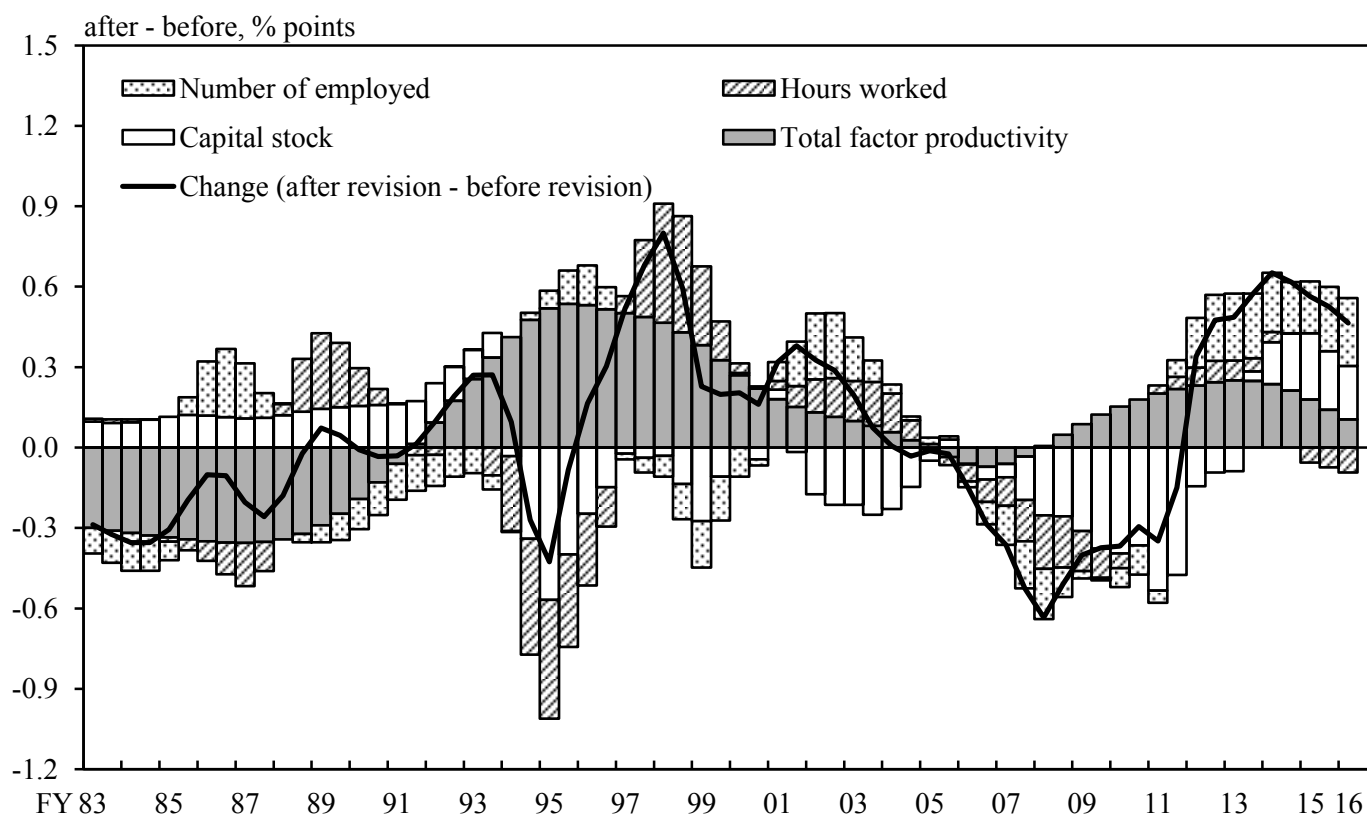
Sources: Ministry of Internal Affairs and Communications; Cabinet Office; Consensus Economics Inc., "Consensus Forecasts," etc.

Revision of the Potential Growth Rate

(1) Potential Growth Rate



(2) Difference between the Potential Growth Rate Before and After the Revision

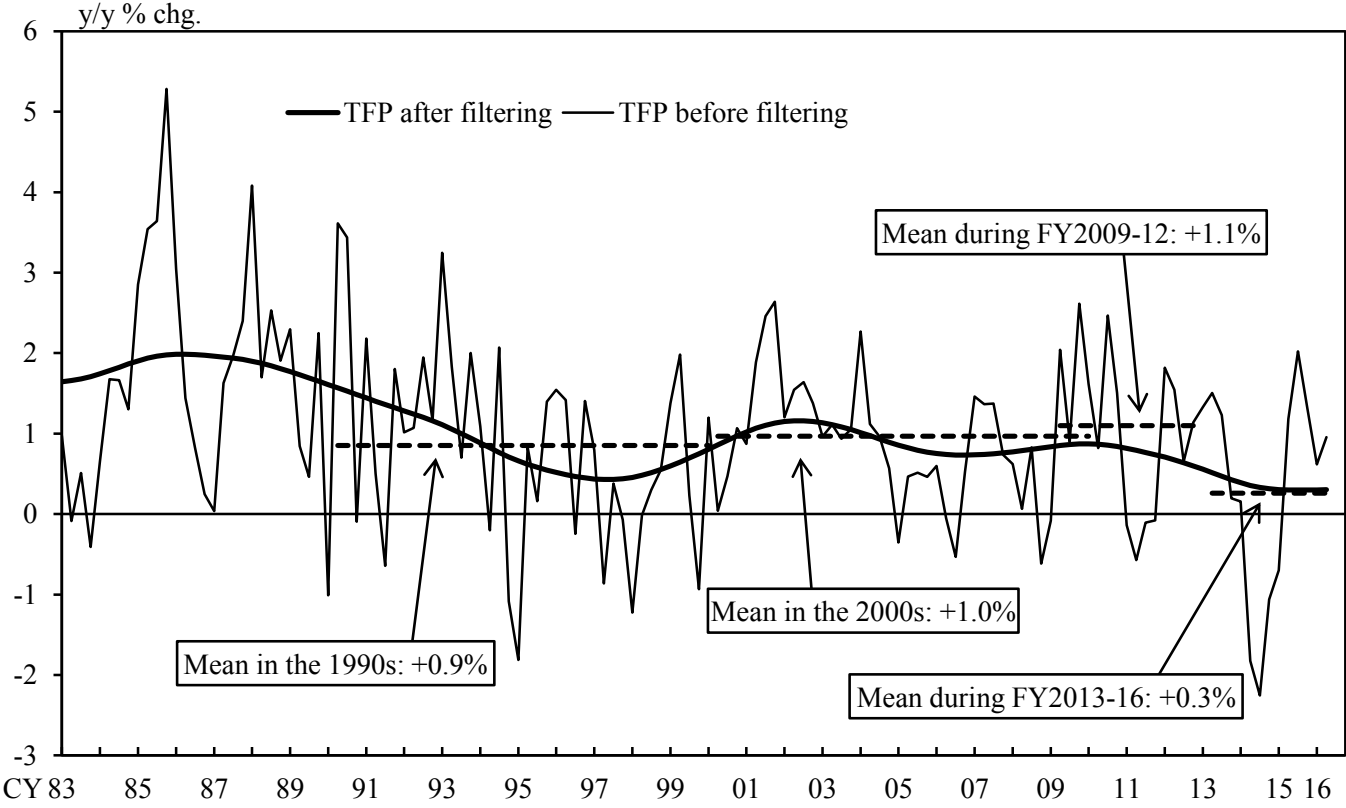


Note: Figures for the second half of fiscal 2016 are those of 2016/Q4. Figures as of Oct. 2016 are up to 2016/Q2.

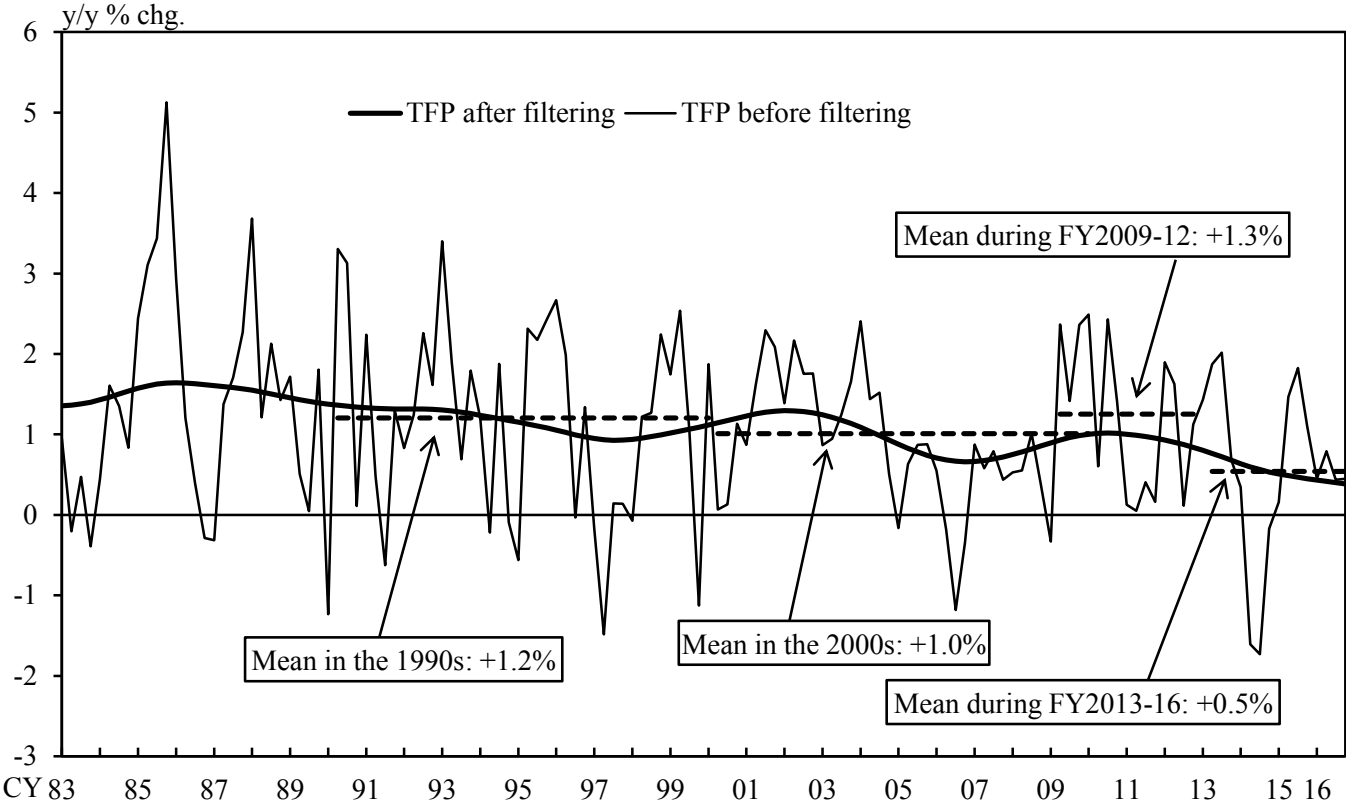
Sources: Cabinet Office; Bank of Japan; Ministry of Internal Affairs and Communications; Ministry of Health, Labour and Welfare; Ministry of Economy, Trade and Industry; Research Institute of Economy, Trade and Industry.

Comparison of TFP Before and After Revision

(1) Before Revision (as of Oct. 2016)



(2) After Revision

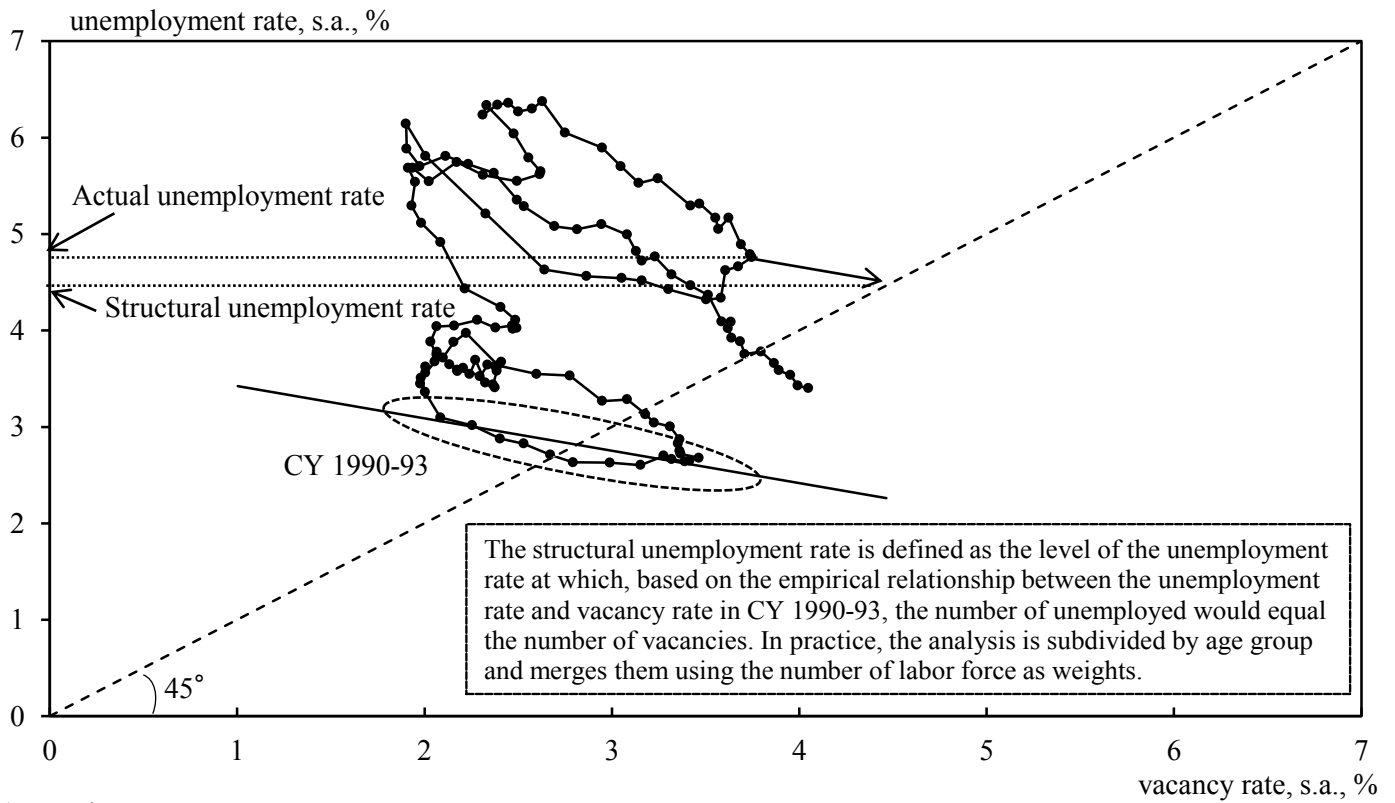


Note: The mean is calculated using TFP before filtering.

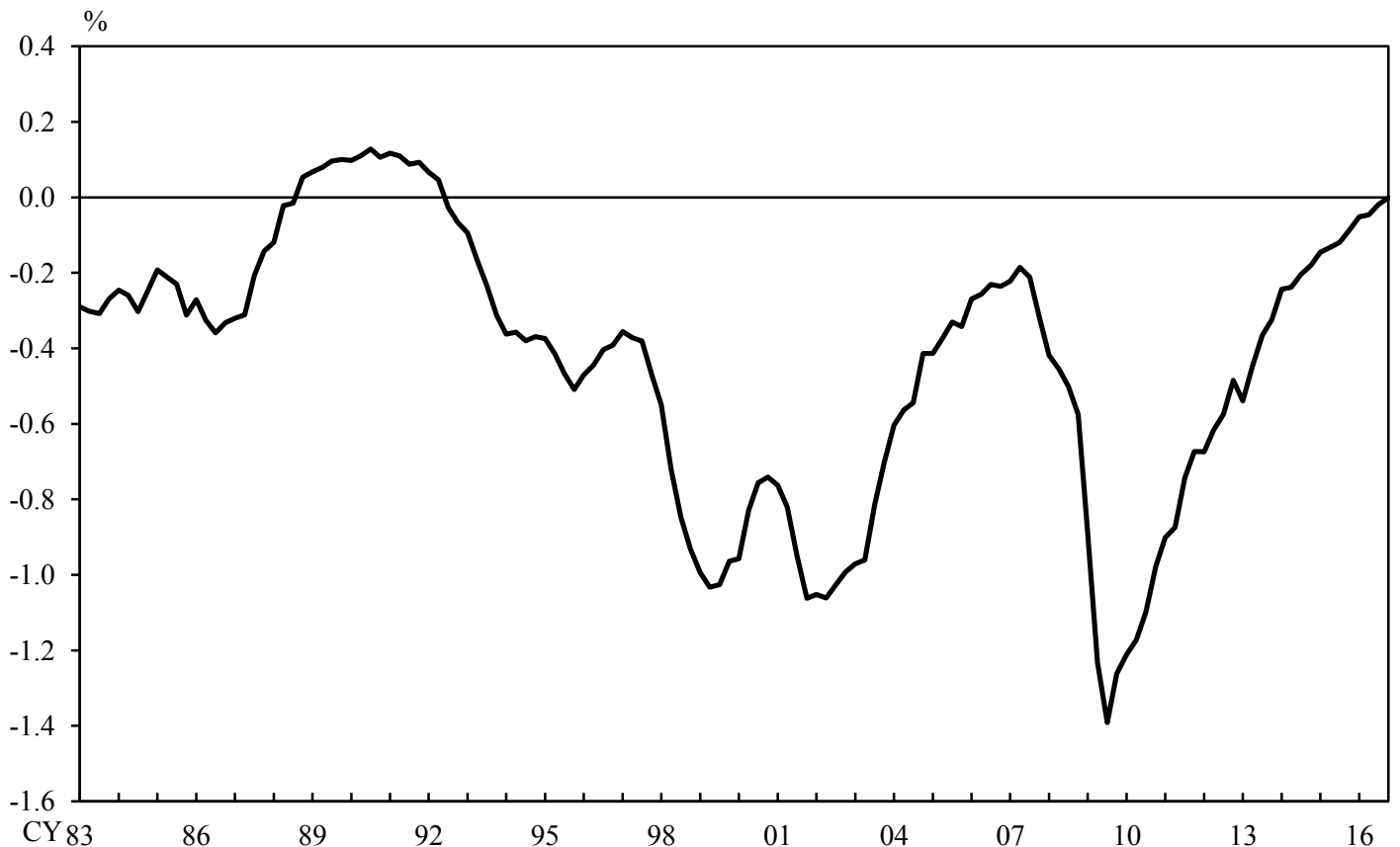
Sources: Cabinet Office; Bank of Japan; Ministry of Internal Affairs and Communications; Ministry of Economy, Trade and Industry; Ministry of Health, Labour and Welfare; Research Institute of Economy, Trade and Industry.

Employment Rate Gap

(1) Unemployment-Vacancy Analysis



(2) Employment Rate Gap



Note: In the unemployment-vacancy analysis, in order to exclude the number of self-employed from the denominator, unemployment is defined as the number of unemployed divided by the sum of the number of employees and unemployed, instead of using the announced unemployment rate.

Sources: Ministry of Internal Affairs and Communications; Ministry of Health, Labour and Welfare.

Utilization Gap in Nonmanufacturing

(1) Production Capacity DI in Nonmanufacturing



(2) Estimation

Estimated Model

$$u_t^{M,adj} = \gamma_0 + \gamma_1 DI_t + \varepsilon_t$$

Estimation Results

Dependent variable: utilization rate in manufacturing, downward-bias-adjusted

Independent variables:		Coefficient	<i>t</i> -value
γ_0	Constant	104.0 ***	238.8
γ_1	Production capacity DI in nonmanufacturing (DI_t)	-1.14 ***	-11.84
Estimation period		1980/Q2 - 2016/Q4	
Adjusted R^2		0.49	
S.E. of regression		5.26	

(3) Utilization Gap in Nonmanufacturing



Note: *** in (2) denotes statistical significance at the 1% level.

Sources: Bank of Japan; Ministry of Economy, Trade and Industry; Cabinet Office.