Working Paper Series

A New Technique for Simultaneous Estimation of the Output Gap and Phillips Curve

Yasuo Hirose [*] ***and Koichiro Kamada*** [**]

Working Paper 01-7

Research and Statistics Department

Bank of Japan

C.P.O BOX 203 TOKYO

100-8630 JAPAN

[*] e-mail: yasuo.hirose@boj.or.jp

[**] e-mail: kouichirou.kamada @boj.or.jp

A NEW TECHNIQUE FOR SIMULTANEOUS ESTIMATION OF THE OUTPUT GAP AND PHILLIPS CURVE

Yasuo Hirose and Koichiro Kamada

Research and Statistics Department, Bank of Japan

October, 2001

We would like to thank Yoichi Matsubayashi (Wakayama University), Sachiko Kuroda Nakada, Shigenori Shiratsuka (the Institute for Monetary and Economic Studies, Bank of Japan), and the many staff of the Research and Statistics Department at the Bank of Japan for their helpful comments. All errors belong to the authors. The opinions expressed here are those of the authors, and should be ascribed neither to the Bank of Japan nor to the Research and Statistics Department. We can be reached at yasuo.hirose@boj.or.jp and kouichirou.kamada@boj.or.jp .

ABSTRACT

A new technique to estimate simultaneously the potential output and Phillips curve is demonstrated. Here we define the potential output as the non-accelerating-inflation level of output (NLO). The NLO is not a mere trend of the actual output, but rather is a critical level of output with the following property: If the actual output is at this level, the inflation rate is neither accelerated nor decelerated. Applying our method to the data on the G7 countries, we estimate the NLO and Phillips curves and investigate their properties. It is shown that during the 1980s and 1990s, the output gap measured from the NLO was negative on average, reflecting the worldwide trend of disinflation. We also point out that the output gap has moved in accordance with corporate sentiments, and thus serves as an indicator of business conditions. In Japan, however, after the potential rate of growth dropped between 1 and 2 percent in the mid-1990s, the output gap was too volatile to allow for accurate evaluation. As for Phillips curves, a cross-country comparison shows that Japan's responsiveness of inflation to the output gap is relatively weak.

(*JEL classification: C63, E30, O40;* keywords: potential output, Phillips curve, Hodrick-Prescott filter)

I. INTRODUCTION

The Phillips curve is a tradeoff between inflation rates and economic activity observed empirically. Since the seminal paper by Phillips (1985), economists have poured a huge amount of time to find its rigid theoretical background and new empirical evidence.[1] In particular, a Phillips curve has strong implications in policy making. Thus, the central bankers, whose ultimate mission is to stabilize price movements, have a special interest in the Phillips curve.

Many of the recent discussions on Phillips curves are related to the estimation of the potential output and the output gap. If we denote the inflation rate by π, the logarithm of the actual output by y, and the logarithm of the potential output by y^N, the simplest form of a Phillips curve is given by

$$\pi_t = \pi_{t-1} + \beta (y_t - y_t^N) + \varepsilon_t . \tag{1}$$

Potential output is defined in various ways. Here, we define the y^N as the *non-accelerating-inflation level of output (NLO)*. If the actual output is at the NLO, the inflation rate is neither accelerated nor decelerated. Given the y^N series, it is easy to estimate the parameter β, based on the standard econometric method (e.g., the ordinary least squares). In estimating a Phillips curve, however, the most problematic is the estimation of y^N. To resolve this problem, we need a technique to estimate y^N and β simultaneously.

Various methods are proposed to estimate the potential output. They are divided into two groups: the production-function approach, and the time series approach. In the former approach, we first estimate an aggregate production function and then substitute a "normal" amount of input in it to calculate the potential output.[2] In the time

---

[1] Turner (1995) and Watanabe (1997) compare Phillips curves across countries. Higo and Nakada (1999) point out the possibility that the properties of Phillips curves are changing over time.

[2] The "normal" amount of production factors is defined in various ways. The following are the definitions of the "normal" state used frequently: (i) where production factors are fully utilized (Kamada and Masuda [2001]); (ii) where production factors are utilized at the rate of the historical average (Economic Planning Agency [2000]); and (iii) where production factors are utilized at such a rate that the inflation rates of the factor prices are stable (Congressional Budget Office [1995]). Our method may be close to the third alternative.

series approach, we view a certain moving average of the actual output as the potential output. The Hodrick-Prescott (HP) filter is a kind of time series approach and is defined as the series y^{HP}, which minimizes the following objective function:

$$\Sigma_{t=1}^{T}(y_t - y_t^{HP})^2 + \theta \cdot \Sigma_{t=2}^{T-1}(\Delta y_{t+1}^{HP} - \Delta y_t^{HP})^2 . \quad (2)$$

The y^{HP} series is so defined as to cling to the actual output (the first term) and as to move smoothly (the second term). The θ determines smoothness in the movements of the y^{HP}. A larger θ forces smoother movements.[3]

Since the y^{HP} obtained through the HP filter is a mere moving average of the actual output, its relationships with prices are quite obscure. Moreover, because of its calculation procedure, the HP filter may not allow the potential output to depart from the actual output for a long time. Hence, replacing y^N by y^{HP} in equation (1) results in a biased estimation of β. As a clue to resolve this problem, suppose that the β is a known parameter and define a new series, z, as follows:

$$z_t = y_t - (\pi_t - \pi_{t-1}) / \beta = y_t^N - \varepsilon_t / \beta .$$

We use equation (1) in the last equality. These equations suggest that we can obtain y^N more accurately by HP-filtering series z, which is adjusted for the developments of the inflation rate, than by HP-filtering series y per se. Since this technique takes the Phillips curve relationship into consideration, it gives y^N a clear definition as the potential output. That is, y^N is the output level such that if the actual output is at this level, the inflation rate is neither accelerated nor decelerated. Our estimation technique developed in the later section hinges upon this insight. Notice that the value of β is necessary to construct the z series. A remarkable feature of our technique is to estimate the potential output and Phillips curve simultaneously, instead of estimating them separately.

The remainder of this paper is constructed as follows. In Section II, we develop the technique for simultaneous estimation of the potential output and Phillips curve formally. In Section III, we apply our method to Japanese data and estimate the potential output and the output gap (the deviation rate of the actual output from the potential output) in Japan from the 1980s.[4] We claim the practical relevance of our methodology

---

[3] The following values are frequently used for the smoothing parameters of the HP filter: 14400 for monthly data, 1600 for quarterly data, and 100 for annual data.

[4] Unless defined differently, the output gap is referred to as the deviation of the actual output from y^N.

for estimating the potential output from the quantitative point of view. Furthermore, we examine the estimation results of the Phillips curves to evaluate the performance of our technique. We also show that the output gap estimated by our technique serves as an indicator of business conditions. If the data on prices and output are in hand, our technique immediately enables us to calculate the potential outputs. In Section IV, we exploit this useful property and calculate the output gap for the G7 countries, based on the actual data. We compare the Japanese output gap with those of other countries, thereby clarifying some characteristics of the Japanese economy. In doing so, we also examine the quantitative importance of our methodology for the G7 countries. In Section V are the caveats in making use of our technique. In Section VI, we conclude our discussion by summing up the results of this paper.

II. THE FILTER

In general, the expectations-augmented Phillips curve is written as follows:

$$\pi_t = \pi_t^e + \beta(y_t - y_t^N) + \varepsilon_t \,,$$

where π is the inflation rate, π^e is the expectation of the inflation rate, y is the logarithm of the actual output, and y^N is the logarithm of the potential output. Hence, we can interpret equation (1) to assume the static expectations: $\pi_t^e = \pi_{t-1}$. Equation (1) is called the NAIRU (non-accelerating-inflation rate of unemployment) type of Phillips curve. According to this Phillips curve, the inflation rate is accelerated with y above y^N, while it is decelerated with y below y^N. In this paper, we call y^N the non-accelerating-inflation level of output (NLO). Below, we relax the assumption of the static expectations slightly and estimate the following Phillips curve instead.

$$\pi_t = \alpha \cdot \pi_{t-1} + (1-\alpha)\pi_{t-2} + \beta(y_t - y_t^N) + \varepsilon_t \,. \qquad (3)$$

We may consider a more complicated model by including changes in the exchange rates as an explanatory variable. We discuss such extensions in the later section.

Thus, our definition here is different from the output gap by Kamada and Masuda (2001) (i.e., the deviation rate of the actual output from the maximum level of output).

In this paper, we estimate the output gap and Phillips curve simultaneously under the assumption that the potential output moves smoothly. Basically, the principle of our technique is the same as that of the ordinary least squares (OLS), minimizing the regression residuals of the Phillips curve. We, however, minimize the following objective function, which is slightly more complicated than the objective function used in deriving the OLS estimator.

$$V(\alpha, \beta, y_1^N, \cdots, y_T^N) \equiv \Sigma_{t=1}^{T}\{\pi_t - \alpha \cdot \pi_{t-1} - (1-\alpha)\pi_{t-2} - \beta(y_t - y_t^N)\}^2 + \lambda \cdot \Sigma_{t=2}^{T-1}(\Delta y_{t+1}^N - \Delta y_t^N)^2 . \quad (4)$$

The one and only difference between equation (4) and the objective function for the OLS is the existence of the sum of squares at the end of the equation. This term is the total amount of penalty for abrupt changes in the potential rate of growth (Δy^N). As λ becomes large, y^N moves smoothly. In the one limit, when λ is infinitely large, y^N moves on a linear trend. In the other limit, when λ is zero, y^N is so determined as to achieve the perfect fit of the Phillips curve into the data.

Our objective is to determine the $T+3$ unknowns, α, β, ($y_1^N, \cdots, y_T^N$), and λ, that minimize the V. It is inefficient, however, to solve for all of these unknowns at once. Rather, we take the following two-step approach. In the first stage, we fix the α and β at arbitrary values and, given them, solve for the optimal ($y_1^N, \cdots, y_T^N$). In doing so, it is convenient to use the fact that the same result is obtained by minimizing $W \equiv V / \beta^2$ defined below, instead of the V.

$$W(\alpha, \beta, y_1^N, \cdots, y_T^N) \equiv \Sigma_{t=1}^{T}(z_t - y_t^N)^2 + \mu \cdot \Sigma_{t=2}^{T-1}(\Delta y_{t+1}^N - \Delta y_t^N)^2 , \quad (5)$$

where $z_t \equiv y_t - \{\pi_t - \alpha \cdot \pi_{t-1} - (1-\alpha) \cdot \pi_{t-2}\} / \beta$ and $\mu \equiv \lambda / \beta^2$. Note that equation (5) is similar to equation (2), which defines the HP filter. The one and only difference is that in equation (5), the y in equation (2) is replaced with the z, which is adjusted for the inflation rate. This similarity suggests that we can readily obtain the T unknowns, ($y_1^N, \cdots, y_T^N$), that minimize the W by HP-filtering the z series. Let $W^*(\alpha, \beta)$ be the minimum value thus obtained. Note that W^* is the minimum value contingent on α and β. In the second stage, we choose the optimal values for α and β to minimize $\beta^2 \cdot W^*(\alpha, \beta)$. This leads us to the minimum value of V.

Next, we discuss how to choose the value of λ. Although λ is an indispensable determinant of y^N, it is μ that directly governs the smoothness in the behavior of y^N, as is clear from equation (5). Since we use quarterly data in this paper, we choose the value of λ such that $\mu = 1600$, as in Hodrick and Prescott (1997). Given the arbitrary value of λ, the minimization procedure developed above returns the optimal value for β. This enables us to calculate $\mu\,(= \lambda / \beta^2)$. It does not necessarily follow that $\mu = 1600$, however. The algorithm we use in this paper is so designed as to search for the value of λ that achieves $\mu = 1600$ eventually (see the appendix for the detailed calculation procedure).[5]

III. POTENTIAL GROWTH AND OUTPUT GAP IN JAPAN

The potential output estimated in this paper is not a simple trend of the actual output, but is rather the output level such that the inflation rate is neither accelerated nor decelerated if the actual output is at that level. In the previous section, we named this output level the NLO and explained its calculation procedure in detail. Yet, the importance of calculating the NLO depends on how far it diverts from a simple trend of the actual output and on how seriously the divergence affects the estimation of a Phillips curve. The purpose of this section is to show quantitatively the importance of

[5] Laxton and Tetlow (1992) reached a similar method for measuring the potential output, and called it the multivariate (MV) filter. They start with the y^{HP} series and add the information obtained from the Phillips curve regression. Haltmaier (1996) is a good source for clarifying the differences between the MV filter and ours in estimating the potential output. The first step of the MV filter is to calculate the y^{HP} by HP-filtering the actual output. The second step is to estimate a Phillips curve, taking the y^{HP} as a "temporary" potential output. Denote the estimated parameters by $\hat{\alpha}$ and $\hat{\beta}$. The third step is to construct the following objective function $\tilde{V}$.

$$\tilde{V} = \Sigma_{t=1}^{T}(y_t - y_t^{LT})^2 + \lambda \cdot \Sigma_{t=2}^{T-1}(\Delta y_{t+1}^{LT} - \Delta y_t^{LT})^2 + \psi \cdot \Sigma_{t=1}^{T}\{\pi_t - \hat{\alpha} \cdot \pi_{t-1} - (1-\hat{\alpha})\pi_{t-2} - \hat{\beta}(y_t - y_t^{LT})\}^2.$$

The "final" potential output is the series, y^{LT}, that minimizes the above equation. Note that by ignoring the first term and letting $\psi = 1$, $\tilde{V}$ is reduced to the objective function V defined before. One drawback of the MV filter is that the Phillips curve and potential output are not estimated simultaneously. Therefore, given the y^{LT} as the potential output, when we estimate a new Phillips curve, the newly estimated parameters of the Phillips curve do not coincide with $\hat{\alpha}$ and $\hat{\beta}$ obtained above, unless by accident. Another drawback is that there are no obvious criteria in choosing the value for ψ. We can say that the simultaneous-estimation technique developed in this paper fixes these drawbacks and pushes the Laxton and Tetlow's method one step further.

simultaneously estimating the potential output and Phillips curve. We use the quarterly data on the Japanese consumer price index and real GDP in this section. The sample spans mainly over the 1980s and 1990s.

We investigate the quantitative properties of the NLO in various ways. To begin with, we call y^{HP} the *HP-filtered trend (HPT)* and compare its growth rate with that of the NLO. We assume 1600 for the smoothing parameter in calculating the HPT as well as the NLO. Next, we call the percentage deviation of the actual output from the NLO the *non-accelerating-inflation output level based gap (NAIOG)* and the deviation from the HPT the *HP-filtered output gap (HPOG)*. Below we compare these two gaps to explore the properties of the NLO. Additionally, we show the usefulness of the NAIOG as a business-condition indicator. Finally, we examine the estimation results of Phillips curves and show the quantitative importance in simultaneously estimating the potential output and Phillips curve.

A. *Potential Output in Japan*

Let us consider the potential rate of growth in Japan. To do so, we calculate the growth rates of the NLO and the HPT. Chart 1 (1) shows the results. A substantial difference is observed between the two series. A close examination, however, shows that the difference has shrunk since the mid-1990s. A clear difference is observed before 1995. For instance, in the early 1980s, as the inflation rate declined from the historically high levels recorded during the second oil shock in 1975, the growth rate of the NLO overran that of HPT. Thereafter, the relationship was reversed with the beginning of the asset bubble and then reversed back at the end of the bubble. From 1995 onward, whether we use the NLO or the HPT, the potential rate of growth is found to be around 1 percent per annum.

We can also estimate the Japanese output gap by means of the NAIOG and HPOG. Chart 1 (2) shows the results. It shows that the two output gaps move more or less separately during the 1980s and 1990s. As shown in Chart 1 (3), the NAIOG has been negative since the 1980s (about –1 percent on average). This implies that more downward pressure has been put on inflation rates than the movement of the actual output would suggest. In this way, the NAIOG appropriately reflects the trend of disinflation that we experienced from the mid-1980s onward. In contrast, the HPOG was zero on average and did not capture the downward pressure on the inflation rates. Notice that the difference between the NAIOG and the HPOG is equal to that between the NLO and the HPT. Therefore, we can measure the average difference between the two output gaps by the following root mean squared error:

$$\rho = \sqrt{\frac{\Sigma_{t=1}^{T}(y_t^N - y_t^{HP})^2}{T}}.$$

The average difference between the two gaps since 1980 is 1.5 percent (see Chart 1 (3)). We can also measure the volatility of the business cycle by calculating the standard errors of the two output gaps. The volatility is slightly less than 2 percent in the NAIOG basis, while it is slightly more than 1 percent in the HPOG basis. Note that the HPOG tends to undervalue the amplitude of the business cycle for technical reasons. Since the HPOG is a moving average of the actual output, it cannot depart from the actual output for a long time. Nonetheless, the difference between the NAIOG and the HPOG, which was substantial in the 1980s, had been reduced since the mid-1990s.

The following statistics measures the difference in smoothness (acceleration rates) between the NLO and the HPT.

$$\kappa = \frac{\Sigma_{t=2}^{T-1}(\Delta y_{t+1}^N - \Delta y_t^N)^2}{\Sigma_{t=2}^{T-1}(\Delta y_{t+1}^{HP} - \Delta y_t^{HP})^2}.$$

κ is greater than unity if the NLO moves more abruptly than the HPT does. The κ in Japan is greater than unity (see Chart 1 (3)). This is attributable to the fast changes in the growth rate of NLO that occurred at the beginning and end of the asset bubble period.

B. *Correlation between the Business Cycle and the Output Gap in Japan*

Here we point out the usefulness of the NAIOG as a business-cycle indicator by showing its consistency with other business-cycle indicators. To begin, we compare the consistency of the NAIOG and the HPOG with the *Reference Dates of Business Cycle (RDBC)*, which is published by the Cabinet Office in Japan. In Chart 2 (1), the shaded areas are the downturn phases of the business cycle, i.e., the peak-to-trough periods defined by the RDBC. The consistency is obvious between the NAIOG and RDBC: The NAIOG falls in the shaded areas, while it rises in the non-shaded areas.

Historical episodes confirm the consistency of the NAIOG with business conditions. The NAIOG declined substantially after the second oil shock (February

1980 to February 1983). It then rose until the period of “yen appreciation depression” (June 1985 to November 1986). During the asset-bubble period, the NAIOG increased again and rapidly. It fell rapidly below zero, however, with the bursting of the bubble economy (February 1991 to October 1993). Along with the short-lived boom during the period 1996-97, the NAIOG recovered up to zero.[6] During the recent recession (March 1997 to April 1999), however, it stayed low and was volatile around –1 percent.[7] In contrast, the HPOG was inconsistent with the recession in the early 1980s. During that period, the NAIOG was falling with the yen appreciation depression, while the HPOG was fluctuating around zero percent. Recently, however, the HPOG has moved along with the business cycle, as the NAIOG has.

The *Short-term Economic Survey of Enterprises in Japan (Tankan)* is a business survey conducted by the Bank of Japan. The Bank uses it for a general assessment of Japan’s business conditions. Let us examine the correlation of the NAIOG and HPOG with the *Tankan*. The *Tankan*’s contents range widely. The Business Conditions DI (the share of firms who reported “favorable” net of the share of firms who reported “unfavorable”) is a representative business-sentiment indicator (Chart 2 (2)). It reflects overall evaluation by entrepreneurs on business conditions, such as projections of current profits. The NAIOG’s correlation coefficient with the DI (with no lag and lead) is 0.68, which is greater than the HPOG’s (0.55). This suggests that the NAIOG reflects business sentiments more accurately than the HPOG.

The NAIOG, however, may be misleading as a business-condition indicator when the economy suffers from stagflation, i.e., when recession coexists with high inflation rates. The Japanese economy experienced a typical stagflation over the period 1973-75. Hit by the first oil shock, Japan’s real economic growth decelerated while inflation rates soared. The NLO falls along with a rise in inflation rates (see the expression of z in Section I). That is, the NAIOG is greater than it would be without the rise in inflation rates. Obviously, however, it does not follow that the recession was ameliorated in this case. This is an example to show the imperfection of the NAIOG as a business-cycle indicator.

[6] Below, we ignore the effects of the front-loaded demands that occurred before the rise in the rate of the consumption tax in 1997/I.

[7] The recent fluctuations of the output gap reflect the instability of the GDP statistics directly.

C. *Phillips Curves in Japan*

The reliability of the estimated potential output depends on how successful the estimation of the Phillips curve is. Here we examine the regression results of the Phillips curve estimated simultaneously with the potential output. The following property is helpful in doing so. That is, once the optimal y^N series is obtained and fixed, the second term of equation (4)'s right hand side becomes constant. Therefore, re-estimating equation (3) by OLS immediately provides the diagnostic statistics for the Phillips curve regression such as the coefficient of determination and the *t*-values for the parameters. Chart 3 gives the estimation results. First, R^2 is above 60 percent. Thus, the Phillips curve fits well into the Japanese data.[8] The estimated parameter on the output gap is about 0.026. This means that a 1 percent increase in the output gap raises the inflation rate of consumer prices per annum by about 0.1 percent. This is quite a reasonable estimate in Japan, where the price trend has been relatively stable.

The next question is how significantly the Phillips curve is affected when estimated simultaneously with the potential output, instead of being estimated separately. To see this, we estimate the potential output (or the output gap) and Phillips curve separately. Then we compare the results thus obtained with the Phillips curve estimated simultaneously with the potential output. For comparison, we use two alternative definitions of output gap that are estimated independently of Phillips curves: (i) the HPOG and (ii) the output gap measured from the maximum output obtained from Japan's aggregate production function (see Kamada and Masuda [2001] for the calculation procedure).

We start with the HPOG. The excellent fit is almost untouched even if we use the HPOG instead of the NAIOG. The estimated parameter on the output gap, however, is now 0.012, which is the half of the estimate obtained when we use the NAIOG.

Another alternative for the output gap in a Phillips curve is the one measured

---

[8] Since the model includes no intercept, we cannot define R^2 as usual. Instead, we calculate the quasi-R^2 defined as follows:

$$\text{quasi-}R^2 = \{\Sigma(\pi_t - \overline{\pi})(\hat{\pi}_t - \overline{\hat{\pi}})\}^2 / \{\Sigma(\pi_t - \overline{\pi})^2 \cdot \Sigma(\hat{\pi}_t - \overline{\hat{\pi}})^2\},$$

where $\overline{\pi}$ is the sample mean of π_t, $\hat{\pi}_t$ is the estimated inflation rate, and $\overline{\hat{\pi}}$ is its mean value. It should be noted that the quasi-R^2 encompasses the usual R^2 as a special case and coincides with it if the model includes an intercept.

from the maximum output calculated from Japan's aggregate production function. We denote this output gap by G_t.[9] In this case, we use the following specification:

$$\pi_t = \alpha \cdot \pi_{t-1} + (1-\alpha)\pi_{t-2} + \beta(G_t - G^N) + \varepsilon_t, \qquad (6)$$

where G^N is a constant; it is called a *natural rate of the output gap*. When we use G_t instead of y^N, the quasi-R^2 declines by 8 percent. Moreover, the estimated parameter on the output gap is much smaller than that obtained when we use y^N. The NAIRU type Phillips curve like equation (6) fits into the data only poorly.[10] To sum up, when the NAIOG is replaced with the other definitions of output gap, the sensitivity of the inflation rate to the output is reduced and thus the NAIRU-type Phillips curve hardly holds.

IV. POTENTIAL GROWTH AND OUTPUT GAP IN THE G7 COUNTRIES

In the previous section, to show the importance of simultaneously estimating the Japanese output gap and Phillips curve, we compared the NLO with the HP-filtered actual output and the NAIOG with various business-condition indicators. These comparisons led us to characterize the Japanese economy from various perspectives, including potential growth, output gap, and sensitivity of inflation rates to the business conditions. Yet, the analysis focusing solely on Japan cannot provide sufficient

---

[9] Kamada and Masuda (2001) define the output gap as the percentage deviation of the actual output from the maximum level of output (y^*). G^N is considered the normal level of economic activity in terms of Kamada and Masuda's output gap. It can be called a natural rate of output gap. We can define the associated level of output by $\tilde{y}_t \equiv y_t^* + G^N$. Then we have $G_t - G^N = y_t - \tilde{y}_t$ from $G_t \equiv y_t - y_t^*$. This shows that equation (6) corresponds to equation (3) exactly.

[10] When we estimate a Phillips curve with the output gap from Japan's aggregate production function as an explanatory variable, we treat the natural rate of output gap, G^N, as a constant. In contrast, Hirose and Kamada (2000) assume a time-variant G^N and show that the parameter on the output gap is inferred to be significantly different from zero. Note, further, that if we replace the output gap by the unemployment rate in equation (1), we obtain Gordon's (1997) time-varying NAIRU.

information to allow for a full characterization of the Japanese economy. Fortunately, as discussed in Section II, our new technique is applicable to any economy with data on prices and production—say, real GDP—at hand. To exploit this advantage, we extend our analysis toward all the G7 countries. Comparisons of Japan's results with that of the other G7 countries help us to clarify the characteristics of the Japanese economy further.

The main purpose of the previous section is to show that the potential output and Phillips curve estimated simultaneously are significantly different from those estimated separately. Here we analyze all the G7 countries similarly and thereby confirm the importance of the simultaneous estimation of the potential output and Phillips curve effectively. We pursue this purpose by making cross-country comparisons among the G7 countries. Our specific interests are as follows: How far does the NLO divert from the HPT? How different is the NAIOG from the HPOG? How strongly are the NAIOG and HPOG correlated with business-condition indicators? How significantly does the difference between the NAIOG and the HPOG affect the estimation results of Phillips curves?[11]

A. *Potential Output in the G7 Countries*

The potential growth of the G7 countries is measured either by the growth rate of the NLO or by that of the HPOG. Chart 4 shows that a measurement of potential growth is heavily dependent on a definition of potential output, as seen in the analysis of the Japanese economy. There are two typical patterns in differences between the NLO growth and the HPT growth. The first group includes the United Kingdom (UK) and the United States (US). In these countries, the growth pattern of the NLO is similar to that of the HPT. Hence, the measurements of potential growth are relatively unambiguous. We can conclude that in the latter half of 1990s, the UK achieved about 3 percent potential growth; that of the US was approximately 4 percent. The second group includes France and Italy. In these countries, the NLO growth rate often moved in the opposite direction to the HPT growth rate. Consequently, in both countries, the HPT

---

[11] For simplicity, we assume equation (3) as a common specification of Phillips curves for all the G7 countries. Appropriate specifications may vary across countries. In particular, the current inflation rate may depend on the previous quarter's output gap rather than on the current output gap for some countries. Furthermore, the lag structure of inflation rates on the right-hand side of a Phillips curve may vary across countries. It should be noted that taking these country-specific factors into consideration may affect the estimation results presented in this paper.

growth was near 2 percent, whereas the NLO growth was below 1 percent.

The following hypothesis may explain the differences between the two groups. In the late 1990s, the boom in the United States was led by growth in the information industries. The information industries succeeded not only in cultivating new demands but also in expanding production capacity due to the enhanced economic efficiency. One consequence was a boom with little inflation. To the contrary, the boom in the Continental countries was not necessarily accompanied by the expansion of production capacity. As a result, the increased aggregate demands pushed up inflation rates, and thus the NLO growth stayed low.

We can measure the output gap in each country in terms of the NAIOG. The means of the NAIOG were negative in the most G7 countries, though ranging widely from – 0.9 percent in the UK to + 0.5 percent in Canada (Chart 5). These figures result from the worldwide trend of disinflation since 1980. In particular, the average NAIOG in Japan was about – 1 percent, the lowest among the G7 countries. This international comparison shows us clearly the strength of the deflationary pressure exerted in Japan. Meanwhile, we can see easily that the average HPOG is 0 percent in each country and failed to identify the deflationary pressure during this period. The ρs, which summarize the differences between the NAIOG and the HPOG, are around 1 percent in all the countries except for Canada. Japan's ρ is the third largest after France and the UK.

Next, we measure the volatility of business cycles in terms of the standard error of the NAIOG. The volatility is slightly less than 2 percent in Japan. The figure is smaller than those in France and the UK, but is almost same as that in the United States. This comparison is imperfect, since the sample periods vary across countries. It points out, however, that the supply-demand balance was not necessarily stable in Japan. It should be noted that for any country, the standard error of the HPOG is smaller than that of the NAIOG. In other words, the HPOG tends to undervalue the volatility of business cycles, although the extent varies across countries.

The differences in smoothness (acceleration) of movements between the NLO and the HPT vary across countries. Furthermore, it is not necessarily true that the NLO moves more abruptly than the HPT, as observed in Japan. The κ measures the difference in smoothness between the movements of the NLO and the HPT. It is greater than unity in the European countries, including France, Germany, and Italy. In contrast, it is less than unity in the other countries, including the US. The latter implies that the NLO moves more smoothly than the HPT. The abrupt movements of the NLO in the

European countries might reflect the three major structural changes that occurred during the 1990s: the unification of Germany (1990), the start of the EU with the Maastricht Treaty coming into effect (1993), and the monetary integration by the introduction of the euro (1999). As shown in the analysis of the Japanese data, it may be misleading to treat the HPT as a proxy for the NLO in an environment where the economic structure is changing rapidly.

B. *Correlation between the Business Cycles and Output Gaps in the G7 Countries*

Here we examine how consistent the NAIOG is with business-condition indicators in the overseas economies. In other words, we check whether the NAIOG is a valid indicator of business conditions internationally (Chart 6). We used the *Tankan* as a business-condition indicator in Japan. Similar business-condition indicators for the G7 countries are as follows: the *Industrial Confidence Indicator* by the European Commission for the European countries (France, Germany, Italy, and the UK),[12] the *NAPM* for the US,[13] and the *Statistics Canada Business Conditions Survey* for Canada.[14]

As we did for Japan, we calculate the correlation coefficients of the NAIOG and the HPOG with business-condition indicators. We show that the NAIOG captures business conditions more accurately than the HPOG does. See Chart 6. In the European countries, the NAIOG's correlation coefficients with business-condition indicators are above 0.5. These are far greater than the HPOG's correlation coefficients with business-condition indicators. In the US, the NAIOG's correlation coefficient is about 0.4. This figure is slightly smaller than those in the European countries. Yet, it is twice as big as the coefficient of the HPOG with a business-condition indicator. Particularly, in France and Italy, as the business sentiments improved, though fluctuating, after the launch of

[12] The European Commission's Industrial Confidence Indicator is a representative business-condition indicator for the EU countries. The indicator is the weighted average of the three DIs for production forecasts, orders received, and product inventories. These DIs are based on business surveys conducted by the research institutes in the member states of the EU.

[13] The NAPM is a representative business-condition indicator for manufacturing sectors in the US. The indicator is the weighted average of the four business-survey-based DIs for production, orders received, product inventories, and employment.

[14] The Statistics Canada's Business Conditions Survey publishes a wide variety of business-survey-based DIs. Among all, we compile the business-condition DI by averaging the three DIs for expected production, new orders, and inventory.

the EU, the NAIOG overran the HPOG. In the 1980s in the UK, the NAIOG rose along with the recovery of the business sentiments, while the HPOG's behavior was not necessarily consistent with such an economic situation. These cross-country comparisons show that in many countries, the NAIOG is correlated more closely with business-condition indicators than the HPOG is.[15]

C. *Phillips Curves in the G7 Countries*

Finally, we examine the regression results of the Phillips curves estimated simultaneously with the potential output. First, we check the diagnostic tests for the Phillips curve regression. When we use the NLO as the potential output, the Phillips curve fits into the data quite well except for France and Germany (Chart 7 (1)). The Durbin-Watson statistics are around 2 for all the countries, which tells us that there is no serial correlation in the residuals of the Phillips curve regression.[16]

With regard to the sensitivity of the inflation rate to the output gap, Japan's Phillips curve belongs to a group with low sensitivity. The sensitivity in Japan is almost the same as that in Italy, half of that in Germany, the UK, and the US, and one third of that in Canada. These cross-country comparisons show that Japan's inflation rate does not respond to the business cycle very much. The sensitivity in France is smaller than that in Japan. The results, however, should be interpreted carefully, since the fit is poor in the Phillips curve regression for France.

Next, we estimate the G7 countries' Phillips curves by replacing the NLO with the HPT (Chart 7 (2)). The results are that the goodness of fit is almost unchanged for each country, while an estimate of the parameter on the output gap is changed for some. That is, though no changes occur in the estimates for the coefficient on the output gap in

---

[15] We assume away leads and lags in calculating correlation coefficients of the NAIOG and the HPOG with business-condition indicators. It may be more sensible, however, to assume the optimal leads and lags for correlation coefficients. In this case, it is shown that differences in correlation coefficients with business-condition indicators between the NAIOG and HPOG are reduced. Nonetheless, the fact is unchanged that the NAIOG's correlation coefficients are greater than the HPOG's, except for Canada. An additional result is that the HPOG delays the business-condition indicators than the NAIOG in some countries.

[16] Since the Phillips curve includes the lags of the left-hand-side variable in the right-hand side, the Durbin-Watson test is likely to conclude that there is no autocorrelation in the regression residuals. Durbin's h is proposed to remedy the problem. But when the sample size is as small as in this analysis, Durbin's h is not necessarily an effective alternative.

Canada, the UK, and the US, estimated figures fall substantially in France and Italy by replacing the NAIOG with the HPOG, as observed in the analysis of the Japanese Phillips curve.

V. CAVEATS

Some caveats are in order here.[17] Our technique makes use of the HP filter and the Phillips curve. Hence, it is likely to inherit their drawbacks. For instance, it is often pointed out that the HP filter lacks economic background. Our method, however, resolves this problem by incorporating the Phillips-curve relationship into the estimation process. The HP filter suffers from other problems, such as the selection of smoothness and the uncertainty of the end-of-sample potential output. The specification of the Phillips curve is also questionable. We discuss these problems below.[18]

A. *Selection of Smoothness*

In this paper, we set a smoothing parameter, μ, of the HP filter at 1600. This figure is often recommended for quarterly data. It is desirable, however, to check from several perspectives whether this choice is appropriate for all the countries and all the time in estimating the potential output.

Theoretically, the potential output depends on the level of μ. It should be quantified, however, to what extent a change in μ affects the estimates of the potential output and thereby the estimation of the Phillips curve. Chart 8 shows how seriously a change in μ affects the NLO, the NAIOG, and the Phillips curve in Japan. The chart tells us that the Phillips curve is untouched when a change in μ is small, say from 1600

[17] There is a large body of literature on the drawbacks of the HP filter. See European Central Bank (2000) for instance.

[18] There may be problems in our technique other than those discussed here. For instance, as Harvey and Jeager (1993) criticize, the HP filter may produce a spurious cycle in a series. Additionally, when the economic structure is changing rapidly, the assumption that the potential output moves smoothly becomes inappropriate. Although these are important caveats, they are beyond our scope and thus ignored in this paper.

to 800 or to 3200. The reason is that almost no changes occur in the NLO. The Phillips curve is affected, however, when we change the level of μ sufficiently, say from 1600 to 160 or to 16000, so that the NLO changes distinctly.

Nonetheless, $\mu = 1600$ is a sensible choice in Japan due to the following reasons. When μ is too small, the NLO moves abruptly and thus does not look like the potential output. To the contrary, when μ is too large, the NAIOG loses its consistency with the business-condition indicator. Therefore, μ should be near 1600. Additionally, as observed in the previous section, the NAIOG moves together with the business-condition indicators in all the G7 countries except for Canada and the US. This is evidence for supporting the choice of $\mu = 1600$ for the G7 countries.

B. *Uncertainty of the Potential Output at the End of Sample*

Basically, the HP filter is a kind of centered moving average of the current observation and the leads-and-lags. There is no data before the beginning of the sample and no data after the end. This implies the possibility that the HP trend is revised every time new data is added. Our method to obtain the potential output includes the HP filter as a part of the estimation process. This implies that the potential output may be updated when new data comes. In particular, a relatively large revision may occur at the end of the sample. This causes a serious problem when policymakers try to measure the output gap accurately and use the measurement in making a real-time assessment of business conditions. Below we examine how seriously the sample addition affects the estimates of the potential output (see also Orphanides and van Norden [1999] and Kamada and Masuda [2001] for similar arguments).

Chart 9 shows how strongly sample addition affects the estimates of the growth rate of the NLO, the NAIOG, and the Phillips curve. The GDP statistics are so volatile in the recent years that a one-year sample addition has a significant effect on the growth rate of the NLO and the NAIOG. More specifically, the NLO may be subject to a four-year-long revision due to a one-year-long sample addition and the NAIOG may be revised by 1 percent. This warns us that careful judgment is required in making use of the NLO and the NAIOG in the real-time assessment of business conditions.

C. *Effects of Exchange Rates on Phillips Curves*

So far our specification of the Phillips curve has excluded the supply-side shocks, such as the introduction and revision of consumption taxes, changes in import prices (particularly oil prices), and changes in exchange rates. If the effects of a shock are short-lived, the HP filter removes the effects. Otherwise, the effects are not filtered out, but the NLO absorbs them.

In the previous section, we show that the NAIOG moves with the business-condition indicators. However, the NAIOG is also affected by the supply-side shocks mentioned above to the extent that the NLO is affected by the supply-side shocks. Suppose for instance that an increase in aggregate demands and an appreciation of the yen occur simultaneously. Prices rise due to the tightening of the goods market. However, the appreciation of the yen induces a fall in import prices and pushes back the inflation rate. A consequence is an increase in the NLO and a fall in the NAIOG.

If one wants to purify the NAIOG as a business-condition indicator, it is necessary to remove the supply-side shocks listed above. One way is to include those supply-side shocks as explanatory variables in the Phillips curve specification. To continue the above case study, we add the appreciation rate of the yen in the right-hand side of the Phillips curve and observe its effects on the estimates of the NLO and Phillips curve. Specifically, we extend the Phillips curve as follows:

$$\pi_t = \alpha \cdot \pi_{t-1} + (1-\alpha)\pi_{t-2} + \beta(y_t - y_t^N) + \gamma \cdot x_t + \varepsilon_t \text{ ,}$$

where x is the appreciation rate of the nominal effective exchange rate of the yen. The necessary extension of estimation procedure is trivial. Thus, we omit its detailed explanation here. One thing to note is that we have a new parameter to estimate, γ .

The estimation result says that the parameter on the appreciation rate is insignificant in terms of *t*-value except for Italy and Japan (Chart 10). As a result, few shifts of the NLO occur, and thus have little influence on the estimates of the other parameters of the Phillips curve. This result suggests that the effects of the yen's appreciation are not included in the NLO, but rather are in the regression residuals of the Phillips curve. Different results, however, may be obtained if we replace the exchange rate by oil prices. That is, a rise in the oil prices can have an impact on the NLO as a huge supply shock and thus on the estimates of the parameters of the Phillips curve.[19]

[19] An extension of our technique is quite easy. In general, it is applicable immediately when a model is written as follows.

$$\pi_t = f(\Gamma, X_t) + \beta \cdot (y_t - y_t^N) + \varepsilon_t \text{,}$$

VI. CONCLUSION

This paper introduced a simple technique to estimate the Phillips curve and potential output simultaneously. By making use of our technique, we simultaneously estimated the Phillips curve and the potential output in the G7 countries in practice and characterized them. The characters of the Japanese economy are summarized as follows.

(i-1) The non-accelerating-inflation level of output (NLO) diverted from the trend of the actual output obtained through the HP filter (HPT). The divergence was especially clear during the 1980s. The diversion, however, had been reduced thereafter. The potential rate of growth was around 1 percent in terms of growth rates of the NLO and the HPT in the late 1990s.

(i-2) The NAIOG (output gap measured from the NLO) is more consistent with indicators reflecting business sentiments than the HPOG (output gap measured from the HPT) and thus serves as a business-condition indicator.

(i-3) The sensitivity of the inflation rate to the output gap declines if the NAIOG is replaced with other output-gap measures. In some cases, the Phillips-curve relationship breaks down.

Next, we investigate characteristics of the Japanese economy through cross-country comparison. The results are summarized as follows.

(ii-1) In the UK and the US, the growth rates of the NLO and the HPT were both 3 to 4 percent during the latter half of the 1990s. To the contrary, in the Continental countries, including France and Italy, the growth rates of the NLO were much lower

---

where $f(\cdot)$ is an arbitrary function, including a non-linear function. The Γ is a parameter to be estimated, X_t is a set of explanatory variables available at period t. In this case, we apply the HP filter to the following series.

$$z_t = y_t - \{\pi_t - f(\Gamma, X_t)\}/\beta \ .$$

than those of the HPT. Additionally, the NLO growth rates in some countries were found to be lower than that in Japan.

(ii-2) Since 1980, the NAIOG had been under zero percent on average in most G7 countries, reflecting the worldwide trend of disinflation. The pressure toward disinflation was particularly strong in Japan.

(ii-3) The NAIOG was more consistent with business-condition indicator than the HPOG for many G7 countries, as observed in Japan.

(ii-4) For some countries, the sensitivity of the inflation rate to the NAIOG was greater than that to the HPOG. This was the case in Japan, but the change in the sensitivity was relatively small compared to other countries.

In making use of our technique, caveats must be mentioned: the choice of smoothness and the uncertainty of the potential output at the end of sample. They are summarized as follows.

(iii-1) The HP-filter smoothness of 1600 is considered reasonable.

(iii-2) Adding a new sample has a significant impact on the estimation of the potential output and the output gap. We should be careful in evaluating the estimate of the potential output at the end of the sample.

The current model does not make clear the factors, such as increases in capital and labor, on which the potential output depends. In particular, the pace of economic productivity growth is important, as is whether or not the NAIRU is changing. To answer to these questions, a model must be built that explicitly takes production factors into consideration (Haltmaier [1996] is one such attempt).

APPENDIX

Algorithm for Numerical Calculation

In this paper, we solve for α, β, λ, and y^N numerically in the following fashion. Roughly speaking, the algorithm consists of three parts: the derivation of the y^N, the calculation of the α and β, and the choice of the λ.

(i) Give λ an arbitrary value.

(ii) Give α and β arbitrary values.

(iii) Construct z out of α and β.

(iv) Calculate μ from λ and β.

(v) Obtain y^N by HP-filtering the z series with smoothness μ.

(vi) Calculate W 's minimum value, W^*.

(vii) Change β by a small amount.

(viii) Repeat the process from (iii) on till the W^* is minimized.

(ix) Change α by a small amount.

(x) Repeat the process from (iii) on till the W^* is minimized.

(xi) Change λ by a small amount.

(xii) Repeat the process from (iii) on till μ is equal to 1600.

Note that once y^N is fixed, the second term in equation (4) becomes a constant. Thus, it is obvious that (α,β), which minimizes the objective function V, also minimizes the first term of equation (4). Therefore, (α,β) obtained by simply estimating the Phillips curve by OLS is theoretically the same as (α,β) obtained by the above algorithm. If the two estimates depart from each other, it is necessary to move α, β, and λ with smaller increments.

REFERENCES

Butler, L., “A Semi-Structural Method to Estimate Potential Output: Combining Economic Theory with a Time-Series Filter (The Bank of Canada’s New Quarterly Projection Model Part 4),” *Bank of Canada Technical Report*, No. 77, 1996.

Congressional Budget Office, “CBO’s Method for Estimating Potential Output,” *CBO Memorandum*, October, 1995.

Economic Planning Agency, *Keizai Hakusho Fiscal 2000* (Economic Survey of Japan Fiscal 2000: The New Era Begins), 2000 (in Japanese).

European Central Bank, “Potential Output Growth and Output Gaps: Concept, Uses and Estimates,” *ECB Monthly Bulletin*, October, 2000, pp. 37-47.

Gordon, J. R., “The Time-varying NAIRU and its Implications for Economic Policy,” *Journal of Economic Perspectives*, Vol. 11, No. 1, 1997, pp. 11-32.

Gordon, J. R., “Foundations of the Goldilocks Economy: Supply Shocks and the Time-Varying NAIRU,” *Brookings Papers on Economic Activity*, No. 2, 1998, pp. 297-346.

Haltmaier, J., “Inflation-Adjusted Potential Output,” *Board of Governors of the Federal Reserve System International Finance Discussion Papers*, 561, 1996.

Harvey, A. C., and A. Jeager, “Detrending, Stylized Facts and the Business Cycle,” *Journal of Applied Econometrics*, Vol. 8, 1993, pp. 231-47.

Higo, M., and S. K. Nakada, “How Can We Extract a Fundamental Trend from an Economic Time-Series?,” *Money and Economic Studies*, Vol. 16, No. 2, 1998, pp. 61-111.

Higo, M., and S. K. Nakada, “What Determines the Relation Between the Output Gap and Inflation? An International Comparison of Inflation Expectations and Staggered Wage Adjustment,” *Money and Economic Studies*, Vol. 17, No. 3, 1999, pp. 129-155.

Hirose, Y., and K. Kamada, “Time-Varying NAIRU and Potential Growth in Japan,” Research and Statistic Department, Bank of Japan, mimeo, 2000.

Hodrick, R. J., and E. C. Prescott, “Postwar U.S. Business Cycles: An Empirical Investigation,” *Journal of Money, Credit, and Banking*, Vol. 29, No. 1, 1997, pp. 1-

16.

Kamada, K., and K. Masuda, “Effects of Measurement Error on the Output Gap in Japan,” *Money and Economic Studies*, Vol. 19, No. 2, 2001, pp. 109-154.

Laxton, D., and R. Tetlow, “A Simple Multivariate Filter for the Measurement of Potential Output,” *Bank of Canada Technical Report*, No. 59, 1992.

Orphanides, A., and S. van Norden, “The Reliability of Output Gap Estimates in Real Time,” *Board of Governors of the Federal Reserve System Finance and Economic Discussion Paper Series*, No. 38, 1999.

Phillips, A. W., “The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861-1957,” *Economica*, No. 25, 1958, pp. 283-99.

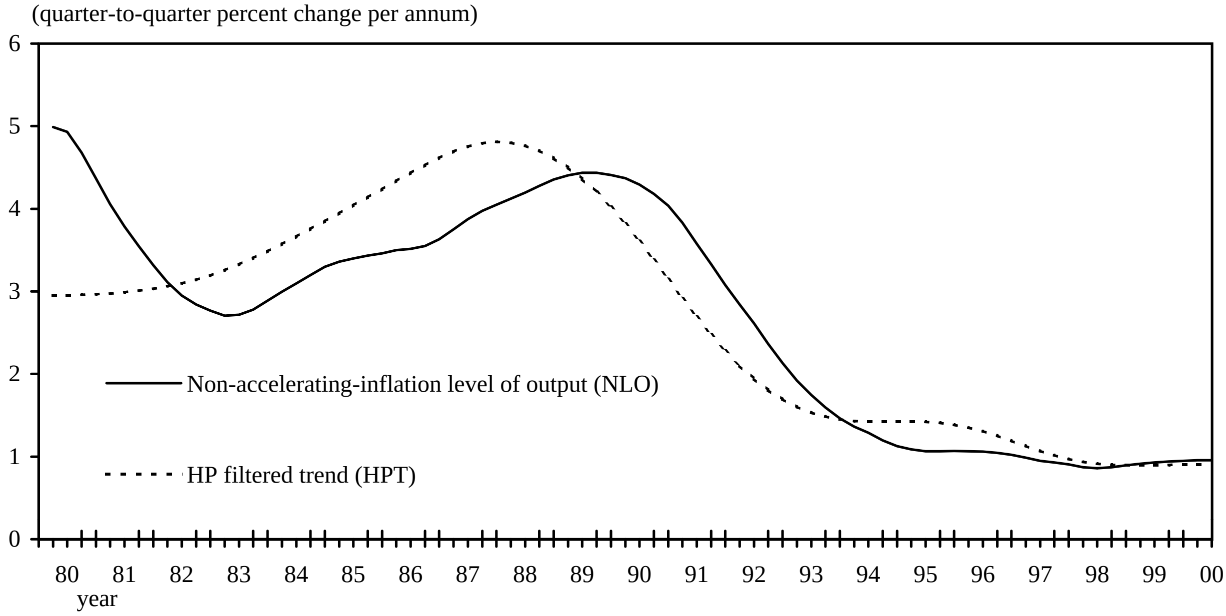
Turner, D., “Speed Limit and Asymmetric Inflation Effects from the Output Gap in the Major Seven Economies,” *OECD Economic Studies*, No. 24, 1995, pp. 57-87.

Watanabe, T., “Output Gap and Inflation: The Case of Japan,” *BIS Conference Papers: Monetary Policy and the Inflation Process*, Vol. 4, 1997, pp. 93-112.

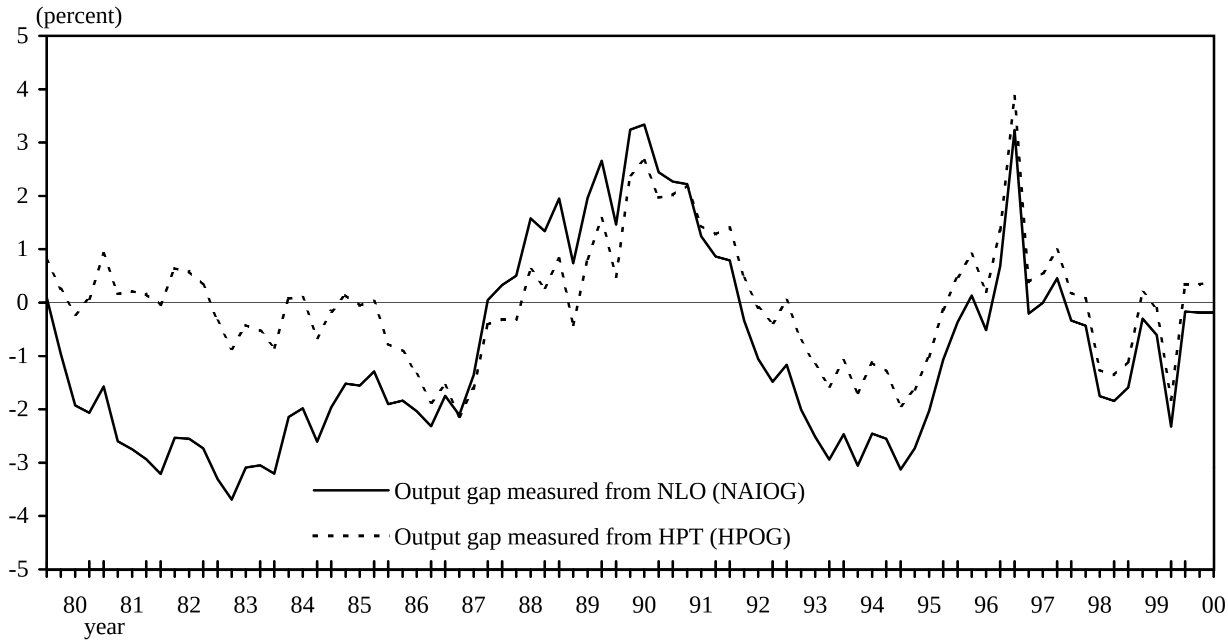
(Chart 1)

Potential Rate of Growth and Output Gap in Japan

(1) Potential Rate of Growth



(2) Output Gap



(3) Basic Statistics

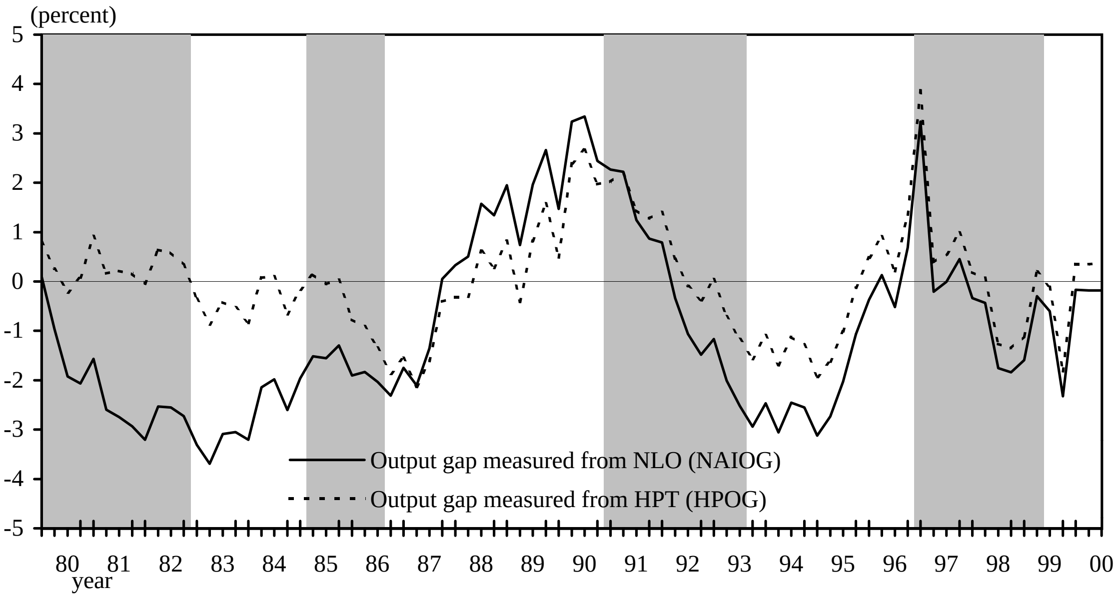
Output gap	Mean	Standard error	ρ	κ	Sample
NAIOG	-0.925	1.790	0.015	2.108	1980/I-2000/III
HPOG	0.000	1.130			

Sources: Cabinet Office, *National Accounts* ; Ministry of Public Management, Home Affairs, Posts and Telecommunications, *Consumer Price Index* .

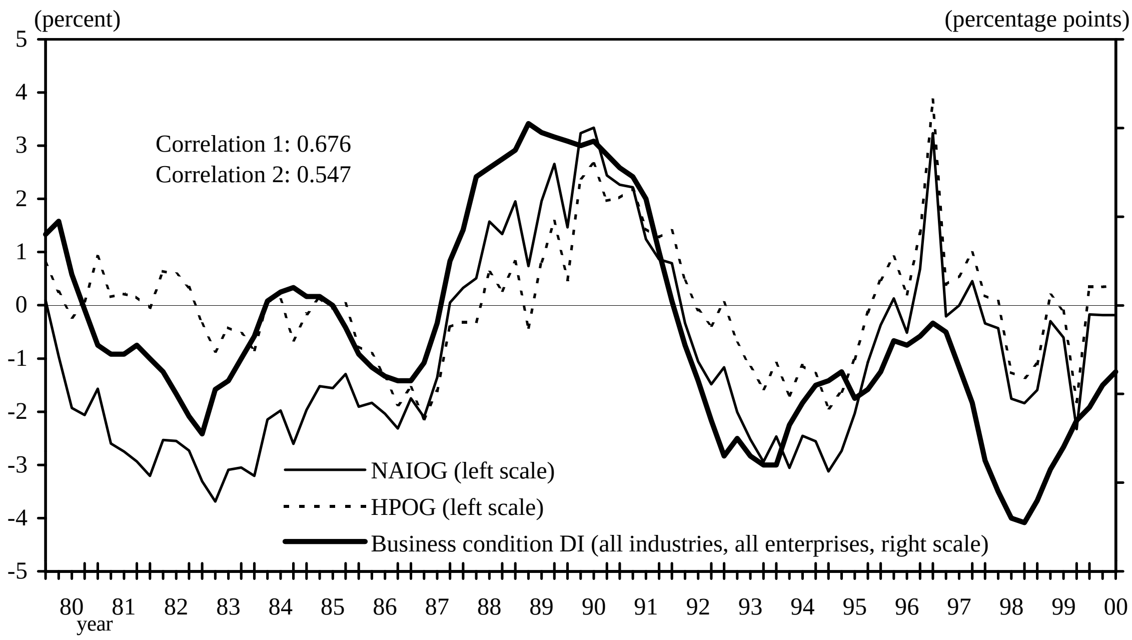
(Chart 2)

Consistency of the Output Gap with Business Condition Indicators in Japan

(1) Consistency with Reference Dates of Business Cycle



(2) Consistency with Business Condition DI of TANKAN



Notes: Correlation 1 refers to the correlation coefficient of NAIOG with business condition DI;
Correlation 2 refers to the correlation coefficient of HPOG with business condition DI.

Sources: Cabinet Office, *National Accounts, Reference Dates of Business Cycle*;
Ministry of Public Management, Home Affairs, Posts and Telecommunications, *Consumer Price Index*;
Bank of Japan, *Short-Term Economic Survey of Enterprises in Japan.*

(Chart 3)

Phillips Curves in Japan

<Specification>

Case 1: NLO

$$\pi_t = \alpha \cdot \pi_{t-1} + (1-\alpha)\pi_{t-2} + \beta(y_t - y_t^N) + \varepsilon_t$$

Case 2: HPT

$$\pi_t = \alpha \cdot \pi_{t-1} + (1-\alpha)\pi_{t-2} + \beta(y_t - y_t^{HP}) + \varepsilon_t$$

Case 3: Output gap measured from maximum output

$$\pi_t = \alpha \cdot \pi_{t-1} + (1-\alpha)\pi_{t-2} + \beta(G_t - G^N) + \varepsilon_t$$

<Estimation Results>

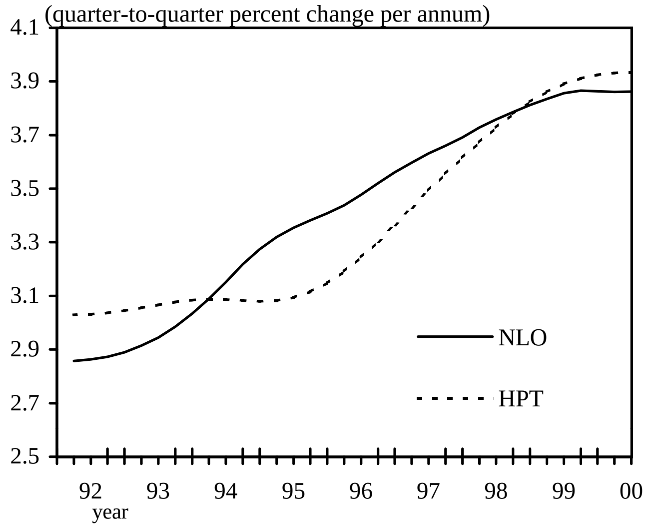
Case	α	β	G^N	R^2	D.W.	Sample
1	0.677	0.026	-	0.635	2.108	1980/I-2000/III
	(6.139)	(1.356)				
2	0.693	0.012	-	0.632	2.083	1980/I-2000/III
	(6.186)	(0.355)				
3	0.561	0.009	-0.047	0.557	2.212	1983/II-2000/III
	(5.461)	(0.796)	(-1.644)			

Notes: 1. Consumer Price Index is adjusted for consumption taxes.
2. Estimation method: the simultaneous estimation developed in this paper for case 1; OLS for cases 2 and 3.
3. t-value in parentheses.
4. R^2 is quasi-coefficient of determination.
5. Smoothness value is 1600 for NLO and HPT.

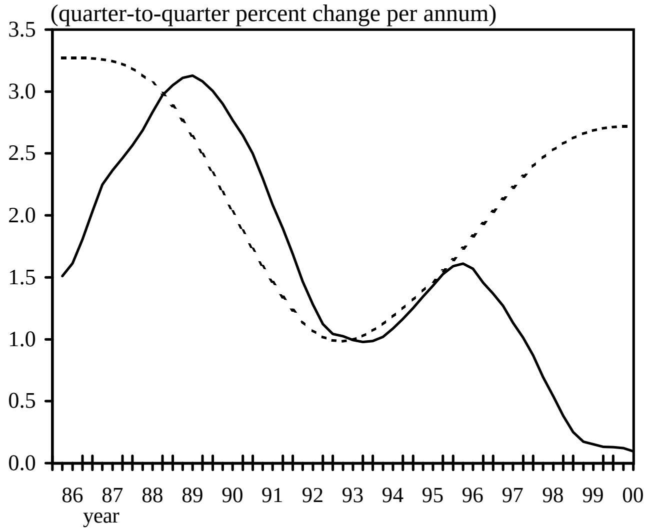
Sources: Cabinet Office, *National Accounts, Gross Capital Stock of Private Enterprises,* etc;
Ministry of Public Management, Home Affairs, Posts and Telecommunications, *Consumer Price Index.*

Potential Rates of Growth in the G7 Countries

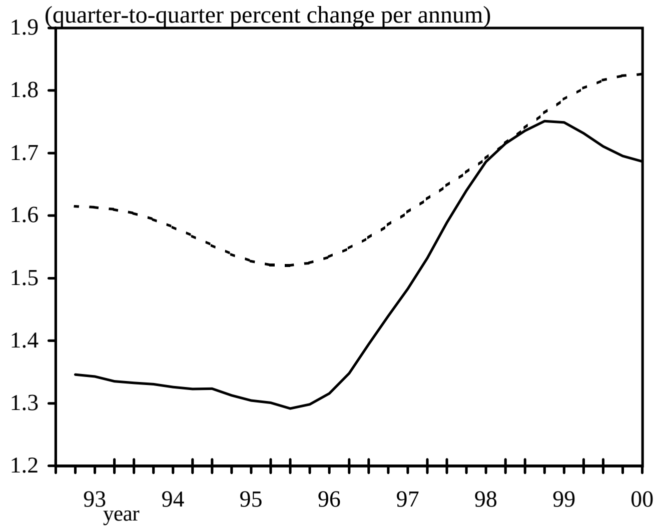
(1) Canada



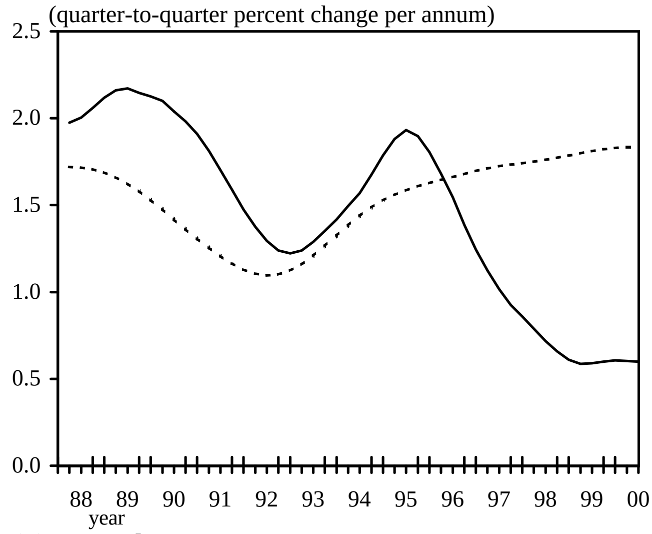
(2) France



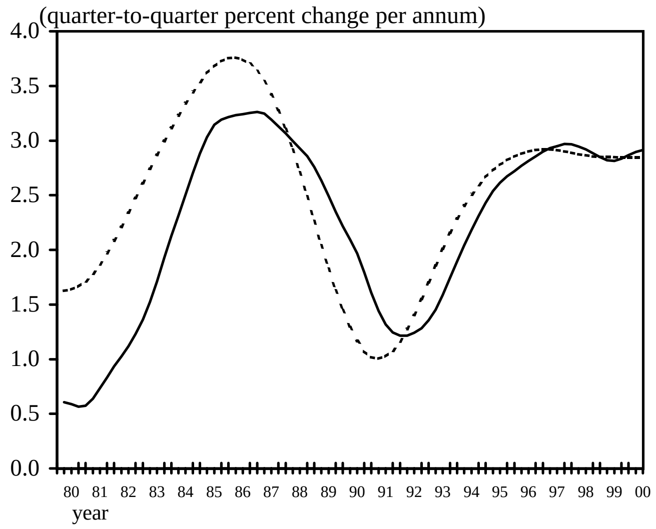
(3) Germany



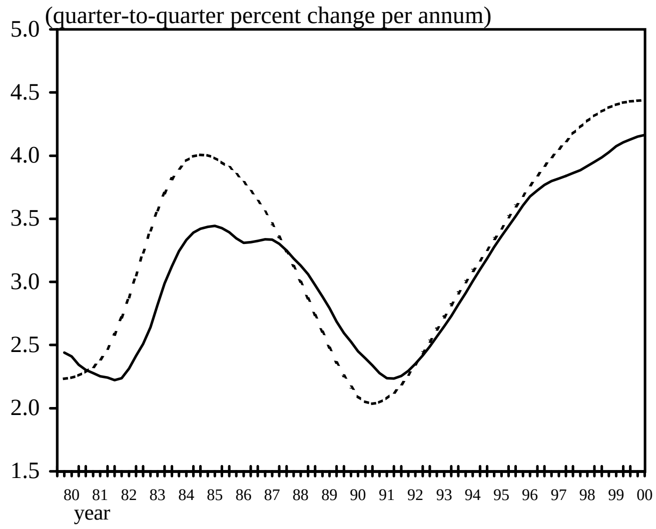
(4) Italy



(5) United Kingdom



(6) United States



Sources: France's GDP is *Comptes Nationaux* by the National Institute of Statistics and Economic Research;
Canada's consumer price index is *CPI excluding food and energy* by the Bank of Canada;
other data are based on *International Financial Statistics* by the International Monetary Fund.

(Chart 5)

Potential Output and Output Gap in the G7 Countries

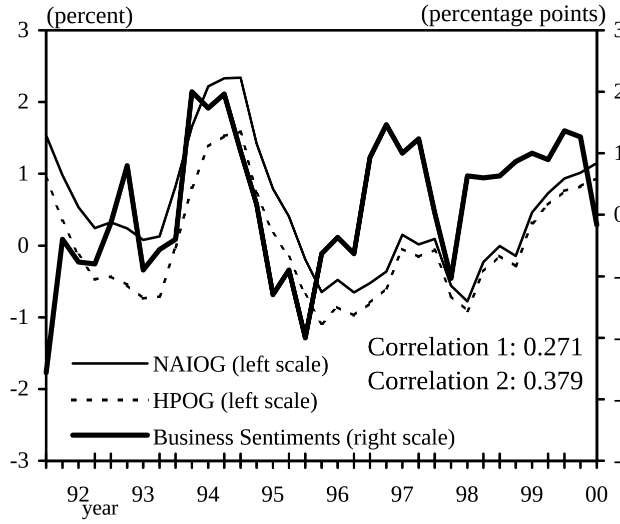
Country	Mean of NAIOG	Standard error of NAIOG	Mean of HPOG	Standard error of HPOG	ρ	κ	Sample
Canada	0.458	0.859	0.000	0.753	0.005	0.918	1992/I-2000/III
France	-0.422	2.246	0.000	0.827	0.019	2.068	1986/I-2000/III
Germany	-0.722	0.635	0.000	0.531	0.008	2.923	1993/I-2000/III
Japan	-0.925	1.790	0.000	1.130	0.015	1.747	1980/I-2000/III
Italy	-0.561	1.344	0.000	0.832	0.012	5.322	1988/I-2000/III
UK	-0.858	2.195	0.000	1.365	0.018	0.930	1980/I-2000/III
US	-0.500	1.815	0.000	1.324	0.011	0.612	1980/I-2000/III

Sources: Japan's data are based on *National Accounts* by the Cabinet Office and *Consumer Price Index* by the Ministry of Public Management, Home Affairs, Posts and Telecommunications;
France's GDP is *Comptes Nationaux* by the National Institute of Statistics and Economic Research;
Canada's CPI is *CPI excluding food and energ* by the Bank of Canada;
other data are based on *International Financial Statistics* by the International Monetary Fund.

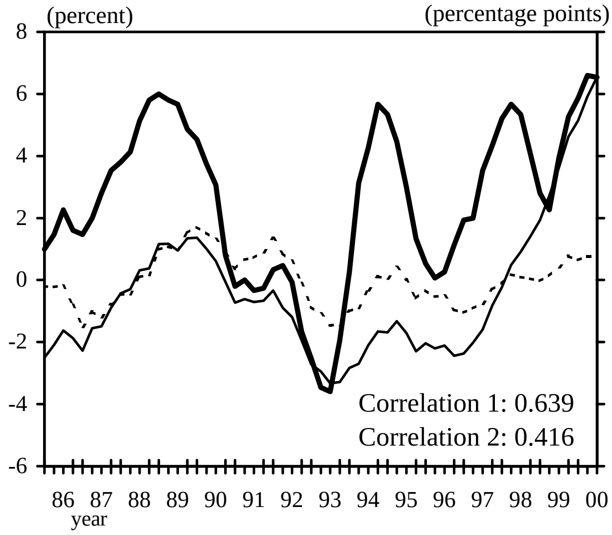
(Chart 6)

Consistency of Output Gap and Business Condition Indicators in the G7 Countries

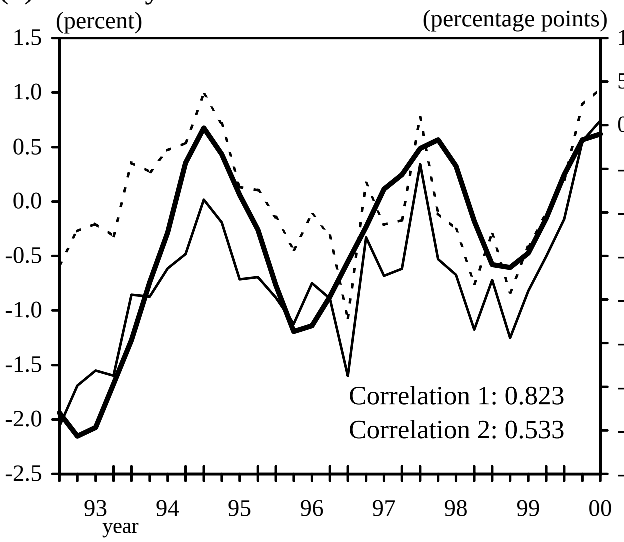
(1) Canada



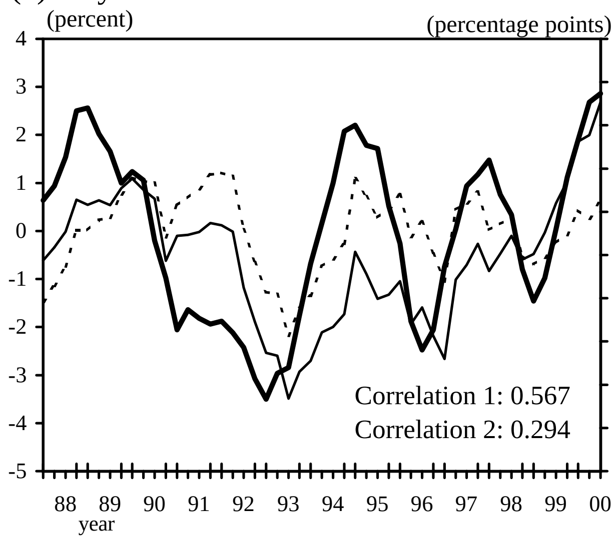
(2) France



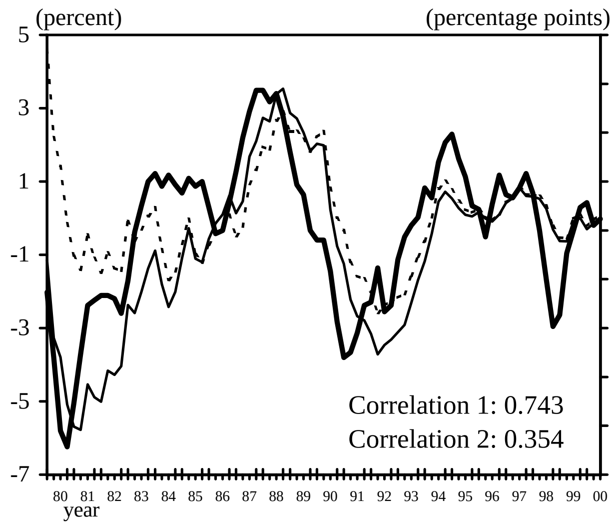
(3) Germany



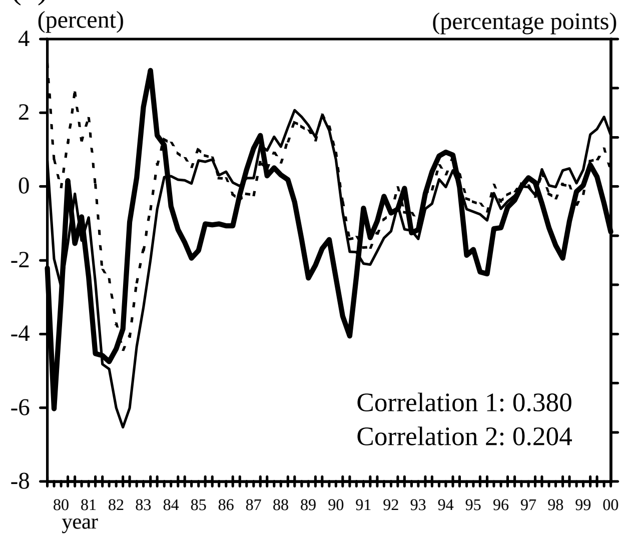
(4) Italy



(5) United Kingdom



(6) United States



Notes: 1. Canada's business condition indicator is a weighted average of expected production, new orders, inventory DIs in *Business Conditions Survey* by Statistics Canada; business condition indicators in France, Germany, Italy, and the UK are *Industrial Confidence Indicators* by European Commission; business condition indicator in the US is *NAPM*.

2. Correlation 1 is the correlation coefficient of NAIOG with the business condition indicator; correlation 2 is the correlation coefficient of HPOG with the business condition indicator.

(Chart 7)

Phillips Curves in the G7 Countries

(1) Phillips Curves with NLO as the Potential Output

Country	α	β	R^2	D.W.	Sample
Canada	0.817	0.090	0.548	2.143	1992/I-2000/III
	(6.507)	(2.290)			
France	0.650	0.015	0.403	2.213	1986/I-2000/III
	(5.026)	(1.063)			
Germany	0.407	0.067	0.482	2.495	1993/I-2000/III
	(2.295)	(0.787)			
Japan	0.677	0.026	0.635	2.108	1980/I-2000/III
	(6.139)	(1.356)			
Italy	0.750	0.028	0.752	2.096	1988/I-2000/III
	(5.358)	(1.179)			
UK	0.653	0.070	0.719	1.856	1980/I-2000/III
	(7.584)	(2.580)			
US	0.724	0.065	0.580	2.192	1980/I-2000/III
	(6.589)	(2.130)			

(2) Phillips Curves with HPT as the Potential Output

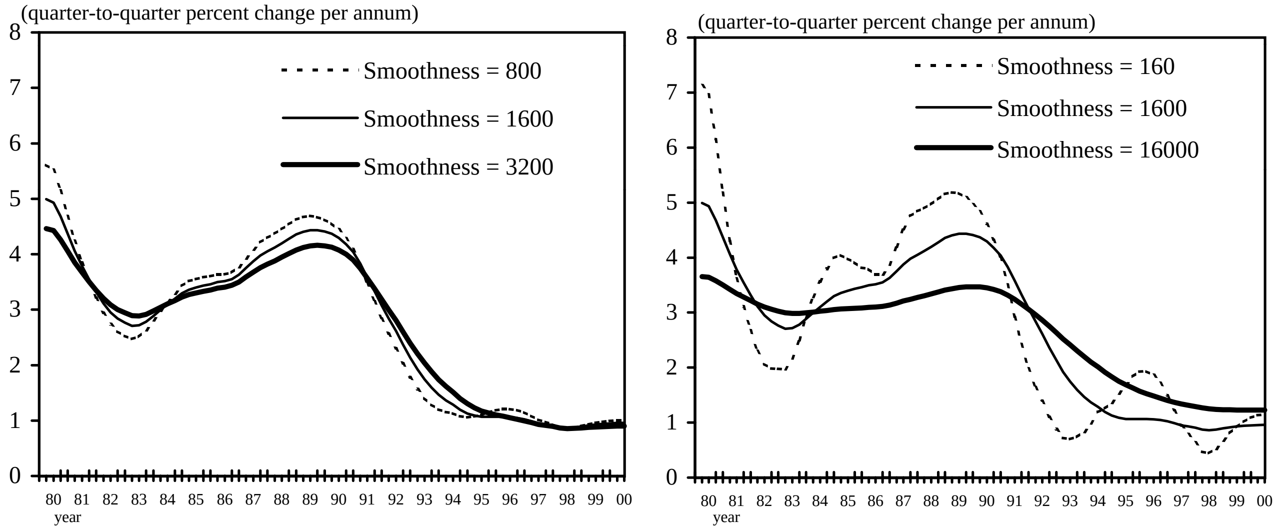
Country	α	β	R^2	D.W.	Sample
Canada	0.813	0.092	0.528	2.029	1992/I-2000/III
	(6.344)	(1.777)			
France	0.660	-0.001	0.396	2.172	1986/I-2000/III
	(5.048)	(-0.036)			
Germany	0.440	0.055	0.496	2.381	1993/I-2000/III
	(2.557)	(0.643)			
Japan	0.693	0.012	0.632	2.083	1980/I-2000/III
	(6.186)	(0.355)			
Italy	0.771	0.009	0.745	2.066	1988/I-2000/III
	(5.434)	(0.217)			
UK	0.705	0.075	0.730	1.823	1980/I-2000/III
	(7.955)	(1.737)			
US	0.743	0.075	0.600	2.153	1980/I-2000/III
	(6.644)	(1.816)			

Notes: 1. Germany's Price index is the GDP deflator; the others are consumer price indexes.
2. Consumer price indexes for France, Italy, and the UK are seasonally adjusted.
3. Japan's consumer price index is adjusted for consumption taxes; the others are unadjusted.
4. A dummy variable is included in regression for Canada to take into consideration the effects of the indirect tax reform in 1994/IV. The coefficient on the dummy is -0.014 (*t*- value = -6.187) for case (1) and -0.013 (*t* value = -5.675) for case (2).
5. *t* -values in parentheses.
6. R^2 is the quasi-coefficient of determination.

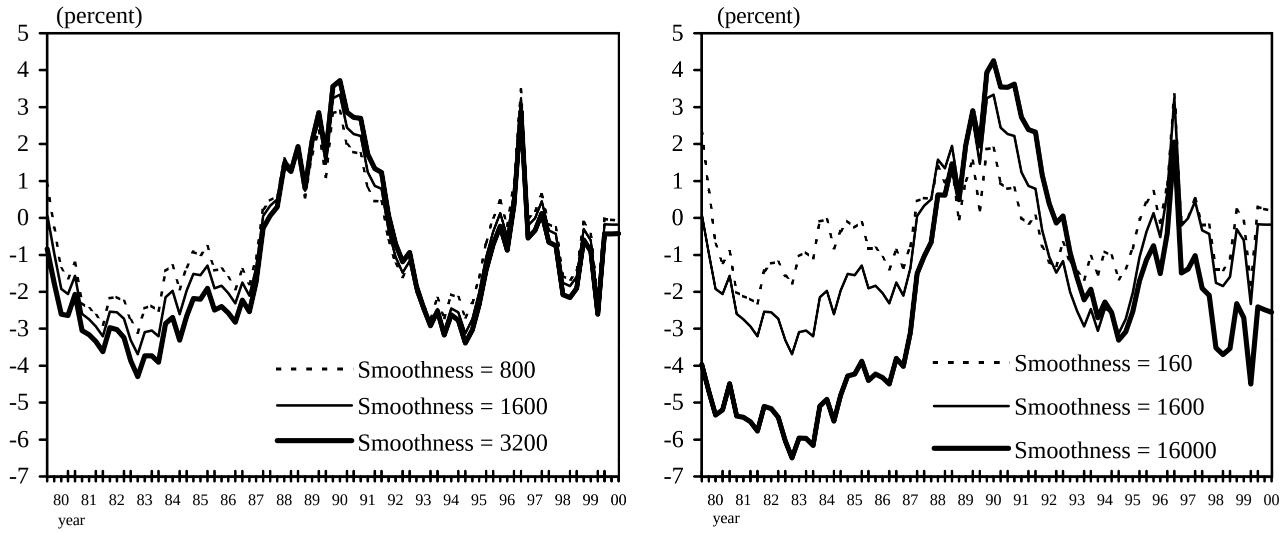
Sources: Japanese data are based on *National Accounts* by Cabinet Office and *Consumer Price Index* by the Ministry of Public Management, Home Affairs, Posts and Telecomunications; France's GDP is based on *Comptes* Nationaux by the National Institute of Statistics and Economic Research; Canada's consumer price index is *CPI excluding food and energy* by the Bank of Canada; the other countries' data are based on *International* Financial Statistics by the International Monetary Fund.

Effects of Changes in Smoothness for Japan

(1) Potential Rate of Growth



(2) Output Gap



(3) Estimated Phillips Curves

Smoothness	α	β	R^2	D.W.	ρ	κ
160	0.656	0.067	0.648	2.159	0.009	2.402
	(6.034)	(2.158)				
800	0.672	0.034	0.638	2.116	0.013	1.964
	(6.119)	(1.539)				
1600	0.677	0.026	0.635	2.108	0.015	1.747
	(6.139)	(1.356)				
3200	0.680	0.020	0.634	2.102	0.017	1.548
	(6.152)	(1.209)				
16000	0.684	0.011	0.630	2.095	0.028	1.169
	(6.157)	(0.947)				

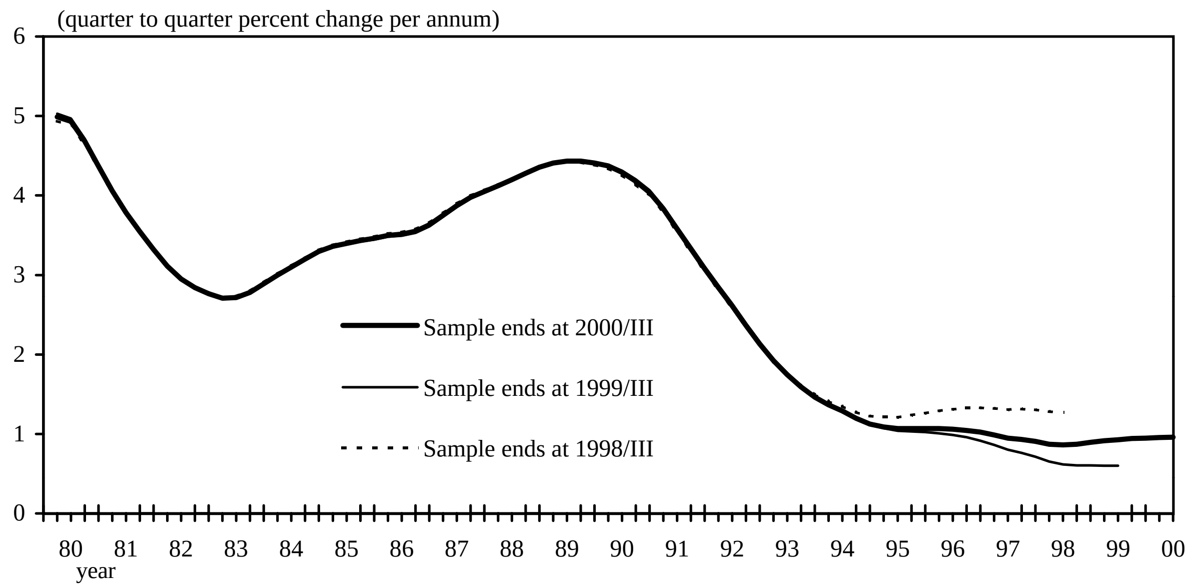
Notes: 1. Sample: 1980/I-2000/III.
2. *t*-value in parentheses.
3. R^2 is the quasi-coefficient of determination.

Sources: Cabinet Office, *National Accounts*; Ministry of Public Management, Home Affairs, Posts and Telecomunications, *Consumer Price Index*.

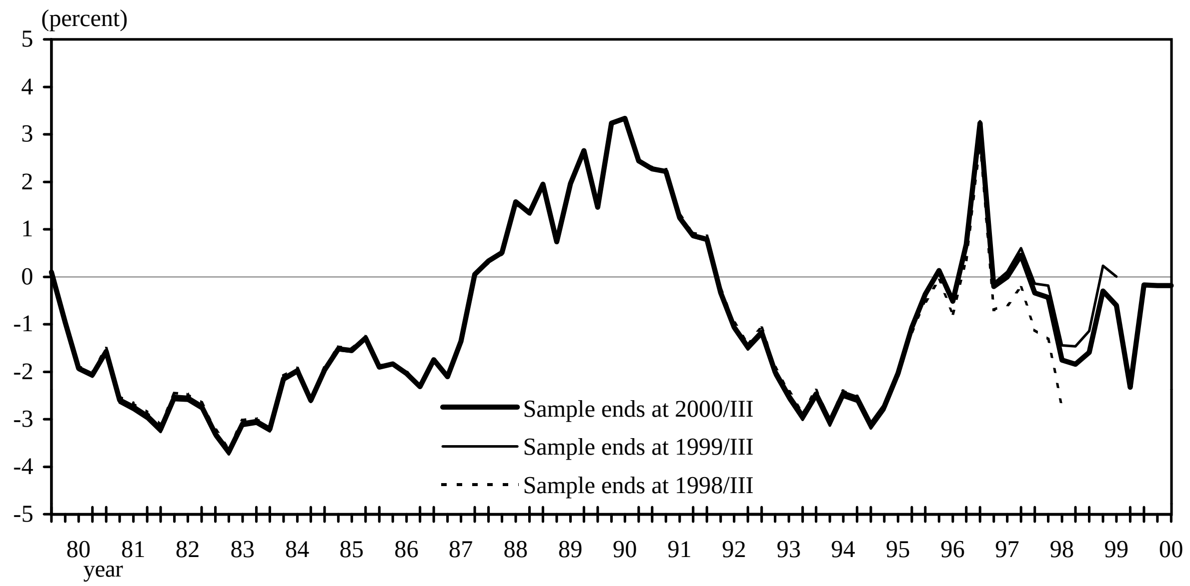
(Chart 9)

Effects of Addition of Sample for Japan

(1) Potential Rate of Growth



(2) Output Gap



(3) Estimated Phillips Curves

Sample	α	β	R^2	D.W.
1980/I-2000/III	0.677	0.026	0.635	2.108
	(6.139)	(1.356)		
1980/I-1999/III	0.678	0.025	0.620	2.109
	(5.992)	(1.293)		
1980/I-1998/III	0.679	0.026	0.610	2.111
	(5.836)	(1.292)		

Notes: 1. Consumer Price Index is adjusted for effects of consumption tax reforms.
2. *t* -value in parentheses.
3. R^2 is the quasi-coefficient of determination.

Sources: Cabinet Office, *National Accounts* ; Ministry of Public Management, Home Affairs, Posts and Telecomunications, *Consumer Price Index* .

(Chart 10)

Effects of Exchange Rates on Phillips Curves

(1) Basic Statistics

	Mean of NAIOG	Standard error of NAIOG	ρ	κ	Sample
Canada	0.322	0.832	0.004	1.024	1992/I-2000/III
France	-0.303	1.837	0.014	1.915	1986/I-2000/III
Germany	-0.827	0.576	0.009	2.777	1993/I-2000/III
Japan	-0.642	2.101	0.018	2.557	1980/I-2000/III
Italy	-0.921	1.416	0.014	2.535	1988/I-2000/III
UK	-0.871	2.202	0.018	0.853	1980/I-2000/III
US	-0.504	1.879	0.012	0.583	1980/I-2000/III

(2) Estimated Phillips Curves

	α	β	γ	R^2	D.W.	Sample
Canada	0.810	0.090	-0.018	0.551	2.154	1992/I-2000/III
	(6.442)	(2.114)	(-0.954)			
France	0.634	0.014	-0.026	0.411	2.210	1986/I-2000/III
	(4.866)	(0.852)	(-0.960)			
Germany	0.426	0.058	-0.014	0.481	2.530	1993/I-2000/III
	(2.186)	(0.738)	(-0.421)			
Japan	0.658	0.019	-0.011	0.643	2.196	1980/I-2000/III
	(5.988)	(1.108)	(-1.456)			
Italy	0.653	0.035	-0.024	0.765	2.189	1988/I-2000/III
	(4.368)	(1.518)	(-1.762)			
UK	0.658	0.070	-0.011	0.719	1.898	1980/I-2000/III
	(7.577)	(2.573)	(-0.681)			
US	0.719	0.065	0.007	0.581	2.184	1980/I-2000/III
	(6.472)	(2.158)	(0.458)			

Notes: 1. Italy's nominal effective exchange rates are lagged two periods; the others are lagged one period.
2. Germany's price index is the GDP deflator; the others are consumer price indexes.
3. Consumer Price Indexes are seasonally adjusted for France, Italy, and the UK.
4. Japan's consumer price index is adjusted for consumption tax reforms; the others' are unadjusted.
5. A dummy variable is included in the regression for Canada to take into consideration the indirect tax reform at 1994/I. The coefficient is -0.014 (*t*- value = -6.181).
6. *t* -value in parentheses.
7. R^2 is the quasi-coefficient of determination.

Sources: Japanese data are based on *National Accounts* by the Cabinet Office and *Consumer Price Index* by the Ministry of Public Management, Home Affair, Posts and Telecommunication;
France's GDP is based on *Comptes Nationaux* by the National Institute of Statistics and Economic Research;
Canada's CPI is *CPI excluding food and energy* by the Bank of Canada.