What Determines the Relation between the Output Gap and Inflation? An International Comparison of Inflation Expectations and Staggered Wage Adjustment

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This paper undertakes a cross-country study on the price-output gap relationship for selected industrialized countries (Japan, the U.S., Germany, the U.K., and Canada). The estimation results show that the price-output gap relationship in these countries can be classified into two categories: (1) a Phillips Curve type (in which the output gap fluctuation affects the inflation rate); and (2) a NAIRU type (in which fluctuations in the output gap affect changes in the inflation rate). In addition, such classifications may vary according to the sample period chosen. During the first half of the observation period (1978–1986), NAIRU-type relations existed in all countries except Japan. During the second half (1987–1997), NAIRU-type relations were observed in the U.S., the U.K., and Canada, while Phillips Curve-type relations were indicated in Japan and Germany. These results lead to the presumption that the price-output gap relationship is influenced by the recent inflation record, which is one of the most important factors that determine the formation mechanism of inflation expectations and the speed of price adjustment.

Key words: Phillips Curve; NAIRU; Expected inflation rate; Price adjustment; Output gap; Inflation; Monetary policy

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The authors would like to thank Professors Fumio Hayashi (University of Tokyo), Toshiki Jinushi (Kobe University), Yukinobu Kitamura (Hitotsubashi University), Tsutomu Watanabe (Hitotsubashi University), Hiroshi Yoshikawa (University of Tokyo), and Messrs. Takeshi Kimura (Bank of Japan), Kenji Nishizaki (Bank of Japan), Yutaka Soejima (Bank of Japan) and many others for their valuable comments.

The views expressed in this paper are those of the authors and do not necessarily reflect those of the Bank of Japan or the Institute for Monetary and Economic Studies.

I. Introduction

A general consensus exists that the ultimate objective of a central bank should be the achievement of "price stability." But this does not imply that it is appropriate for the central bank to focus solely on current inflation trends in the conduct of monetary policy. That is, general prices are lagging indicators—shocks occurring in the real economy are reflected in general prices only after some time lag—and an undue focus on prices exposes the central bank to the risk of missing the proper timing for policy action. Thus, in order to avoid large "price fluctuations" so as to minimize the time lag in policy action, the central bank must take preemptive measures before the impacts of various events affect price levels, by closely observing the movements of the leading indicators.

There is a common view that a considerable trade-off relation exists between the output gap (defined as the rate of difference between real and potential GDP) and price fluctuations, and because it is a leading indicator of price fluctuation the output gap is listed among the indicators to be watched by central banks. This relationship has been analyzed[1] for various countries, primarily by the policy makers. The standard approach in these studies has been to regress the inflation rate against the output gap (that is, estimating the inflation function) and to check their performance and predictive power.

The type of inflation function used in these estimations differs according to the assumptions that are made concerning the relationship between the output gap and price fluctuations. Possible assumptions include (1) a Phillips Curve[2]-type relationship (in which the inflation rate changes according to the size of the output gap); (2) a NAIRU-type relationship (*n*on-*a*ccelerating *i*nflation *r*ate of *u*nemployment, in which the inflation rate accelerates according to the size of the output gap); and (3) verification of the existence of a speed-limit effect (whereby real GDP [actual value] is below potential GDP and when this differential gets smaller, the inflation rate rises).[3] Relatively few NAIRU models have been studied in Japan compared with the Western countries, where such studies are the mainstream.[4]

Watanabe (1997) is one of the few papers that apply the NAIRU model to an examination of the price-output gap relationship in Japan. He posits that it is possible to categorize countries into the three above-mentioned types and attempts to verify this hypothesis by estimating a single nested inflation function. From the

1. Recent studies include Lown and Rich (1997), who analyzed price trends in the U.S., and Fisher, Mahadeva, and Whitley (1997), who analyzed the British case.
2. For Japan, Ueda and Yoshikawa (1984) have undertaken Phillips Curve estimations in the past.
3. C. Romer (1996) can be cited as an early study verifying the speed limit effect. This study checked for the existence of the speed limit effect using long-term U.S. data covering the period from the 1890s to the 1990s and arrived at the following conclusions: (1) a speed limit effect was observed during the first half of the period of observation, but gradually weakened over time and completely disappeared after 1973; and (2) the observation of a speed limit during the early portion of the study is attributed to the important share of raw materials in the U.S. economy during this period. Because of their specific properties, primary product prices rise very sharply in response to supply shortages, even in the presence of a considerable output gap on the macroeconomic level. In an economy largely dependent on primary products, this upward movement in primary product prices can easily trigger price increases throughout the economy. Turner (1995) has attempted a similar study for all G-7 countries.
4. NAIRU studies of Japan have been undertaken as a part of comparative studies covering a number of countries, such as Turner (1995) and Fair (1997).

results, he concludes that a Phillips Curve-type relationship exists in the case of Japan.[5] While no verification is attempted, the paper also presents the conjecture that a NAIRU-type relationship exists in the case of the U.S. Is he correct in asserting that countries can be clearly classified according to these types of relationship which exist between the output gap and price fluctuations? And if so, then what determines this classification? These are the fundamental themes of this paper.

The main findings of this paper can be summarized as follows. The estimation results of our study confirm Watanabe (1997) insofar as it is possible to classify major industrialized countries (the analysis covered Japan, the U.S., Germany, the U.K., and Canada) into specific types according to the price-output gap relationship. However, our results also indicate that a country can move from one type to another depending on the period examined.[6] This implies that country classifications are not solely determined by structural factors, such as the system of wage determination. In addition, it is possible that the classification is influenced by people's expectations as reflected in the speed of nominal price adjustments. In other words, our findings point to the possibility that a country's price-output gap relationship, which is closely related to expectation formation, depends on a country's inflation history resulting from various past events and shocks, including the performance of monetary policy.

The remainder of this paper is organized as follows. In Chapter II, we present a brief conceptual review of the relationship between the output gap and prices. In Chapter III, we observe each country's past inflation rate and output gap fluctuations. Next, we estimate the time correlation between the inflation rate and two variables, i.e., the output gap and the rate of change of import prices. In Chapter IV, we estimate the NAIRU-type inflation functions for Japan and other countries and interpret the results. Based on these results, in Chapter V we estimate a Phillips Curve-type function for cases in which the NAIRU type does not hold. Finally, in Chapter VI, we focus on the possibility that differences in estimated results among countries are influenced by how inflationary expectations are formed, and we conclude with a hypothesis on this point.

II. The Relationship between Output Gap and Prices: Phillips Curve Type vs. NAIRU Type

In this chapter, we shall present a brief standard explanation of the relation between the output gap and prices.[7]

The Phillips Curve, a representative expression of the short-term trade-off relationship between inflation and unemployment, is normally expressed as follows (Friedman-Phelps type):

5. A nested model is used containing the GDPGAP term (Phillips Curve type), rate of change of GDPGAP term (speed-limit type), and a lag term representing the inflation rate (NAIRU type), and the statistical significance of each term is verified. Although the same type of model is used by C. Romer (1996) (see Footnote 3), Romer differs from Watanabe (1997) in that she interprets the inflation-rate lag term to represent the inertia of the inflation rate and does not use it for the verification of NAIRU.
6. Given the assertion of C. Romer (1996) (see Footnote 3) that the speed-limit effect had disappeared, in this paper we did not attempt to verify the speed limit. (We actually did undertake some estimations of the speed limit for Japan, but failed to discern any speed-limit effects.)
7. The following explanation is primarily based on Blanchard (1997).

$$\pi_t = \pi_t^e + \alpha_1(u_t - u^*) + \varepsilon_t, \quad (1)$$

where π represents the inflation rate, π^e the expected inflation rate, u the unemployment rate, u^* the natural rate of unemployment, and ε an error term that corresponds to a supply shock. (See Section VI.A for details of arguments concerning the expected inflation rate.)

In this paper, however, we do not use the unemployment rate, which indicates the supply-demand balance in the labor market. Instead, the output gap is used as an indicator of the supply-demand balance in the entire economy. Therefore, using Okun's Law, equation (1) is rewritten as follows:

$$\pi_t = \pi_t^e + \alpha_1 GDPGAP_t + \varepsilon_t, \quad (2)$$

where *GDPGAP* represents the difference between real and potential GDP.[8]

According to equation (2), the inflation rate is affected by the following three factors: the expected inflation rate (π^e), the output gap (*GDPGAP*), and supply shocks or other exogenous shocks represented by ε. Such shocks include terrible weather conditions, natural disasters, and fluctuations in oil prices and foreign exchange rates. Hence, if supply shocks and the expected inflation rate are held constant, equation (2) indicates that there is a positive correlation between the output gap and inflation rate.[9]

In the following, we use a somewhat naive model to check two patterns of inflation expectations under equation (2).

Where the expected inflation rate is constant ($\pi_t^e = \alpha_0$)

In this case, equation (2), which represents the Phillips Curve, can be rewritten as equation (3).

$$\pi_t = \alpha_0 + \alpha_1 GDPGAP_t + \varepsilon_t. \quad (3)$$

Equation (3) implies that people expect that, on average, the inflation rate will be a constant value (α_0). In other words, people predict that the inflation rate will remain stationary around a certain value. In this case, a trade-off relation does exist between the output gap and the inflation rate. In this paper, we refer to this case as the "Phillips Curve type."

8. Under the definition used in this paper, potential GDP refers to GDP under stationary conditions in which the inflation rate neither moves up or down, and where the expected inflation rate and supply shocks are treated as given. In the context of the unemployment rate, potential GDP corresponds to the natural rate of unemployment (u^*). See the Appendix on computational methods for the derivation of potential GDP.

9. When the expected inflation rate changes, or if there is a major supply shock, it is possible that a previously observed positive correlation between output gap and the inflation rate may disappear. Another possibility is that a major supply shock may in itself trigger a change in the expected inflation rate. For example, it is said that as a consequence of the oil crises of the 1970s, the previously stable trade-off relation between output gap and the inflation rate became ambiguous in many countries. This is an illustration of the case where a supply shock triggers changes in the expected inflation rate, which in turn boosts the actual inflation rate, while also simultaneously exercising a major negative impact on the real economy. This type of situation arises notwithstanding the fact that although supply shocks are usually temporary, people's formation of expected inflation changed by those shocks tends to persist over a considerable period of time. In the case of the oil crises, it is believed that this mechanism destabilized the trade-off relationship between output gap and the inflation rate over an extended period of time.

Where the expected inflation rate is equivalent to the actual value of the most recent inflation rate ($\pi_t^e = \pi_{t-1}$)

In this case, equation (2) can be rewritten as equation (4).

$$\pi_t = \pi_{t-1} + \alpha_1 GDPGAP_t + \varepsilon_t. \tag{4}$$

Equation (4) implies that, in each period, people adjust their expected inflation rate to match the realized inflation rate in the preceding period. (For instance, if the inflation rate was 3 percent in the preceding period, people expect the inflation rate in the current period to be 3 percent also.) This assumption is based on the notion that the actual inflation rate is in a nonstationary state subject to random walk.[10] The notable feature in this case is that the trade-off relationship between the output gap and the inflation rate, seen in the Phillips Curve type above, no longer exists and is replaced by the following relationship.

$$\pi_t - \pi_{t-1} = \alpha_1 GDPGAP_t + \varepsilon_t, \tag{5}$$

where a positive correlation is seen between the acceleration in the inflation rate (change in the inflation rate) and the output gap. This represents the NAIRU-type relationship, which became the subject of debate, primarily in the U.S., during and after the 1970s, when an acceleration in the inflation rate was experienced. In this paper, we define cases where the output gap affects not the inflation rate, but rather the change in the inflation rate, as a "NAIRU-type" relationship.

As outlined above, in the standard textbook treatment, relations between the inflation rate and the output gap are examined under two basic types of expectation patterns. However, the assumptions which underpin these two models (that the expected inflation rate is tied down to a "certain constant" or "realized value in the previous period") are too restrictive in comparison to real-world conditions. To ease this restriction, in this paper we use a type of model described in equation (6).

$$\pi_t = \alpha_0 + \sum_{i=1}^{s} \beta_i \pi_{t-i} + \alpha_1 GDPGAP_t + \varepsilon_t. \tag{6}$$

Equation (6) describes a model in which the expected inflation rate (π_t^e) depends not only on a constant term (α_0) and the actual value of inflation in the preceding period (π_{t-1}), but goes further into the past to take into consideration the lag term in the inflation rate ($\pi_{t-2}, \pi_{t-3}, \pi_{t-4} \ldots$).

In this paper, we say that a (broadly defined) NAIRU-type relationship holds when the coefficients of the lagged inflation terms in equation (6) satisfy the conditions of equation (7) below, and the coefficient of the output gap is statistically significant.

$$\sum_{i=1}^{s} \beta_i = 1. \tag{7}$$

10. Assuming that π_t is subject to a random-walk process ($\pi_t = \pi_{t-1} + e_t$, $e_t \sim IID(0, \sigma^2)$), the expected inflation rate would then be defined as $\pi_t^e = E(\pi_t) = \pi_{t-1}$.

In equation (5), a NAIRU-type relationship is strictly defined as a case in which the coefficient of the inflation rate in the previous period (β_1) is equal to one. On the other hand, in this paper, we add on a certain number (s) of inflation-rate lag terms and say that a NAIRU-type relationship holds when the sum of the coefficients is one (with the additional condition that the *GDPGAP* coefficient (α_1) is significantly different from zero). In other words, when at some point the sum of the coefficients will be equal to one, as additional inflation lag terms are added on, the trade-off relation between the inflation rate and output gap will disappear.

On the other hand, in this paper, we say that a Phillips Curve-type relationship holds when the conditions of equation (7) are not met (that is, $\sum_{i=1}^{s}\beta_i < 1$), and the *GDPGAP* coefficient is statistically significant. In this case, the expected inflation rate can be obtained from

$$\pi_t^e = \alpha_0 + \sum_{i=1}^{s}\beta_i\pi_{t-i}. \tag{8}$$

Equation (8) indicates that the expected inflation rate is the sum of a certain portion[11] of past rates of inflation and a constant term.[12] This implication here is that a shock generates only a mild adjustment in inflationary expectations (that is, the sum of lagged inflation terms never reaches one, no matter how many additional lag terms are taken into account), and as a result, a trade-off relationship is maintained during the period.[13]

In this paper, we begin by using equation (6) to verify whether the NAIRU-type relationship exists in each country. Based on these findings, we attempt to classify the countries studied into the two types stated above.

Why does such a short-term trade-off relationship exist between output gap and prices? Two general explanations are possible. Those are (1) a Lucas-type explanation based on imperfect information or some misperceptions; and (2) a "nominal price rigidity" explanation such as a staggered price adjustment (Taylor type) or menu cost model (Mankiw type).[14] We develop our following discussion based on the latter type of assumption. In the following chapter, we first attempt to estimate equation (6) in order to classify countries into the two types stated above.

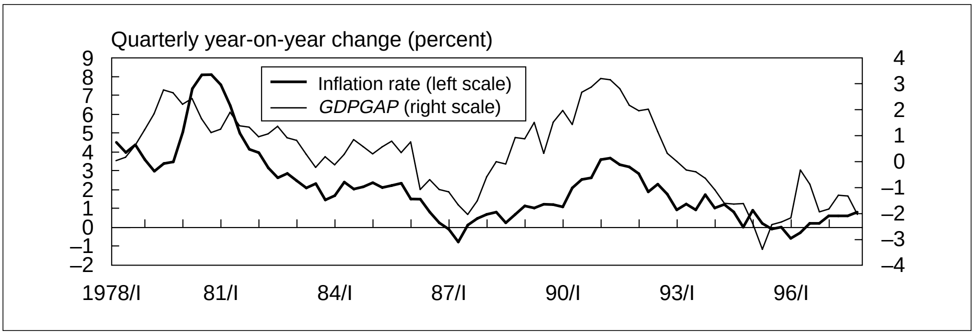
11. In this context, a "certain portion" arises from the fact that past rates of inflation are only partially reflected in the expected inflation rate because the sum of the lagged inflation terms is less than one.
12. The NAIRU-type in equation (6) is derived by easing the restrictions of equation (5). On the other hand, equation (8) is interpreted to represent a form of the Phillips Curve type of equation (3), which restricts expectations to the constant term.
13. When the summation of inflation lag terms is less than one, this implies that, in the event of a shock, the impact of the expected inflation rate on the actual inflation rate will diminish over the long term so that ultimately, only the constant term will exert an influence on the actual inflation rate.
14. See D. Romer (1996) for details. These discussions were predated by the interpretations of Lipsey and Tobin, who provided the following points to explain a negative correlation between the inflation rate and the unemployment rate on the macroeconomic level. Those are (1) the labor market is comprised of heterogeneous agents that are subject to imperfect information; and (2) apart from macroeconomic fluctuations, the economy is consistently subject to inter-sectoral shocks (see Yoshikawa [1984] for details).

III. The Relationship between Inflation Rate and Output Gap in Individual Countries

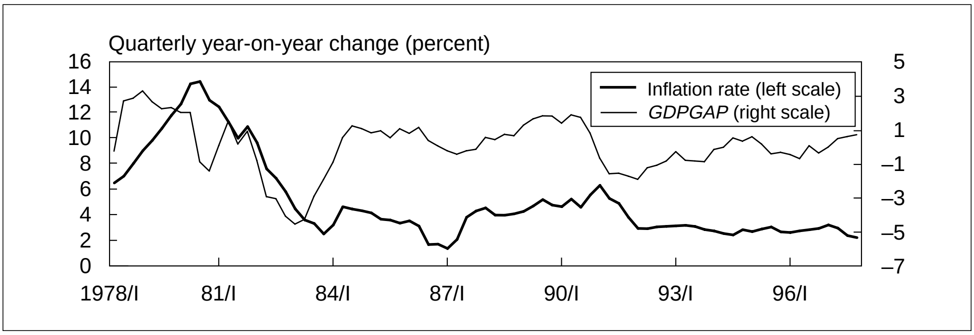
Figure 1 presents the trends in the inflation rate and output gap for Japan, the U.S., and Germany for a period of approximately 20 years beginning in 1978.

Figure 1 Inflation Rate and Output Gap in Individual Countries

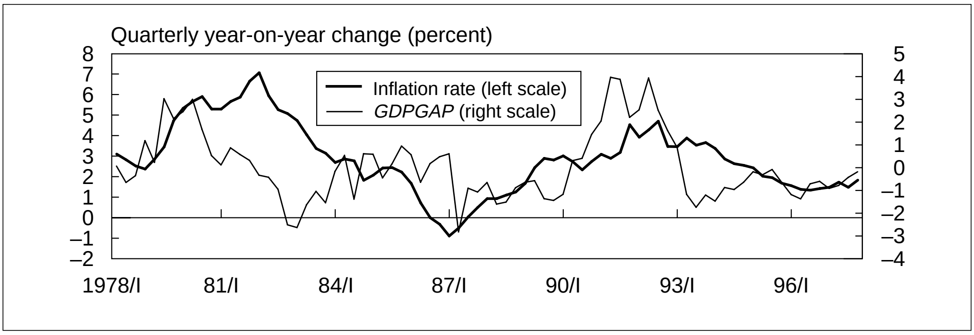
[1] Japan



[2] U.S.



[3] Germany



Notes: 1. Regarding the impact of value-added tax (VAT) on inflation rate movements, adjustments have been made in Figure 1 for both the introduction and the subsequent increases in Japan's consumption tax. However, in the German case, VAT was increased four times during the period of observation but adjustments have not been made in Figure 1.
2. Japan's output gap was computed using production functions. For the remaining four countries, output gaps were estimated using HP filters. For details, see the Appendix.

In general, the two variables tend to move in the same direction with some time lags. From a temporal perspective, as compared to the 1990s, this tendency appears to have been stronger in the period between second half of the 1970s and the first half of the 1980s, when the amplitude of price fluctuations was greater.

To examine this relationship in greater detail, we computed time correlation coefficients for the following four combinations: inflation rate and output gap; inflation rate and rate of change in import prices (quarterly year-on-year change: [percent]); changes in inflation rate and output gap; and changes in inflation rate and rate of change in import prices. This was done for five countries: Japan, the U.S., Germany, the U.K., and Canada. (According to Chapter II, seeking the differential of the inflation rate is equivalent to assigning a value of "one" to the coefficient for the inflation term in the preceding period.) The change in import prices was included as a proxy for supply-side shocks, which generate changes in the inflation rate. To make allowances for the sharp changes in oil prices during the 1970s, the period of estimation was divided into two segments: from 1978/I to 1986/IV (the "first half"), and from 1987/I to 1997/III (the "second half"). During the first half, domestic rates of inflation were greatly affected by sharp swings in oil prices, while during the second half oil prices were generally stable.[15]

Based on the results of the time correlation coefficients obtained, Table 1 lists the number of lags exhibiting the highest correlations and the coefficient of correlation at that point.

Regarding the relationship between the inflation rate and the output gap, Table 1 shows that, in all countries, the output gap leads the inflation rate, and that the correlations are relatively high, ranging between 0.6 and 0.8. These relationships are stronger in the second half. Furthermore, for Japan, the U.S., and Germany, the lead time tends to become shorter. Turning next to the relation between changes in the inflation rate and the output gap, during the first half, in all countries except Japan, a relatively high correlation is observed with very little time lag. By the second half, however, this relationship breaks down in Japan, the U.S., and Germany.

Table 1 Results of Time Correlation

		Japan		U.S.		Germany		U.K.		Canada	
		No. of lags	Corr. coeff.	No. of lags	Corr. coeff.	No. of lags	Corr. coeff.	No. of lags	Corr. coeff.	No. of lags	Corr. coeff.
Inflation rate/ *GDPGAP*	First half	2	0.6683	6	0.5471	7	0.5427	4	0.7083	6	0.6511
	Second half	1	0.8445	3	0.6845	1	0.6176	7	0.8227	5	0.7464
Change in inflation rate/*GDPGAP*	First half	1	0.3170	0	0.6557	1	0.5704	0	0.5837	0	0.6664
	Second half	—	—	2	0.2713	—	—	0	0.5716	2	0.3356
Inflation rate/ import price	First half	1	0.8028	1	0.8882	0	0.8186	6	0.7669	2	0.7916
	Second half	5	0.4368	0	0.4789	—	—	0	0.1385	–1	–0.6464
Change in inflation rate/import price	First half	0	0.6221	–4	0.5992	–1	0.6605	–3	0.4378	–2	0.6376
	Second half	0	0.3679	–1	0.5712	—	—	—	—	—	—

Notes: 1. Number of lags: "+" indicates that the output gap or the rate of import price change is leading. "–" indicates that the inflation rate or a change in the inflation rate is leading.
2. A dash indicates cases with no clear correlation.

15. Import price is used as a proxy variable for supply shocks. This is because import price not only reflects the impact of energy price fluctuations, it also reflects the fluctuations in foreign exchange rates, etc.

During the first half, import prices lead the inflation rate with a high correlation. This confirms that import prices had a strong impact on fluctuations in the inflation rate during this period. In addition, it is observed that import prices lead the changes in the inflation rate, with a relatively high correlation in the first half. However, it is notable that by the second half, the relationships between import prices and the inflation rate, and between import prices and the changes in the inflation rate break down in most countries.

Based on these time correlation coefficient results, we may interpret these to indicate that a positive correlation between the inflation rate and the output gap signifies a Phillips Curve-type relationship, and that a positive correlation between changes in the inflation rate and the output gap signifies a NAIRU-type relationship. Thus, the conclusions of Watanabe (1997) can be said to be more or less on the mark. However, this result shows that the relation between price fluctuations and the output gap as observed for individual countries tends to change over time. Thus, in addition to a classification by country, it can be inferred that such types for individual countries may change over time.

IV. Estimation of the NAIRU-Type Inflation Function

A. The Specific Function Used in Estimations

In this chapter, we estimate the inflation functions in order to verify the findings of Chapter III more rigorously.

We derive equation (9) by adding to equation (8) the rate of change of import prices as a proxy variable for supply-side shocks.

$$\pi_t = \alpha_0^N + \sum_{i=1}^{s} \beta_i^N \pi_{t-i} + \alpha_1^N GDPGAP_{t-1} + \sum_{i=0}^{1} \gamma_i^N IMPORT_{t-i} + \varepsilon_t^N, \qquad (9)$$

where π is the rate of change of CPI (quarterly year-on-year change); *GDPGAP* is the differential rate between real and potential GDP;[16] *IMPORT* is the rate of change of import prices (relative prices); ε^N is the error term; and subscript t indicates time.[17] The period of estimation is the same as the period used for computing time correlation coefficients, dividing the whole sample period into the first half (1978/I to 1986/IV) and the second half (1987/I to 1997/III).

16. The *GDPGAP* term may have a simultaneous equation bias. Taking this into consideration, we lagged the term by one period. This meets with the results of the time correlation coefficients in the previous chapter, which implies that the output gap leads the inflation rate in all countries.

17. Strictly speaking, in addition to the conditions of equation (7) (summation of lagged inflation terms = 1), the condition of $\alpha_0 = 0$ in equation (9) must be satisfied for NAIRU. However, potential GDP was computed for the entire undivided period (see the Appendix), so that average *GDPGAP* is not necessarily zero for each of the two segments. Furthermore, in countries experiencing more frequent accelerations of inflation than decelerations, the average changes in inflation rate for the period can be positive, or vice versa. For these reasons, the estimation results do not necessarily satisfy the condition $\alpha_0 = 0$.

In equation (9),[18] the coefficient subject to the restriction of "sum of $\beta_i^N = 1$" is defined as the null hypothesis (H_0), and the coefficient not subject to this restriction is defined as the alternative hypothesis (H_1).[19] If the null hypothesis cannot be rejected by F statistic test, we conclude that a NAIRU-type relationship exists. As in the case of the time correlation coefficients, the countries covered are Japan, the U.S., Germany, the U.K., and Canada.[20]

B. Results

The results of the *F* test are shown in Table 2.

Table 2 is to be read as follows. As the number of lagged inflation terms is successively increased, when the null hypothesis that "the sum of the inflation rate lag coefficient series = 1" is rejected at the 1 percent level of statistical significance, this is indicated by "×." If the null hypothesis is not rejected at the 1 percent level, but is rejected at the 5 percent level, this is indicated by "(O)." Finally, if the null hypothesis is not rejected at the 5 percent level, this is indicated by "O."

Table 2 Results of *F* Test

	Sample period	Up to first	Up to second	Up to third	Up to fourth	Up to fifth	Up to sixth	Up to seventh
Japan	First half	×	×	×	×	×	×	×
	Second half	×	×	×	×	×	×	×
U.S.	First half	○	○	(○)	○	(○)	(○)	(○)
	Second half	(○)	(○)	(○)	(○)	(○)	(○)	(○)
Germany	First half	○	○	○	○	○	○	○
	Second half	×	×	×	×	×	×	×
U.K.	First half	○	○	○	(○)	○	○	(○)
	Second half	○	○	○	○	○	○	○
Canada	First half	○	○	○	○	○	○	○
	Second half	○	○	○	○	○	○	○

18. In equation (9), the *GDPGAP* lag term is restricted to one period. Given that actual price adjustments require considerable time, it would be more reasonable to say that the *GDPGAP* from earlier periods also affects the inflation rate. However, the addition of further *GDPGAP* lags to equation (9) will bias the estimation results because of the correlation between the *GDPGAP* lag term and inflation rate lag term. To avoid this problem, in equation (9) we have only used the one lagged *GDPGAP* term. What this means is that the impact of *GDPGAP* from earlier periods is contained in the inflation rate lag terms. See Chapter V for estimations with additional *GDPGAP* lag terms.
19. In this study, the number of lags has been restricted to a maximum of seven quarters (two years) because the average duration of a half-cycle (from the top of a business cycle to the bottom, or conversely, from the bottom of a business cycle to the top) is about two years. In addition, the duration during which monetary policies remain in the same direction is also about two years. Thus, the choice of seven quarters was made in consideration of the fact that central banks are most interested in determining whether a trade-off relationship exists within a "short term" of about two years.
20. Regarding the impact of the introduction and changes in VAT rates on inflation, adjustments were made for individual countries using VAT dummies. (For Japan, adjustments were previously made using the computations of the Bank of Japan's Research and Statistics Department.) However, note that the dummy does not assure us of full adjustment because of differences in VAT coverage on goods among countries, the frequent practice of lowering other taxes prior to raising VAT.

According to the *F* test results, a NAIRU-type relationship existed in (1) the U.S., Germany, the U.K., and Canada during the first half; and (2) the U.S.,[21] the U.K., and Canada during the second half. On the other hand, the test results indicated the existence of a Phillips Curve-type relation in (1) Japan[22] during the first half; and (2) Japan and Germany during the second half.[23] These results meet the interpretations gained from the observation of time correlation coefficients in Chapter III.

Our estimation results confirm that the relationship between price fluctuations and the output gap differ among countries, and that the type of relationship which prevails in a country may change from one period to another. Table 3 presents the summary for the best fitting case for each country.[24]

See Table 3 to check for the size of the coefficients of inflation-rate lagged terms. Compared with the other four countries, in the case of Japan in the second half, the coefficient of one lagged inflation rate term is around 0.5. This is conspicuously smaller than the 0.8–1.1 range seen in the case of the other countries. Furthermore, in the case of Japan, the sum of the coefficients for all the lag periods comes to only about 0.6. While this is clearly smaller than those for the three NAIRU-type countries (the U.S., the U.K., and Canada), it is also considerably smaller than that of Germany (about 0.8), for which a NAIRU-type relationship has been rejected. Regarding the coefficient for *GDPGAP*, it is notable that for all of the four countries in which the coefficient of the *GDPGAP* was statistically significant in both the first and second halves, the coefficient was generally smaller in the second half.

21. For the United States in the second half, the NAIRU-type null hypothesis is rejected at the 5 percent level. However, the null hypothesis was not rejected at the 1 percent level no matter how many lags were taken into account. Therefore, some reservations remain on whether or not to identify the United States as a NAIRU-type country in the second half.
22. Note that estimation results for Japan in the first half indicate that the *GDPGAP* coefficient was not significant either. *GDPGAP* was significant in second half for Japan, and for both first and second halves for all other countries.
23. Because the sum of the lag coefficients over seven quarters fell short of one for Japan in the first half, and Japan and Germany in the second half, further computations were attempted with the addition of one more year of lags, bringing the total to three years (11 quarters). For Japan in the first half and Germany in the second half, a NAIRU-type relationship could not be confirmed even when the lags were extended to 11 quarters. For Japan in the second half, the null hypothesis of "sum of $\beta_i^N = 1$" could no longer be rejected after 10 quarters.
24. The following test results are shown in Table 3: in cases of test result "O," the estimation results for cases with restriction; in case of test results "(O)" or "×," the estimation results for cases without restriction.

Table 3 Estimation Results for the NAIRU-Type Inflation Function

[1] First Half: 1978–1986

	Const.	First lag	Second lag	Third lag	Fourth lag	Fifth lag	Sixth lag	Seventh lag	*GDPGAP*(1)	*IMPORT*	$\overline{R}^2$	S.E.	m-test	REST = 1
Japan	0.5507 (2.574)*	1.0200 (5.411)**	–0.6505 (–2.477)*	0.7770 (3.165)**	–0.7503 (–2.971)**	0.5008 (2.008)	–0.1403 (–1.109)		0.0725 (0.490)	0.0244 (3.443)**	0.9572	0.4339	1.0944 (1.715)	×
U.S.	0.3682 (1.216)	0.8480 (4.315)**	–0.4586 (–1.916)	0.7183 (3.012)**	–0.7739 (–3.267)**	0.5143 (3.331)**			0.2271 (3.028)**	0.0862 (3.055)**	0.9790	0.5740	0.2083 (0.681)	(○)
Germany	–0.4003 (–3.900)**	0.9295 (6.445)**	–0.5039 (–2.726)*	0.4573 (2.261)*	–0.2433 (–1.194)	0.3604 (3.372)**			0.2284 (4.021)**	0.0458 (4.275)**	0.9839	0.2528	0.0228 (0.061)	○
U.K.	1.0321 (1.752)	0.8187 (4.987)**	0.1980 (0.838)	0.0715 (0.325)	–0.4274 (–2.100)*	0.2097 (0.951)	0.2215 (1.046)	–0.2150 (–1.814)	0.6085 (2.706)*	–0.0591 (–1.635)	0.9338	1.1878	–0.8647 (–2.431)*	(○)
Canada	0.0299 (0.172)	1.2580 (6.838)**	–0.1938 (–0.740)	–0.0188 (–0.069)	–0.4680 (–1.809)	0.7095 (2.645)*	–0.2869 (–1.939)		0.2084 (3.107)**	–0.0111 (–0.743)	0.9780	0.4620	0.1757 (0.388)	○

[2] Second Half: 1987–1997

	Const.	First lag	Second lag	Third lag	Fourth lag	Fifth lag	Sixth lag	Seventh lag	*GDPGAP*(1)	*IMPORT*	$\overline{R}^2$	S.E.	m-test	REST = 1
Japan	0.5289 (3.273)**	0.4051 (2.454)*	0.1539 (0.879)	0.0231 (0.156)					0.2435 (3.383)**	0.0163 (1.897)	0.8519	0.4280	–0.0577 (–0.109)	×
U.S.	0.2534 (1.301)	0.8146 (6.222)**	–0.1024 (–0.666)	0.1114 (0.764)	–0.2615 (–1.738)	0.3261 (2.852)**			0.1712 (3.103)**	0.0710 (2.811)**	0.9167	0.3014	–0.0713 (–0.260)	(○)
Germany	0.4776 (3.069)**	0.8254 (6.040)**	–0.0341 (–0.215)	0.3618 (2.287)*	–0.3624 (–3.263)**				0.1276 (3.144)**	0.0288 (1.816)	0.9362	0.2996	–0.2216 (–0.878)	×
U.K.	–0.0550 (–0.637)	0.9195 (5.305)**	–0.0249 (–0.110)	–0.1714 (–0.787)	–0.0136 (–0.057)	0.5102 (2.523)*	–0.2199 (–1.407)		0.2590 (3.603)**	0.0030 (0.315)	0.9567	0.3999	–0.2212 (–0.578)	○
Canada	–0.1667 (–1.463)	1.1911 (6.269)**	–0.3899 (–1.305)	0.0715 (0.243)	–0.3148 (–1.203)	0.4422 (–2.726)*			0.1877 (–2.808)**	0.0213 (0.613)	0.9018	0.5620	0.2514 (0.633)	○

Notes: 1. Figures in parentheses are *t*-values. Asterisks, * and **, indicate statistical significance at the 5 percent and 1 percent levels, respectively (same for below).
2. M-test tests for serial correlation in the error term when the explanatory variable indicates a self-lag in the dependent variable.
3. The results of *F* test are shown in the REST = 1 column.

V. Estimation of the Phillips Curve-Type Inflation Function

A. The Specific Functions Used in the Estimation

The results of Section IV.B indicate that for Japan a NAIRU-type relationship cannot be verified in either the first or the second half of the estimation period. Furthermore, the results show that for Germany a NAIRU-type relationship can be verified only during the first half. Thus, the results hint at a Phillips Curve-type relationship in the case of Japan and Germany. In this chapter, we shall supplement our investigation by estimating the Phillips Curve-type inflation function for these countries using equation (10) below.

$$\pi_t = \alpha_0^P + \sum_{i=1}^{s} \alpha_{1i}^P GDPGAP_{t-i} + \sum_{i=0}^{1} \gamma_i^P IMPORT_{t-i} + \varepsilon_t^P, \quad (10)$$

where ε^P is the error term.

Equation (10) is based on the following notion. When in equation (9) the sum of the coefficients of the lagged inflation terms does not reach one no matter how many lag periods are added (that is, when the size of the coefficient is relatively small), we successively shift the time in equation (10) backward by one period and input the results in equation (9).

We here assume a case in which the coefficient of the lagged inflation terms is small to begin with, and grows progressively smaller as we go back in time. This can be expressed as follows. Let us assume that we obtain the following equation from the estimation results of equation (9) (the *IMPORT* segment has been abbreviated).

$$\pi_t = \alpha_0 + \beta_1\pi_{t-1} + \beta_2\pi_{t-2} + \beta_3\pi_{t-3} + \beta_4\pi_{t-4} \ldots + \alpha_1 GDPGAP_{t-1} + \varepsilon_t,$$

where $\sum_{i=1}^{s}\beta_i \neq 1$ (<1).

For time $t-1$, the above equation can be rewritten as follows.

$$\pi_{t-1} = \alpha_0 + \beta_1\pi_{t-2} + \beta_2\pi_{t-3} + \beta_3\pi_{t-4} + \beta_4\pi_{t-5} \ldots + \alpha_1 GDPGAP_{t-2} + \varepsilon_{t-1}.$$

By substituting this expression in the above formula, and by continuing to repeat the process while successively shifting the time backward, ultimately we arrive at a point where it becomes possible to replace the inflation-rate lagged term with the *GDPGAP* lagged term and the constant component.[25]

Thus, in equation (10), the equation contains a large number of *GDPGAP* lags, and fixes the π^e term to be constant. In this case, the sum of the coefficients of the *GDPGAP* lagged terms in equation (10) represents the size of the sacrifice ratio—the amount of GDP that must be sacrificed in order to reduce the inflation rate by 1 percent.[26]

B. Results

Based on the above interpretation, we estimate the Phillips Curve-type function for Japan in the first and second halves, and for Germany in the second half, when the NAIRU-type null hypothesis was rejected at the 1 percent level, as shown in Section IV.B. For reference, we also estimate the function for the U.S. in the second half. In these estimations, we include seven lag periods covering a duration of about two years. This follows the finding in Chapter III that it took about seven lag periods for the entire impact of *GDPGAP* on price fluctuations to be exhausted.

The estimation results summarized in Table 4 show that the *GDPGAP* coefficient was statistically significant in Japan and Germany in the second half. Thus, equation (10) also confirms the existence of a Phillips Curve-type relationship in these instances. Regarding the U.S., where the NAIRU-type null hypothesis could not be fully rejected, although the *GDPGAP* coefficient was significant, the coefficient of determination was smaller than in the cases of Japan and Germany.[27] On the other hand, the *GDPGAP* coefficient was not significant for Japan in the first half,

Table 4 Estimation Results for Phillips Curve-Type Function

[1] First Half: 1978–1987 [Reference]

	Const.	*GDPGAP*	*IMPORT*	$\bar{R}^2$	S.E.	D.W.	F-value
Japan	3.001 (2.40)*	0.110 (0.23)	0.058 (3.19)**	0.62823	1.27867	0.718	7.572

[2] Second Half: 1988–1997

	Const.	*GDPGAP*	*IMPORT*	$\bar{R}^2$	S.E.	D.W.	F-value
Japan	1.212 (16.01)**	0.597 (10.74)**	0.017 (1.62)	0.80783	0.48769	1.265	20.617
U.S.	3.320 (24.46)**	0.945 (5.66)**	0.087 (2.31)*	0.55816	0.69428	0.411	6.895
Germany	2.365 (21.13)**	0.717 (6.43)**	0.141 (3.77)**	0.69523	0.65483	0.922	10.581

25. For convenience in computation, input is stopped after a certain number of periods. However, the coefficient of the remaining inflation-rate lag terms is negligible as it is the product of a higher order of β.
26. Of course, the sacrifice ratio can also be computed *ex post* facto using equation (9). Hence, this is not unique to equation (10).
27. In light of this point, it seems that the U.S. should be categorized as exhibiting a NAIRU-type relationship in the second half. Hence, the interpretations of Section V.B concerning the U.S. should be viewed for reference only.

indicating that a Phillips Curve-type relationship did not exist. This agrees with the results of the estimation of equation (9), where the *GDPGAP* term was not found to be significant. It can be concluded from this that price fluctuations in Japan during the first half were largely determined by import prices.

Among these three countries in the second half, the coefficient is largest for the U.S., followed by Germany and finally Japan. This indicates that the Japanese Phillips Curve is flatter than those of the other two countries, implying that Japan faced a larger sacrifice ratio (*GDPGAP*/inflation rate).

Turning next to the impact of import prices, the import-price coefficient is statistically significant in the case of Japan in the first half. In the second half, the relationship becomes considerably weaker and can be statistically rejected at the 5 percent level. The same holds true for the U.S. in the second half, where the size of the coefficient remains relatively small although it cannot be statistically rejected at the 5 percent level. This finding meets the interpretations of the time correlation coefficients in Chapter III. However, the findings for Germany do not necessarily agree with the interpretations of Chapter III. In the case of Germany, the coefficient for import prices is not small and is significant at the 1 percent level. Various interpretations are possible on this point. One such interpretation focuses on the impact of the sharp increase in oil prices occurring on two occasions: the second half of the 1980s, and in early 1990 as a result of the Gulf War. The findings for Germany can be attributed to the fact that these oil price increases preceded the inflationary pressures due to domestic factors, which emerged around 1990 and in 1992, mostly as a result of the impact of German unification.[28]

C. Interpreting the Results

Reverting to the standard explanation summarized in Chapter II, our estimation results so far can be interpreted as follows. In countries subject to NAIRU-type conditions, inflationary expectations are "formed on the basis of the recently realized inflation rate." In countries subject to Phillips Curve-type conditions, inflationary expectations are formed around a certain constant value. What can be said of countries subject to a NAIRU-type relationship in the first half, but not in the second half? In such cases, it may be considered that the process of inflationary expectation formation changed. Specifically, during the first half, which was marked by high rates of inflation, the price-adjustment speed was fast because people immediately transferred any inflationary pressures to prices. In contrast, the price-adjustment speed during the second half was considerably slower because of the relatively low rates of inflation.

Let us now turn to the estimation results of Section V.B and focus on the value of the constant term for Japan (1.21) , the U.S. (3.32), and Germany (2.37) during the second half (all of which are significant at the 1 percent level). Applying the preceding interpretation to these figures, we can say that the core inflation rates for these countries were approximately 1 percent for Japan, 3 percent for the U.S., and 2 percent for Germany. The actual inflation rate experienced in these countries can

28. If this interpretation is correct, then it is possible that the size of the *GDPGAP* coefficient obtained from the estimation results for Germany in the second half has been underestimated.

be viewed as the sum of this core rate and the impact of short-term fluctuations in *GDPGAP* resulting from changes in business conditions, and various exogenous shocks. For reference, we also take a look at Japan's result for the first half, where neither a Phillips Curve- nor a NAIRU-type relationship existed. It is interesting to note that the constant value for Japan during the first half was 3.00, considerably higher than that experienced in the second half. This means that people in Japan had in mind a core inflation rate of 3 percent during the first half. When inflationary pressures subsided in the second half of the 1980s and thereafter remained very low, people made a corresponding downward adjustment in what they believed to be a new core inflation rate (1.21).

VI. Phillips Curve Type or NAIRU Type: Some Observations on Determinants

A. Is the Inflation Rate Lag Term Equivalent to "Expectations"?

In this paper, we have used lagged inflation terms as a proxy for the expected inflation rate formed by the public.[29] However, in addition to the expected inflation rate, recent Keynesian discussions have frequently focused on an element of inertia.[30] It can be said that this is because "expectations" are not easily observed, and therefore even when the existence of "expectations" is assumed, it is very difficult to distinguish between "expectations" and the speed (inertia) at which expectations begin to affect prices.[31]

Therefore, when attempting to compare countries by type, it is important to take into account the differences in wage negotiation systems among countries, which can be one of the keys to distinguishing between expectations and inertia. In the next section, we survey the previous literature concerning the degree to which the speed of price adjustment is affected by differences among countries in their wage negotiation systems. Following this exercise, we make some observations concerning the estimation results of this paper.

29. There is a discussion by Sargent (1971), who was critical of interpreting lagged inflation terms (i.e., the sum of the coefficients concerned equals one) as pure "rational expectations." By pointing out that the realized inflation rate was stationary for the U.S., he argued that "imposing restriction amounts to supposing that the public's method of forming expectations of inflation was very irrational in the sense of being widely inconsistent with the actual inflation process."
30. For instance, D. Romer (1996) says that this term constitutes an intercept of the Phillips Curve and is an indicator of underlying inflation rate, and that it is a reflection of inertia generated by the time needed for price adjustments other than the expected inflation. Gordon (1997) also hints at the possibility that lagged inflation terms contain elements other than expectations, saying, "The role of the lagged inflation terms is to capture the dynamics of inertia, whether related to expectation formation, contracts, delivery lags or anything else."
31. Consider the actual mechanism of wage negotiations. Workers require a certain wage level derived from their previous year's wage level by incorporating an upward "projected inflation rate" in order to maintain real wages. A NAIRU-type relationship emerges if the projected inflation rate is primarily derived from the realized inflation rate in the most recent period (or several preceding periods). This can be interpreted either as inertia as it is a past value, or expectation insofar as the most recent information available at any given time is being used to make projections concerning the inflation rate.

B. Dynamics of Price Adjustment: The Relationship between Structural Factors and Expectations

We see the national differences in wage-setting systems, a key factor affecting price adjustments, by using a table from Bruno and Sachs (1985) that shows the international comparisons of social systems of wage-setting.

Bruno and Sachs (1985) quantified such factors as rate of unionization, the level at which wage negotiations are undertaken, the degree of harmony in employer-employee relations, the number of strikes, the length of labor contracts, and indexation. The results are used in defining two indices: "corporatism" and "nominal wage responsiveness." Countries are then categorized on the basis of these two indices (Table 5).

The horizontal axis (corporatism) is primarily affected by the level at which wage negotiations are conducted and the degree of harmony in labor relations. Corporatism rises as the negotiations become increasingly centralized and harmonious. Specifically, direct negotiations between top echelons of labor unions and management organizations and the adoption of a single, nationwide wage increase rate are assigned a rating of "high corporatism." As opposed to this, separate negotiations conducted on the corporate or factory level are assigned a rating of "low corporatism." "Medium corporatism" covers the intermediate zone where negotiations are conducted on an industry-by-industry basis.

Bruno and Sachs (1985) indicate that a mechanism exists under higher levels of corporatism which prevents sharp increases in wages. That is, under a centralized and harmonious framework for labor negotiations, employees more readily acknowledge that excessive wage increases on a national scale do not result in their gains because they just raise the level of inflation. Furthermore, changes in inflationary expectations tend to be milder because of the "concentration of expectations" generated under a system of nationwide wage-setting.

The vertical axis (nominal wage responsiveness) primarily reflects such factors as the intervals between negotiations and the synchronicity of individual negotiations. A rating of "high" is assigned to situations in which negotiation intervals are short and the timing of individual negotiations is scattered. In other words, higher ratings indicate that less time is needed for inflationary expectations to be reflected in wage settlements.

Table 5 Wage-Setting Systems in Labor Markets

		Corporatism		
		Low	Medium	High
Nominal wage responsiveness	High	Australia New Zealand <u>U.K.</u>		Netherlands Denmark
	Medium	Belgium France Italy	Finland <u>Japan</u>	Austria <u>Germany</u> Norway Sweden
	Low	<u>Canada</u> <u>U.S.</u>	Switzerland	

Note: Countries covered in this paper are underlined.
Source: Bruno and Sachs (1985).

Based on their interpretations, the social framework for wage negotiations can be expected to have a major impact on how inflationary expectations are transmitted to wages and prices. Of the five countries covered in this study, Table 5 indicates that the U.S., the U.K., and Canada have low levels of corporatism. The prediction here is that these countries are prone to inflation. The situation is particularly unfavorable for the U.K. because it also registers a high level of nominal wage responsiveness. On the other hand, among the five countries of our study, Germany is identified as the country least prone to inflation. Japan is situated in the intermediate zone for both of the indices. Thus in the context of Bruno and Sachs (1985), countries can be divided between NAIRU-type countries (such as the U.K.) where price adjustments proceed at high speed, and Phillips Curve-type countries (such as Germany) where price adjustments advance more slowly.

However, these indications do not necessarily agree with the estimations of this paper. For instance, based on its social framework for wage negotiations, Germany is identified as a country less prone to inflation. But our findings indicate that NAIRU-type conditions did in fact exist in Germany during the first half of the period of observation. This inconsistency hints at the possibility that, over time, a country may move from one type to another while retaining the same institutional framework. What this means, in the context of this paper, is that while the wage-setting framework may be an important factor in explaining the dynamics of price adjustment in individual countries, it cannot in itself be the determining factor. Therefore, it is more likely that the process of inflationary expectation formation itself plays an essential role in determining the speed of price adjustment.[32]

C. Some Considerations on the Results

In this section, we shall additionally investigate whether there are other common factors that characterize the cases where the results of our estimations indicate the existence of a NAIRU-type relationship.

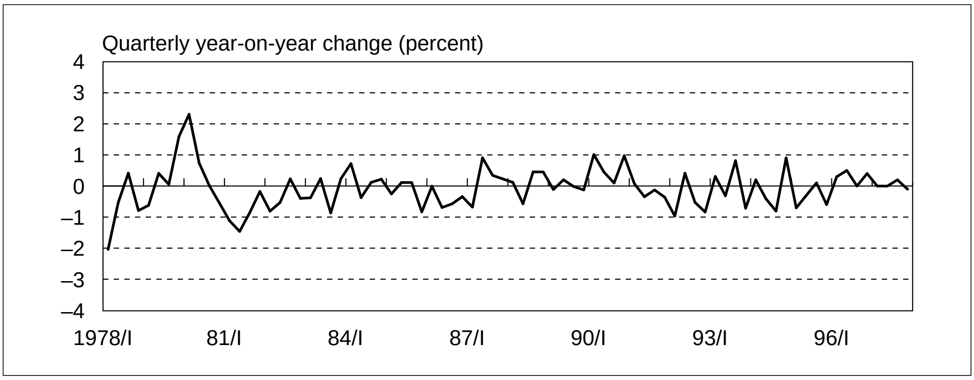
Although there is a tendency for NAIRU-type relationships to be observed during high inflation periods, exceptions are easy to find. For instance, Japan did not show NAIRU-type patterns during the period of sharp rise in price level following the second oil crisis. Other countries (the U.K. and Canada) continued to show NAIRU-type patterns during the second half when inflationary events, such as the oil crisis, had already dissipated. It can be inferred from these observations that the amplitude of inflation is not the only factor determining the generation of NAIRU-type patterns.

32. The assertion that national differences in wage-setting systems contribute to differences in economic performance has been made by others besides Bruno and Sachs (1985). (A list of such studies is contained in OECD [1997].) Consensus remains to be reached on various matters, but particularly concerning "corporatism" where classifications tend to be based on discretionary factors. Using data sets with differing classifications and periods of observation, some researchers have identified a "U-shaped phenomenon" whereby centralized and decentralized countries register better economic performances than the intermediate group of countries (OECD [1997]). In addition, it should be noted that the economic impact of national differences in wage-setting systems may differ between periods of high and low rates of inflation.

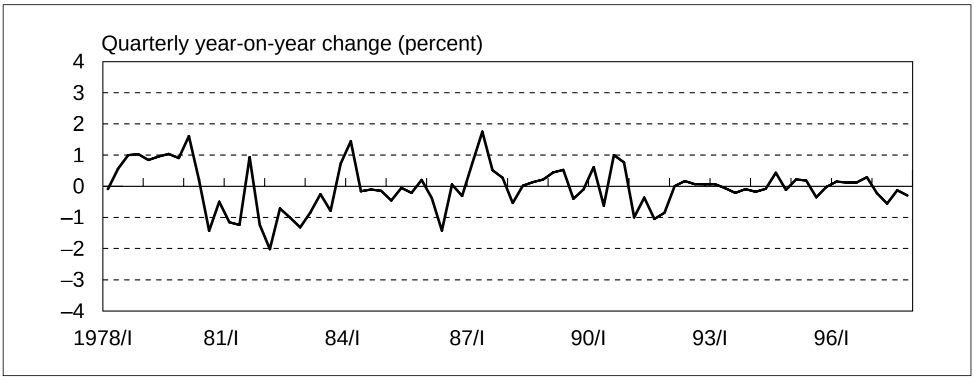
To test this contention, we shift our perspective from the inflation rate to the changes in inflation rate (Figure 2).[33] Figure 2 traces the trends in the changes in inflation rate since 1978.

Figure 2 Trends in the Changes in Inflation Rate (1978–1997)

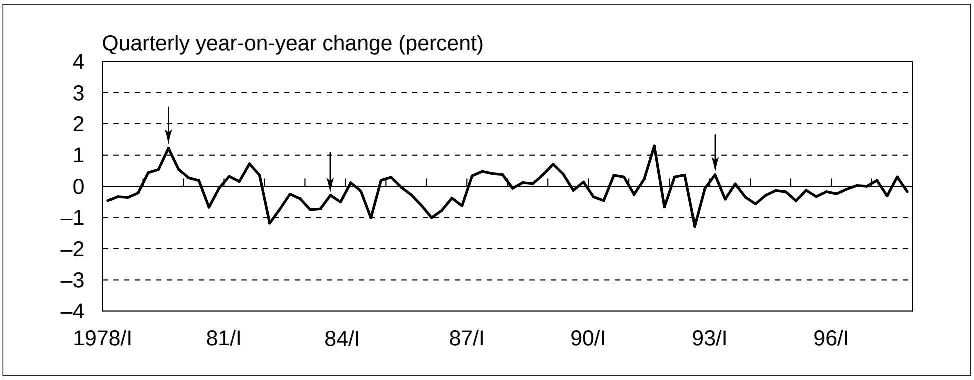
[1] Japan



[2] U.S.

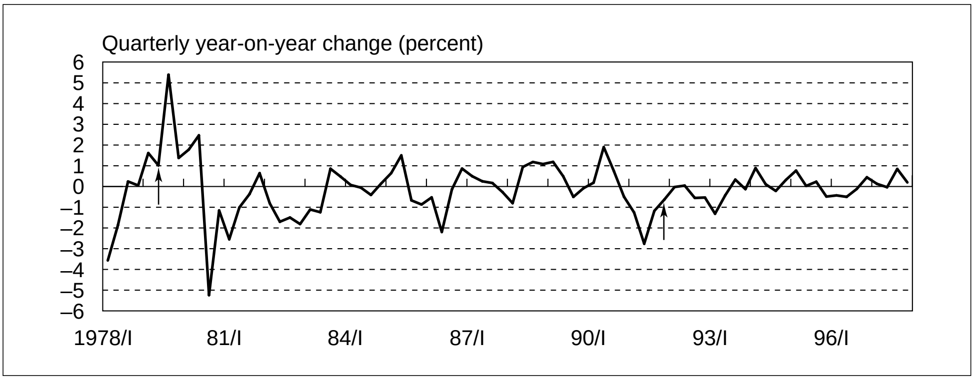


[3] Germany (Valued-Added Tax Not Adjusted)

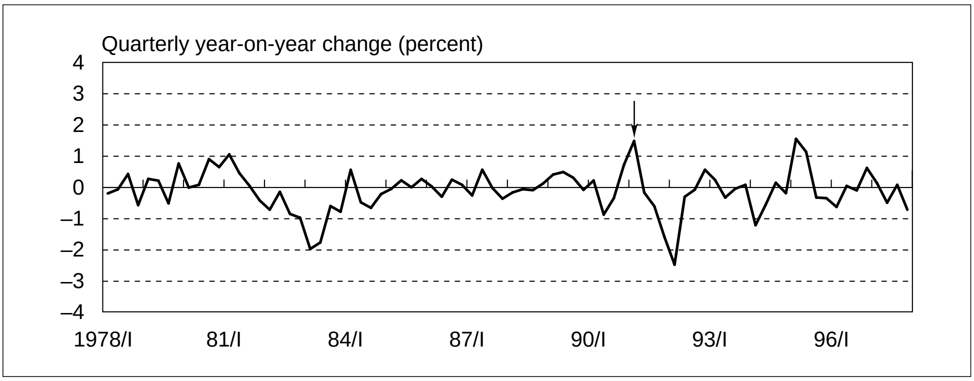


33. The changes in inflation rate for each country shown in Figure 2 are not adjusted for the impact of the introduction and raising (lowering) of VAT rates. Therefore, it should be noted that the following is only a very rough analysis. (For reference purposes, introduction of VAT or changes in VAT rates are indicated by arrows.)

[4] U.K. (Value-Added Tax Not Adjusted)



[5] Canada (Value-Added Tax Not Adjusted)



Let us focus on the U.K. and Canada, which show NAIRU-type patterns in both periods. Can we identify any common elements in these two countries? What catches the eye is the fact that both two countries have frequently experienced sharp upward or downward accelerations in inflation rate, defined here as an acceleration rate exceeding ±1 percent. Such sharp fluctuations happened not only in the second oil crisis but also throughout the entire period. Moreover, they can be repeatedly observed during a relatively short period of, for example, three years. The Japanese case stands in clear contrast to the U.K. and Canadian cases. During the first half, the rate of acceleration exceeded the ±1 percent band on only one occasion. This consisted of a sharp upward spike, immediately followed by a downward spike. Other than this single incident, no large swings were observed in the case of Japan.

Throughout the second half, the change in inflation rate for Japan remained within the ±1 percent band. Turning to the U.S. in the second half, when a NAIRU-type relationship was confirmed only at the 5 percent level, we observe that movements in the changes in inflation rate have been relatively moderate since 1990. The same tendency is observed in the case of Germany in the second half, when a NAIRU-type relationship can no longer be confirmed. The graph shows that, with the exception of a temporary and sharp rise in inflation experienced at the time of unification (followed by a sharp drop triggered by the introduction of tight money policies), the German price fluctuations were virtually stable during the second half.

To get a more detailed picture, we turn to Table 6, which presents the mean and variance of the realized values of inflation rates in the five countries in this study. The figures have been computed separately for the first and second halves of the period under observation.

Table 6 reveals that the four NAIRU-type countries of the first half all have relatively large variances in the 2–5 percent range during this period. On the contrary, the variances in the rates of inflation for Japan and Germany in the second half when both show a Phillips Curve-type relationship, and the U.S. in the second half when the NAIRU-type remains in doubt, stand in the vicinity of 1 percent. The two NAIRU-type countries of the second half (the U.K. and Canada) continue to register relatively large variances of about 2 percent. These findings generally conform to the indications of this section.

From these observations, we infer the possibility that the formation of inflationary expectations is related to the past record of the changes in inflation rate. In other words, a NAIRU-type relationship comes into being as a result of sharp price swings. Specifically, we posit the following hypothesis: a NAIRU-type relationship is generated when major price increases (or major price decreases) occur and when the "change in inflation rate exceeds (approximately) ±1 percent per quarter," not once, but "twice or more" going in the same direction during a period of approximately three years. As a result of these sharp fluctuations, the pattern of the formation changes to one determined by the most recent actual inflation rate, which consequently increases the speed of price adjustment.[34]

This can be interpreted to mean that there is a trade-off relationship between the loss generated by the divergence between the expected and realized inflation rates, and the cost resulting from making revisions in expectations. And, using this trade-off, people select the appropriate pattern of expectation formation in every period in order to minimize the combined loss and cost. Needless to say, the wage-setting systems discussed in Section VI.B constitute one of the factors determining the size of the cost of making revisions in expectations. However, the results of our observations in this section point to the fact that under conditions of sharp price fluctuations where the change in inflation rate approximately exceeds the 1 percent per quarter, the differences in revision costs which may exist among countries are not likely to be large.

Table 6 Mean and Standard Error of Inflation Rates by Country

		Japan	U.S.	Germany	U.K.	Canada
First half	Mean	3.3460	6.8843	3.5172	8.5867	7.7574
	S.E.	2.0971	3.9616	1.9927	4.6179	3.1303
Second half	Mean	1.1302	3.5724	2.3538	4.3751	3.0152
	S.E.	1.1125	1.0445	1.1861	1.9224	1.7933

34. Of course, the validity of this hypothesis cannot be ascertained through simple comparisons of trends in the changes in inflation rate and the observation of similarities among countries. In addition to the output gap, factors specific to individual countries (national character, etc.) may contribute largely to the determination of price trends. It is possible that the results cited above came about because such specific factors accidentally came to the surface. Thus, we attempted the same estimation of NAIRU coefficients for Japan between 1968–1977 (GDPGAP was computed using HP filter). The results showed that for Japan also, the NAIRU-type null hypothesis could not be rejected even at the 5 percent level. (In other words, the NAIRU-type relationship existed in Japan.) This finding somewhat supports the interpretations in this paper.

This assertion implies that the pattern of expectation formation and the speed at which expectations affect prices depend importantly on the past behavior of the inflation rate (most importantly, in the context of this paper, the frequency of the incidence of accelerations in the inflation rate). This has direct implications concerning the policy actions of central banks. That is, the past behavior of the inflation rate can be determined by the following considerations. (1) When the economy was hit by a shock triggering sharp price changes, did the central bank take appropriate actions to quell the situation? (2) Did the central bank boost inflationary trends by over-utilizing the rigidities in nominal prices to stimulate the economy? The crucial question here is whether the policy actions of the central bank have lost their effectiveness because the impact of policy actions is quickly transferred to nominal prices. In other words, policy effectiveness depends in large part on the past behavior of the central bank itself.

Let us take for example Germany in the second half, when the country experienced the very large shock of unification. Notwithstanding this shock, Germany was able to retain its Phillips Curve-type relationship because policy management remained very firmly committed to fighting inflation. Another notable example is the policy of inflation targeting adopted by the U.K. and Canada since the start of the 1990s. The announcement of numerical targets by the central bank can be interpreted as a framework for heightening the "concentration of expectations." If the central banks of these two countries strictly abide by this framework, it is possible that the NAIRU-type wage structure which currently exists in these two countries will in the future be transformed into a Phillips Curve-type structure.[35]

VII. Conclusion

In this paper, we undertook a cross-country study of the price-output gap relationship for selected industrialized countries (Japan, the U.S., Germany, the U.K., and Canada). The estimation results showed that the price-output gap relationship in these countries could be classified into two categories: (1) a Phillips Curve type (in which the output gap fluctuation affects the inflation rate); and (2) a NAIRU type (in which the output gap fluctuation affects changes in the inflation rate). In addition, we found that such country classifications could vary according to sample periods.

We divided the estimation period into two parts. During the first sample period (1978–1986; the first half), NAIRU-type patterns were seen in all countries except Japan. During the second period (1987–1997; the second half), NAIRU-type patterns were identified in the U.S., the U.K., and Canada, while Japan and

35. With regard to Japan during the second half (when a Phillips-type relationship is observed), it should be noted that there was a time when the Bank of Japan's consistent easing policy resulted in asset price inflation by over-utilizing the rigidities in nominal prices to stimulate the economy. However, the easing policy somehow did not change inflation expectation formation sufficient to boost general goods inflation. The relation between expectation formation, asset prices, and general prices is a subject that must be discussed in a future study.

Germany exhibited Phillips Curve-type patterns. Our results are summarized in Table 7.

Table 7 Country Classifications

	First half (1978–1986)	Second half (1987–1997)
Phillips Curve type	—	Japan, Germany
NAIRU type	U.S., Germany, U.K., Canada	(U.S.), U.K., Canada

Note: The United States in the second half appears in parentheses because from the *F* test, the null hypothesis (i.e., NAIRU-type stands) is not rejected at the 1 percent level, but is rejected at the 5 percent level.

Taking into account the wage-setting systems of these countries, the difference between the Phillips Curve type and NAIRU type can be interpreted to represent differences in the speed of price adjustments, which reflect the difference in how inflation expectations are formed. (Phillips Curve type: price adjustments are made at a relatively slow pace around the “core inflation rate” [constant term]. NAIRU type: price adjustments are made at a faster pace as the expected inflation rate for the current period, determined on the basis of the actual inflation rate in the preceding period, is reflected in prices.)

Based on this interpretation, the estimations for the first half of the period indicate that, in most countries, expectations were formed on the basis of past realized inflation rates and that, therefore, the speed of price adjustment was high. Going into the second half, our estimations indicate that more stable patterns of expectation formation prevailed in countries experiencing more moderate inflation, such as Japan and Germany. In these countries, inflation expectations were relatively stable and seemed to be formed around a constant term, hence the speed of price adjustment slowed down.

Observed differences in price adjustment speeds among countries and between different time periods led us to a hypothesis concerning the existence of a switching mechanism allowing rapid changes in the patterns of expectation formation. That is, whenever sharp swings in the inflation rate are experienced within a short period of time, people switch their expectation formation from the constant value to the most recent realized inflation rate. (A single incident of sharp changes in the inflation rate is not enough to induce the switch. The switching occurs during a period of marked instability and repeated up-and-down fluctuations in the inflation rate.) This hypothesis contains important implications concerning the policy actions of central banks. Specifically, if a central bank is able to avoid the occurrence of sharp fluctuations in the inflation rate in both the upward and downward directions in any given short period of time, the process of expectation formation will be stabilized. On the contrary, even if inflationary expectation formation is initially stable, excessively exploiting the trade-off relationship will eventually activate the switching mechanism, and the trade-off relationship will be lost, since such policy action will produce sharp fluctuations in inflation within a short period of time.

Although evidence of NAIRU-type patterns were observed in the U.S., Canada, and the U.K., these countries have also been experiencing greater price stability in recent years. Whether the continuation of current stable inflation in these countries will lead them eventually to be Phillips Curve-type countries is still an open question at this point. Similarly, we have no way to predict whether NAIRU-type patterns will reemerge in the future as a result of sharp downward swings in inflation, or sharp upward swings triggered by economic overheating in these countries.

A further question that must remain unanswered at this stage concerns the applicability of the findings of this paper to current conditions in Japan, which are marked by near-zero inflation. In other words, are the dynamics of upward nominal value adjustment directly applicable to downward adjustments, or do asymmetries exist between upward and downward movements?

Nevertheless, we believe that it is important for policy makers to continue their analysis of the relationship between prices and the output gap and other leading indicators, as well as the expected inflation rate, and to pursue the questions which remain unanswered in this paper.

APPENDIX: PROCEDURE FOR OUTPUT GAP ESTIMATION

The output gap measures the difference between a country's potential output (potential GDP) and the current level of output. The output gap has been widely used as an indicator of the "tightness" or "looseness" of the prevailing supply and demand conditions in an economy. However, there is no clear consensus on how to specify and to compute "potential output."

For instance, some relatively orthodox approaches frequently used in the past are: simply applying a linear trend to real GDP time-series data; deriving it by estimating macroeconomic production functions; and using time-series methodologies, such as HP filters, by smoothing time-series data that are then interpreted to represent potential GDP. More recently, efforts have been made to integrate the various merits of these approaches, and several papers have been written using "multivariate filters" to compute potential GDP (examples include Haltmaier [1996] and Giorno *et al.* [1995]). Given the availability of the above various approaches, we decided to use the methodology of Watanabe (1997) to compute Japan's potential GDP. For the remaining four countries, we opted for the relatively simple HP filter approach. These computation methods are briefly described below.

A. Obtaining Japan's Potential GDP

Following the methodology of Watanabe (1997), we compute potential GDP based on estimated production functions. The process is summarized as follows.

(1) Assume a Cobb-Douglas production function. Divide both sides by volume of labor input, and arrive at the following equation through logarithmic transformation. (Y is real GDP, K is capital stock multiplied by the rate of capital utilization, L is employed persons, H is total working hours, and $t_{1,2}$ is linear time trend.)

$$\ln(Y_t/L_tH_t) = \alpha_0 + \alpha_1 \ln(K_t/L_tH_t) + \alpha_2 t_1 + \alpha_3 t_2,$$

where we assume the growth rate of TFP is α_2 for the normal period and $\alpha_2 + \alpha_3$ for the bubble period.

(2) Input the potential values of capital, employable population, and total labor hours in the production function derived in (1). We define potential inputs as the historical maximum actual value of each variable.

(3) Compute to derive potential GDP.[36]

B. HP Filter Approach Used for Countries Other than Japan

The process used in deriving the output gaps for countries other than Japan is summarized below.

In the HP filter[37] approach, the following equation is minimized by breaking down the original series into a growth element (g_t) and a cyclical element (c_t).

36. See Watanabe (1997) for details of derivation of potential values for individual factors, and computation of production functions and potential GDP.
37. The HP filter methodology was formulated by Hodrick and Prescott (1980).

$$\min_{\{g_t\}_{t=-1}^{T}} \left\{ \sum_{t=1}^{T} c_t^2 + \lambda \sum_{t=1}^{T} \left[(g_t - g_{t-1}) - (g_{t-1} - g_{t-2}) \right]^2 \right\}.$$

"Summation of the square of the cyclical element"

"Summation of the square of the second order difference of the growth element"

In this paper, we used the growth component (g_t) obtained from this filter as the potential GDP for the four countries other than Japan. However, a problem arises here. As shown by Higo and Nakada (1998), the addition of new data to the HP filter results in the revision of the most recent values (covering a period of about three years). In order to make an improvement partially, the time-series data were extended to 1999/IV based on OECD projected value of real GDP.

C. Obtaining the Output Gap

Using potential GDP computed as above, the output gap was obtained through the following equation.

$$GDPGAP = (\text{real GDP} - \text{potential GDP})/\text{potential GDP} \times 100.$$

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