The Phillips Curve and Underlying Inflation

Hitoshi Mio

This paper examines methods of controlling the supply shock in the estimation of the Phillips curve and discusses the relationship between the supply shock and inflation inertia. The empirical results clearly show that controlling the supply shock effect, not only for current inflation but also for lagged inflation using the asymmetry of the price change distribution, substantially outperforms the traditional method in terms of the robustness to alternative lag specifications, predictive power, and parameter stability for changes in the estimation period, which are the essential properties for the practical use of the Phillips curve. These results suggest that (1) because supply shocks hit broad sectors, it is not appropriate to restrict the proxy for the supply shock to the relative price changes of a fixed commodity basket; and (2) the inflation inertia corresponds to the underlying inflation from which the supply shock effect has been eliminated.

Key words: Underlying inflation; Trimmed mean CPI; Price change distribution; Temporary relative price shock

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I would like to thank Kousuke Aoki, Fumio Hayashi, Michael McAleer, and Hiroshi Yoshikawa for helpful comments and suggestions. All remaining errors and the views expressed herein are mine and are not necessarily those of the Institute for Monetary and Economic Studies or the Bank of Japan.

I. Introduction

The purpose of this paper is to examine methods of controlling the supply shock in the estimation of the Phillips curve and to discuss the relationship between the supply shock and inflation inertia.[1]

In the 1970s, two shift parameters, namely, the s*upply shock* term and the *lagged inflation* term, were added to amend the Phillips curve specification. For the proxy for the supply shock, the relative price changes of a fixed commodity basket that commonly includes import goods, foods and energy-related goods have been widely used. Two classical views seem to support this amendment. The first is that, unlike the supply for manufacturing goods, the supply for certain commodities is highly price inelastic and experiences supply shocks frequently (for example, Gordon [1975] and Okun [1981]). The second is that the exogenous relative price changes of intermediate commodities (crude oil, for example) can be regarded as aggregate supply shocks (Bruno and Sachs [1985]). In practice, it seems that researchers follow this strategy to control the supply shock in the estimation of the Phillips curve.

Alternatively, Ball and Mankiw (1995) show the interesting result that the asymmetry (or skewness) of the cross-sectional price change distribution is better than the traditional proxy (the relative price change of a fixed commodity basket). Taking a hint from their findings, I estimated alternative Phillips curve specifications using the traditional proxy and the Ball and Mankiw-type proxy for the supply shock and compared the performance.

The analysis here is different from Ball and Mankiw's in two respects: first, controlling the supply shock not only for the dependent variable, i.e., the *current inflation*, but also for the *lagged inflation*, which is the proxy for the inflation inertia; and second, calculating the asymmetry of the price change distribution using the changes in the trimmed mean CPI,[2] proposed by Bryan and Cecchetti (1994).

The empirical results clearly show that controlling the supply shock not only for the current inflation, but also for the lagged inflation, using the asymmetry of the price change distribution outperforms the traditional method in terms of the robustness to the various lag specifications, predictive power, and the parameter stability for changes in the estimation period, which are the essential properties for the practical use of the Phillips curve. These results suggest that (1) because supply shocks hit broad sectors, it is not appropriate to restrict the proxy for the supply shock to the relative price changes of a fixed commodity basket; and (2) the inflation inertia corresponds to the underlying inflation rate from which the supply shock effect has been eliminated.[3]

The outline of this paper is as follows. Following the introduction, Section II summarizes the key features of the methods for controlling the supply shock in the

1. In this paper, the term *inflation inertia* is defined as a broad concept containing inflation expectations.
2. I simply call this the trimmed CPI.
3. The definition of *underlying inflation* in this paper is not necessarily compatible with the use in the literature, which generally discusses the issue for the extraction of underlying inflation. See Bryan and Cecchetti (1999b), Higo and Nakada (1998), Mio and Higo (1999), and Shiratsuka (1997) for discussions of Japan. Also see Álvarez and Matea (1999), Bakhshi and Yates (1999), Bryan and Cecchetti (1994, 1999a), Gartner and Wehinger (1998), Monetary Authority of Singapore (1998), and Roger (1997) for recent examples in other countries.

estimation of the Phillips curve. Section III presents the empirical results of the estimation and compares the performance. Section IV discusses the background of the empirical findings, and Section V concludes. The Appendix explains an indicator of the asymmetry of the price change distribution, which is employed as the indicator of the supply shock.

II. Specification of the Phillips Curve and the Supply Shock

A. General Specification of the Phillips Curve

The general specification of the Phillips curve is given as equation (1).[4]

$$\pi_t = \alpha + \sum_{i=1}^{l} \beta_i \pi_{t-i} + \sum_{j=1}^{m} \gamma_j GAP_{t-j} + \sum_{k=0}^{n} \theta_k SupSHOCK_{t-k} + \varepsilon_t. \quad (1)$$

The dependent variable is the inflation rate. The first term on the right-hand side is the constant, the second is lagged inflation, a proxy for inflation inertia, the third is the output gap, the fourth is a proxy for the supply shock, and the fifth is the error. Among these, the second and the fourth were added to amend the specification of the Phillips curve to avoid the serial correlation in the error term.[5]

In the recent literature, little attention seems to have been paid to the relationship between lagged inflation and the supply shock.[6] Although the subsequent analyses mainly focus on methods for controlling the supply shock, note that these also have implications for another key issue of this paper, namely, "what kind of relationship exists between the supply shock and inflation inertia?"

The subsequent two subsections summarize the key features of alternative methods for controlling the supply shock in estimating the Phillips curve.

B. Method of Controlling Supply Shock: The Gordon Method

The traditional method of controlling the supply shock is to exclude a fixed commodity basket from the price index and/or to add the relative price changes of a fixed commodity basket to the right-hand side of the equation. In the following discussion, I call this method the "Gordon method" for convenience.[7] Two classical views seem to support this amendment. The first is that, unlike manufacturing goods, the supply of certain commodities is highly price inelastic and experiences supply shocks frequently (for example, Gordon [1975] and Okun [1981]). The second is that the

4. The Phillips curve and the aggregate supply curve are likely to be treated interchangeably. See Blanchard (1997), Mankiw (1997), and D. Romer (1996) for the conventional derivation of the upward-sloping aggregate supply curve. Also see Cooley and Quadrini (1999) and Gali and Gertler (1999) for recent attempts to derive the structural Phillips curve relationship.
5. On the other hand, C. Romer (1996) addresses this supply shock issue from the perspective of the simultaneous equation bias due to the correlation between the output gap and the error term. She assumes that the output gap lagged one year has no correlation with the current year's supply shock which affects the error term, and performs estimation using the output gap lagged one year as the instrumental variable.
6. As I will point out in Section IV, however, some of the traditional research, including Gordon (1975), is found to discuss this issue.
7. Following Gordon ([1997], footnote 2) who argues that he is one of the originators of this method, I call this the Gordon method.

exogenous relative price changes of intermediate commodities, such as crude oil, can be regarded as an aggregate supply shock (for example, Bruno and Sachs [1985]). In practice, it seems that research widely follows this strategy to control the supply shock in the estimation of the Phillips curve.

Table 1 shows some recent examples from the United States and Japan using the Gordon method. In the United States, using the relative price changes of import goods, foods, and energy-related goods seems to be common. In Japan, using "CPI excluding fresh foods (CPI ex. fresh foods)"[8] for both dependent variable and lagged inflation, and adding the changes in import prices to the right-hand side of the equation, is dominant.[9]

Table 1 Recent Examples from the United States and Japan Using the Gordon Method

	Countries	Dependent variable	Proxy on the right-hand side of the equation
Gordon (1990)	United States, etc.	GNP deflator	Relative price of food, energy, and import goods, price control "Nixon" dummy, oil shock dummy
Fuhrer (1995)	United States	CPI ex. food and energy	Relative price change of crude oil
Gordon (1997)	United States	CPI-U-X1, etc.	Relative price of food, energy, and import goods, price control "Nixon" dummy
Staiger, Stock, and Watson (1997)	United States	Headline CPI	Relative price of food, energy, and price control "Nixon" dummy
Fair (2000)	United States	Business nonfarm price deflator	Import price deflator (deviation from time trend)
Watanabe (1997)	Japan	CPI ex. fresh foods	Import price
Tanaka and Kimura (1998)	Japan	CPI ex. fresh foods	Import price
Higo and Nakada (1999)	Japan, etc.	Headline CPI	Import price

C. Method of Controlling the Supply Shock: The Ball and Mankiw Method

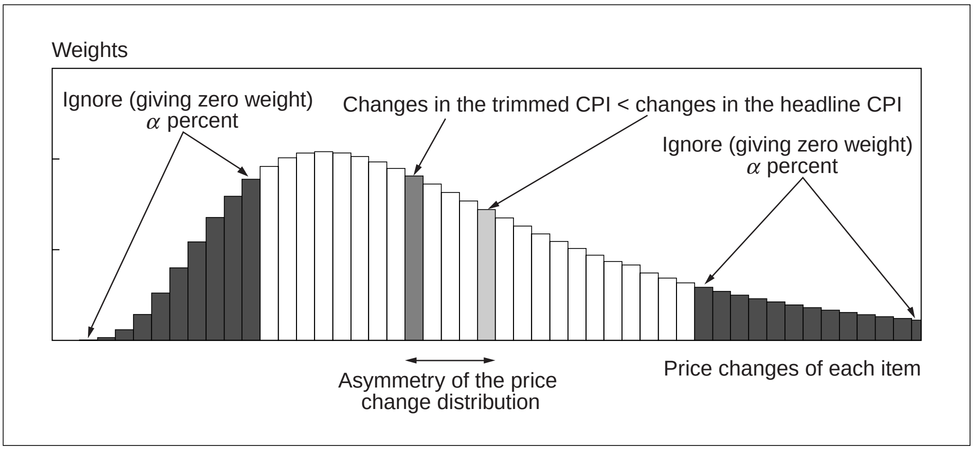
In contrast to the widely accepted Gordon method, Ball and Mankiw (1995) propose an alternative method that uses the asymmetry (or skewness) of the cross-sectional price change distribution as a proxy for the supply shock.[10] As in the previous subsection, I call their method the "BM method" for convenience. They argue that due to the existence of menu costs, relative price adjustments among sectors do not proceed smoothly, resulting in supply shocks to limited sectors that can temporarily affect aggregate inflation. To clarify their hypothesis, they estimate the Phillips curve using the traditional Gordon method and the proposed BM method, and find that the latter outperforms the former. Therefore, they conclude that the menu cost model is relevant.

8. The CPI ex. fresh foods is computed by removing fresh fish and shellfish, fresh vegetables, and fresh fruits from the headline CPI.
9. The analysis in Japan presented in Table 1 adds changes in the *absolute* import prices, not the *relative* import prices. While Bruno and Sachs (1985) suggested that using the changes in *relative* import prices is appropriate, using either *absolute* or *relative* import prices does not affect the empirical results in the following sections since the changes in import prices are overwhelmingly larger than the changes in domestic (general) prices in Japan.
10. I simply call this the price change distribution.

In spite of their argument, it is difficult to conclude that the menu cost model has achieved a consensus among economists.[11] However, once we accept their view that supply shocks can potentially hit broad sectors, it might be natural to reexamine the relevance of the traditional Gordon method which assumes that sectors facing supply shocks are fairly limited and can be determined *a priori*. Taking a hint from their proposal, I estimated the Phillips curve using trimmed CPI for the calculation of the the asymmetry (or skewness) of the cross-sectional price change distribution as a proxy for supply shock.[12]

The steps to compute the trimmed CPI are as follows: calculate the price change of each item, find items that are located in a fixed proportion of each tail of the price change distribution, ignore these outliers and average the price changes of the remaining items with their weights (Figure 1).[13] When some sectors face large supply

Figure 1 The Trimmed CPI and the Asymmetry of the Price Change Distribution



11. Reviewing the literature that tries to reconcile the observed correlation between the first (inflation rate) and higher moments (variance and skewness) of the price change distribution, the argument that shocks to the money supply are the primary source of the observed correlation was widely accepted during the late 1970s and the beginning of the 1980s, coincident with the diffusion of the Lucas-Phelps aggregate supply curve (see Barro [1976], Hercowitz [1981], Parks [1978], and Vining and Elwertowski [1976]).

    On the other hand, two theories recently suggest that supply shocks to sectors create this correlation. The first is Ball and Mankiw (1995), which assumes that the existence of the menu cost makes the smooth relative price adjustment difficult. The second is Balke and Wynne (2000), which states that this correlation can be found without the menu cost if the production functions in the very short run can be regarded as the Leontief type and/or if the shocks *per se* are correlated with each other. Balke and Wynne's first assumption seems analogous to Bruno and Sachs (1985), which provides the traditional understanding for the macroeconomic consequence of exogenous oil price changes.

    Some empirical studies also show that the shocks to the money supply are not likely to be the sole or the major source of the correlation between the first and higher moments of the price change distribution (see Fischer [1981], Bomberger and Makinen [1993], and Debelle and Lamont [1997]). However, the debate has not matured by any means (see Ball and Mankiw [1999] and Jaramillo [1999]).
12. See Nishizaki and Watanabe (1999) for another example using the BM method in Japan.
13. I use 88 items of the Japanese CPI for the computation of the trimmed CPI. See Shiratsuka (1997) and Mio and Higo (1999) for the details of the items used. Based on Mio and Higo (1999), this paper adopts 30 percent trimmed CPI (i.e., trimming 15 percent off from each tail of the price change distribution) for the following analysis. In addition, the change in the headline CPI in this paper indicates the 0 percent trimmed CPI, which is approximately equal to the changes in the five-year chain-weighted geometric mean index (see Mio and Higo [1999]). The 0 percent trimmed CPI and the change in the headline CPI (arithmetic mean) generally in use virtually show no difference in practice.

shocks, prices of products for those sectors are likely to experience large relative price changes. Consequently, the price change distribution tends to skew and a divergence is likely to emerge between the changes in the headline CPI and the trimmed CPI: the larger the skewness, the greater the divergence between the two. Focusing on this characteristic, this paper adopts the asymmetry of the price change distribution computed by the divergence between the changes in the headline CPI and trimmed CPI as a proxy for the supply shock.[14]

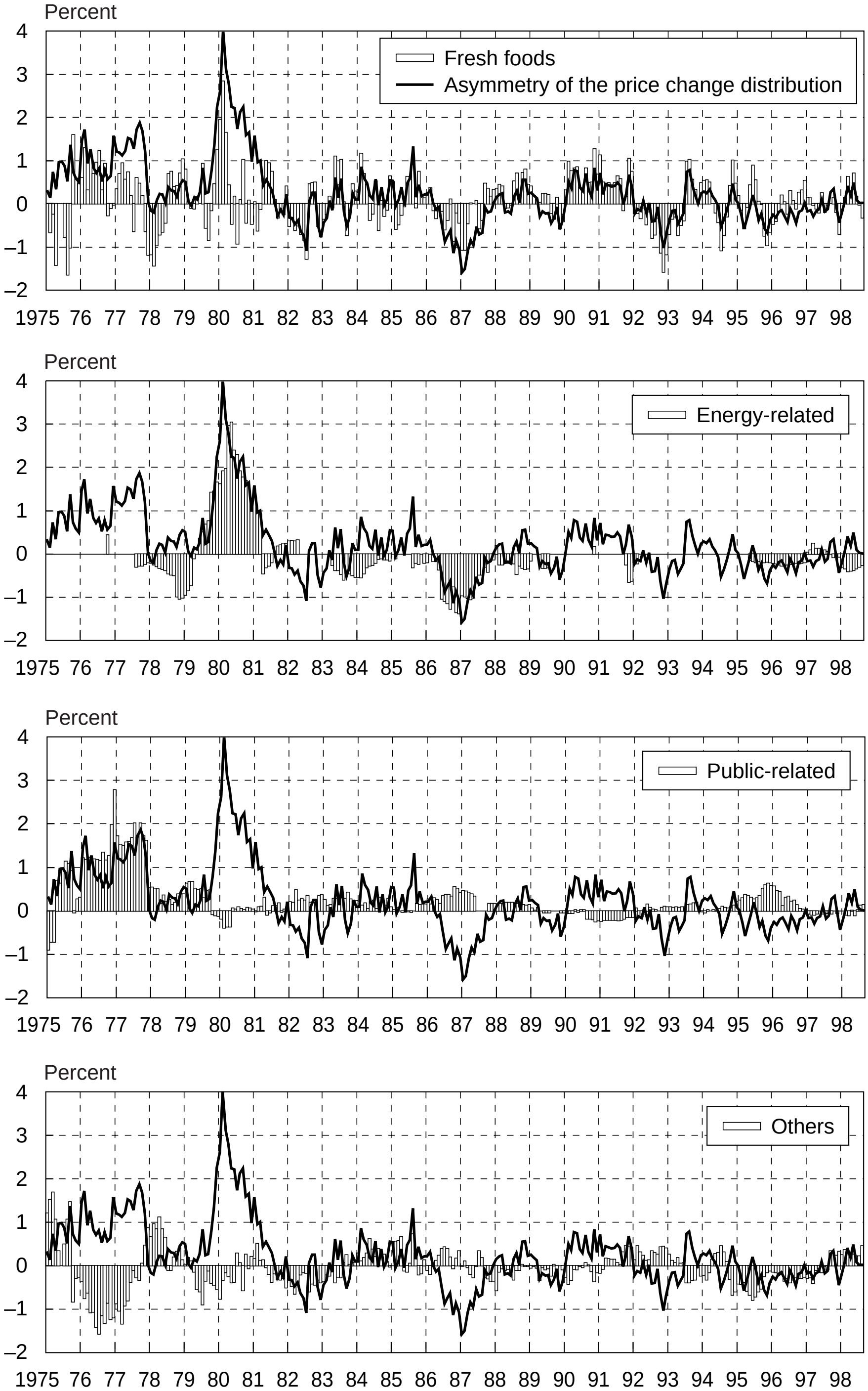
There is some evidence that supply shocks may hit broad sectors. Figure 2 presents some items that contribute to creating the asymmetry of the price change distribution.[15] It turns out that broad items are located in the tails of the price change distribution. Surprisingly, since 1975, 87 of the 88 items are located in the 15 percent tail of the price change distribution at least once.

As a result, as Figure 3 shows, the relative import price used for the Gordon method and the asymmetry of the price change distribution used for the BM method basically do not seem to have a strong positive correlation except for the period around 1980. In other words, the relative import price and the asymmetry of the price change distribution are not interchangeable proxies for the supply shock.

In the next section, the empirical performance of the BM method is compared with the Gordon method. Table 2 summarizes the characteristics of the Gordon method and the BM method. The traditional Gordon method (the second row) adopts the relative price changes of a fixed commodity basket. In contrast, the BM method (the third row) does not fix the basket *a priori* and adopts the asymmetry of the price change distribution. Type A (the second column) adds the proxy for the supply shock to the right-hand side of the equation, and Type B (the third column) utilizes the underlying inflation rate from which the supply shock effect has been eliminated prior to the estimation.[16]

14. See the Appendix for more details about the derivation and the interpretation of the asymmetry of the price change distribution.
15. See the Appendix for the calculation.
16. The inflation rate used in Type B is often called the *core inflation rate*.

Figure 2 Contribution of Certain Items to the Asymmetry of the Price Change Distribution



Note: See Mio and Higo (1999) for the details of the items.

Figure 3 Two Proxies for the Supply Shock

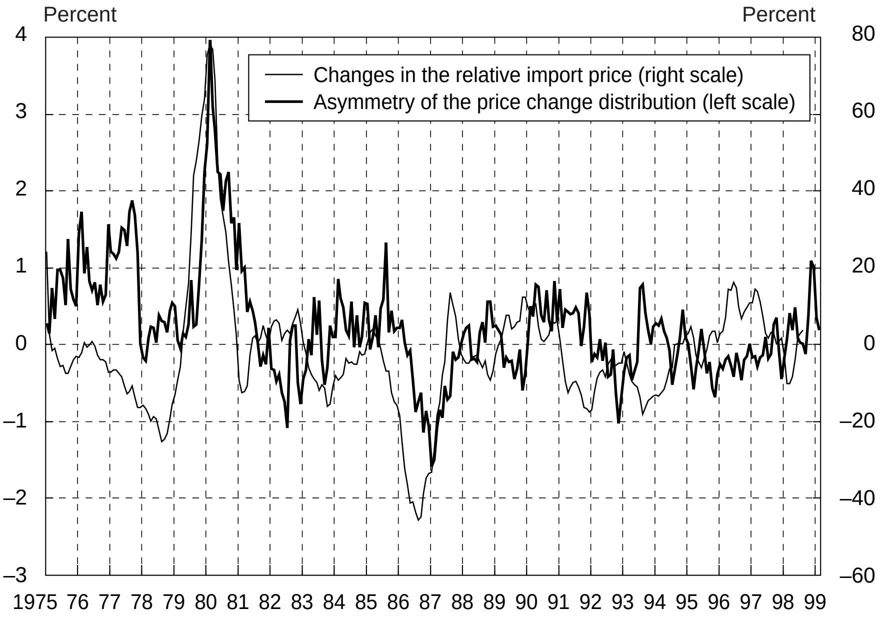


Table 2 Alternative Methods for Controlling the Supply Shock

	A type: Adding a proxy to the right-hand side of the equation	B type: Using underlying inflation
The Gordon method: Using the relative price changes of a fixed basket	Adding the relative price changes of foods, energy-related goods, and import goods	Utilizing the CPI ex. food and energy as underlying inflation
The BM method: Using the asymmetry of the price change distribution	Adding the asymmetry of the price change distribution	Utilizing the trimmed CPI as underlying inflation

III. Estimation Results

In this section, I estimate four Phillips curve specifications. Their performance is compared in three terms: empirical robustness to the various lag specifications, predictive power and the parameter stability for changes in the estimation period. I choose these three terms because they are the essential properties for the practical use of the Phillips curve.

A. Estimating Four Specifications

In this subsection, I estimate four specifications with various lag lengths for the lagged inflation, the lagged output gap, and the present and lagged supply shock term:[17] two using the traditional Gordon method and two using the BM method.[18]

Gordon-A type

$$\dot{CPIttl}_t = \alpha + \sum_{i=1}^{l}\beta_i \dot{CPIttl}_{t-i} + \sum_{j=1}^{m}\gamma_j GDPGAP_{t-j} + \sum_{k=0}^{n}\theta_k \dot{RIMP}_{t-k} + \varepsilon_t. \quad (2)$$

Gordon-AB type

$$\dot{CPIexf}_t = \alpha + \sum_{i=1}^{l}\beta_i \dot{CPIexf}_{t-i} + \sum_{j=1}^{m}\gamma_j GDPGAP_{t-j} + \sum_{k=0}^{n}\theta_k \dot{RIMP}_{t-k} + \varepsilon_t. \quad (3)$$

BM-A type

$$\dot{CPIttl}_t = \alpha + \sum_{i=1}^{l}\beta_i \dot{CPIttl}_{t-i} + \sum_{j=1}^{m}\gamma_j GDPGAP_{t-j} + \sum_{k=0}^{n}\theta_k SKEW_{t-k} + \varepsilon_t. \quad (4)$$

BM-B type

$$\dot{Trim30}_t = \alpha + \sum_{i=1}^{l}\beta_i \dot{Trim30}_{t-i} + \sum_{j=1}^{m}\gamma_j GDPGAP_{t-j} + \varepsilon_t. \quad (5)$$

where

$CPIttl_t$: headline CPI at time t
$CPIexf_t$: CPI ex. fresh foods at time t
$Trim30_t$: 30 percent trimmed CPI at time t
$GDPGAP_t$: output gap at time t[19]

17. Since I assume that the present output gap does not affect the inflation rate, I do not use the present output gap for the explanatory variable. This also avoids the endogenity problem due to the correlation between $GDPGAP_t$ and ε_t. See Footnote 5.
18. Names for each specification correspond to those presented in Table 2.
19. See Watanabe (1997) for the computation of the output gap. He first estimates a Cobb-Douglas type production function to obtain two share parameters and the series of the TFP (total factor productivity). Then he calculates potential output using the maximal labor population, the fixed capital stock, and the deterministic TFP time trend. Finally, he computes the output gap, which is defined as (actual output − potential output)/potential output. Breaks in the TFP trend are assumed in 1985 and 1992. In this paper, since the sign of the output gap is opposite to that presented in Watanabe (1997), (i.e., the output gap is defined as (potential output − actual output)/potential output), the summation of the parameter estimates for the output gap coefficients, $\sum_{j=1}^{m}\hat{\gamma}_j$, is expected to be negative.

$SKEW_t$:	asymmetry of the price change distribution at time t
	= changes in the headline CPI – 30 percent trimmed CPI
	$(\dot{CPIttl}_t - \dot{Trim30}_t)$
$RIMP_t$:	relative import price at time t
	= domestic wholesale import price index/headline CPI
l:	length of lagged inflation (l = 1~3)
m:	length of the output gap (m = 1~3)
n:	length of the supply shock (n = 0~3)

Dots (•) above variables indicate year-to-year changes.[20]

To understand the relationship between equations (4) and (5), the following transformation is helpful. Assuming that $l = n$, $\theta_0 = 1$, and $\beta_n = -\theta_n$, equation (4) can be rewritten as follows.

$$\dot{CPIttl}_t = \alpha + \sum_{i=1}^{n}\beta_i \dot{CPIttl}_{t-i} + \sum_{j=1}^{m}\gamma_j GDPGAP_{t-j} + \sum_{k=0}^{n}\theta_k SKEW_{t-k} + \varepsilon_t,$$

$$\dot{CPIttl}_t - SKEW_t = \alpha + \sum_{i=1}^{n}\beta_i \left(\dot{CPIttl}_{t-i} + \frac{\theta_i}{\beta_i} SKEW_{t-i}\right) + \sum_{j=1}^{m}\gamma_j GDPGAP_{t-j} + \varepsilon_t,$$

$$\dot{Trim30}_t = \alpha + \sum_{i=1}^{n}\beta_i \dot{Trim30}_{t-i} + \sum_{j=1}^{m}\gamma_j GDPGAP_{t-j} + \varepsilon_t.$$

This means that equation (5) can be interpreted as a special case of equation (4) in the sense that equation (5) is the coefficient constrained version of equation (4). Also, note that supply shock is controlled not only for current inflation but also for lagged inflation. If this is really the case, the inflation inertia is likely to be closely related to the underlying inflation rate from which the supply shock effect has been eliminated by the BM method.

Table 3 presents the estimation results for four specifications with various lag lengths for the lagged inflation, the output gap, and the supply shock term. First, little difference is found in adjusted R^2 among the various specifications. When l is two or more, the autocorrelation problem generally disappears.[21]

Next, focusing on coefficients of the output gap term, in equations (4) and (5) the null hypothesis that the coefficient is zero is rejected, regardless of the length of the lagged inflation. In contrast, in equations (2) and (3), the null is not rejected for various lag specifications. This suggests that in terms of the stability for various lag specifications, using the BM method produces a more favorable performance compared with using the traditional Gordon method. None of the specifications has consecutive coefficients that are significant.

20. Quarterly inflation rates are calculated by the simple three-month average of the monthly inflation rate. Influence on the CPI from the introduction of the consumption tax (April 1989) and the increase in the consumption tax rate (April 1997) are adjusted using estimates by the Research and Statistics Department, the Bank of Japan.

21. For equation (4), it appears that there may be a negative first-order autocorrelation in the error term. Thus, generalized least square estimation is performed and the same analysis is conducted for the subsequent sections. The results, however, show little difference from those using ordinary least squares. Hence, only the results for ordinary least squares are presented.

Table 3 Results of Estimated Phillips Curves for Various Lag Specifications

	α	β_1	β_2	β_3	γ_1	γ_2	γ_3	θ_0	θ_1	θ_2	θ_3	*h*-alt	Adjusted R^2
Equation (2), n = 0													
1	0.179	0.932			−0.012			0.022				1.252	0.965
2	0.965	0.932			−0.009	−0.003		0.022				1.247	0.965
3	0.152	0.932			−0.004	−0.095	0.096	0.022				1.224	0.965
4	0.177	1.003	−0.068		−0.011			0.021				0.334	0.965
5	0.175	1.003	−0.069		−0.014	0.004		0.021				0.323	0.965
6	0.145	1.011	−0.076		−0.010	−0.093	0.101	0.020				0.102	0.965
7	0.183	1.026	−0.152	0.059	−0.013			0.021				0.187	0.965
8	0.183	1.026	−0.152	0.059	−0.013	0.000		0.021				0.191	0.964
9	0.153	1.030	−0.146	0.050	−0.009	−0.091	0.095	0.021				0.015	0.964
Equation (3), n = 0													
10	0.123	0.952			−0.011			0.019				4.004	0.973
11	0.114	0.952			−0.031	0.023		0.019				4.038	0.973
12	0.110	0.952			−0.030	0.010	0.014	0.019				4.017	0.972
13	0.115	1.092	−0.136		−0.008			0.017				0.924	0.974
14	0.096	1.100	−0.144		−0.048	0.046		0.017				0.814	0.973
15	0.090	1.101	−0.145		−0.048	0.027	0.020	0.017				0.803	0.973
16	0.122	1.138	−0.283	0.099	−0.012			0.017				−0.382	0.974
17	0.102	1.148	−0.293	0.100	−0.054	0.048		0.017				−0.561	0.974
18	0.102	1.148	−0.293	0.100	−0.054	0.048	0.000	0.017				−0.563	0.973
Equation (4), n = 3													
19	0.269	0.912			−0.050			1.243	−0.830	−0.139	−0.105	3.676	0.983
20	0.274	0.913			−0.040	−0.011		1.242	−0.830	−0.014	−0.017	3.662	0.983
21	0.267	0.913			−0.039	−0.031	0.021	1.238	−0.826	−0.014	−0.105	3.645	0.982
22	0.202	1.286	−0.343		−0.037			1.190	−1.256	0.308	−0.069	1.597	0.985
23	0.193	1.290	−0.349		−0.056	0.022		1.191	−1.261	0.314	−0.066	1.501	0.985
24	0.180	1.294	−0.353		−0.054	−0.014	0.038	1.183	−1.259	0.318	−0.063	1.368	0.985
25	0.227	1.379	−0.613	0.164	−0.040			1.179	−1.327	0.588	−0.217	−2.127	0.986
26	0.219	1.383	−0.617	0.163	−0.057	0.020		1.179	−1.331	0.592	−0.214	−2.369	0.986
27	0.210	1.383	−0.612	0.158	−0.056	−0.002	0.023	1.175	−1.328	0.586	−0.208	−2.312	0.985
Equation (5)													
28	0.282	0.946			−0.066							5.286	0.969
29	0.291	0.947			−0.046	−0.024						5.284	0.969
30	0.278	0.947			−0.043	−0.066	0.044					5.167	0.969
31	0.195	1.404	−0.440		−0.041							1.551	0.976
32	0.183	1.410	−0.447		−0.065	0.027						1.395	0.976
33	0.163	1.415	−0.451		−0.061	−0.030	0.060					1.109	0.976
34	0.215	1.511	−0.717	0.164	−0.046							−1.487	0.977
35	0.205	1.516	−0.720	0.163	−0.065	0.022						−1.844	0.977
36	0.190	1.513	−0.706	0.153	−0.063	−0.019	0.043					−1.850	0.976

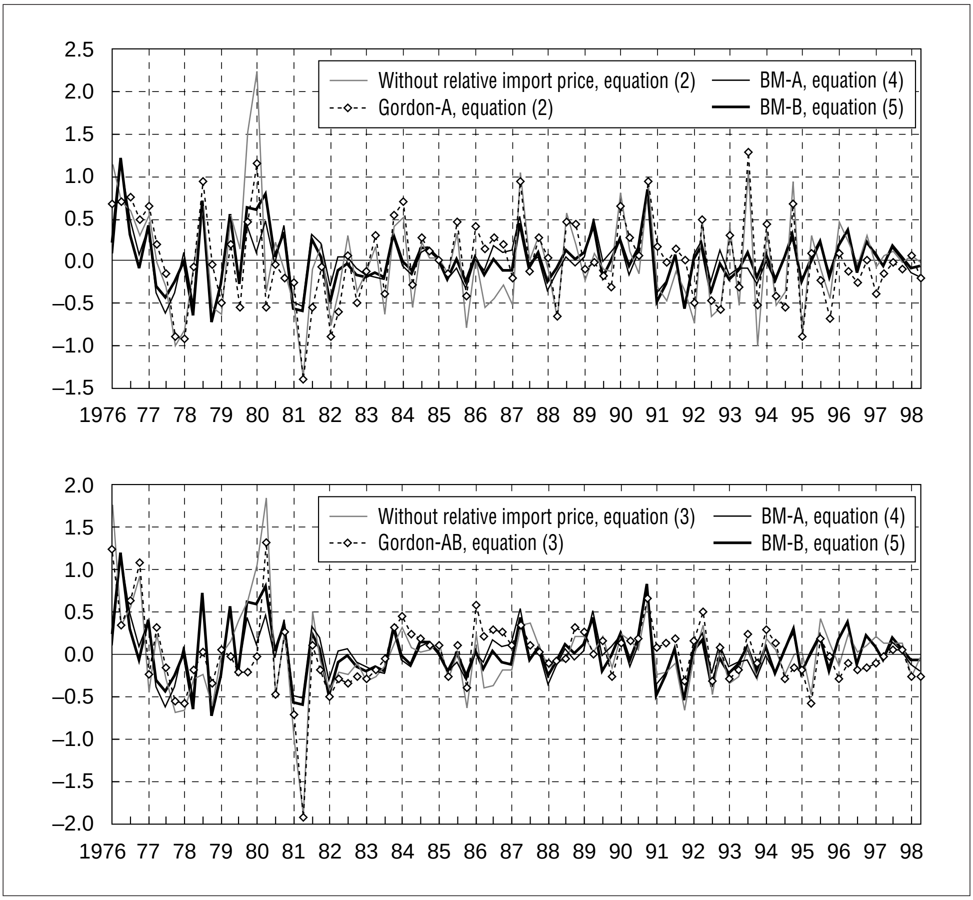
Notes: (dark shading) indicates significance at a 5 percent confidence level.
(light shading) indicates significance at a 10 percent confidence level.

Estimation method: OLS
Estimation period: 1975/I to 1998/II

Coefficients of the changes in the relative import price in equations (2) and (3) are highly significant and are stable among various lag specifications. This rather strong and favorable result might lead researchers to use the Gordon method for controlling the supply shock in Japan.

Checking residuals for various specifications in Figure 4,[22] it turns out, however, that adding the relative import price to the right-hand side of the equations contributes to eliminate a large spike in residual around the year 1980, but not to the other large spikes.

Figure 4 Residuals for Various Specifications



B. Relationship between the Inflation Inertia and Supply Shock

In this subsection, I examine the relationship between inflation inertia and the supply shock. There are two distinctive features in the estimated coefficients of equation (4). First, as the length of the lagged inflation increases, the length of the lagged supply shocks that are statistically significant also increases.[23] Second, when the lengths of the lagged inflation and the supply shock term are equal ($l = n$), the coefficient for θ_0 nearly equals one and coefficients for the corresponding lagged inflation and the

22. The length of the lagged inflation (l) and output gap (m) are set to three and one, respectively, for all four specifications. See Footnote 25.
23. In contrast, as I mentioned above, only the current change in the relative import price is significant for the Gordon-type equations (2) and (3). These features remain the same even when the length of the lagged inflation term is fixed and the length of the supply shock term is changed.

supply shock have almost the same absolute values but the opposite sign ($\beta_n \cong -\theta_n$). This implies that the estimation of the BM-A type, which adds the asymmetry of the price change distribution to the right-hand side of the equation, and the BM-B type, which uses the trimmed CPI from which the supply shock effect has been eliminated prior to the estimation, essentially produce the same results, as suggested in the previous subsection.[24]

These findings suggest that the underlying inflation from which supply shock effects have been eliminated by the BM method is a good proxy for the inflation inertia.

C. Predictive Power and Stability of the Estimated Coefficients

In this subsection, I examine the robustness of the four alternative specifications by comparing the predictive power and the stability of the estimated coefficients. The length of the lagged inflation (l) and the output gap (m) are set to three and one, respectively, for all four specifications.[25]

First, I compute the recursive root mean square error (RMSE) for four specifications. Each specification is first estimated for the period 1985/I (all estimation periods begin in 1976/I) and a dynamic one- to four-quarter-ahead prediction is made beginning in 1985/II. This process is repeated through the estimation period ending in 1997/II and 50 one- to four-quarter-ahead predictions are derived. Finally, RMSEs are calculated using these predictions and the actual values.[26]

The RMSEs are presented in Table 4. It is quite striking that two- to four-quarter-ahead RMSEs using the Gordon method are approximately twice as large as those using the BM method. Using the BM method substantially improves the predictive power compared with using the traditional Gordon method.

Next, the parameter stability to changes in the estimation period for each specification is examined. Extending the estimation period to 1998/II, 54 estimates are obtained for each coefficient. Table 5 presents the coefficient of variation (CV) for each estimated coefficient.

As shown in Table 5, the CVs for coefficients using the Gordon method are all considerably larger than those using the BM method. This implies that the estimated coefficients using the Gordon method are substantially influenced by changes in the estimation period, and thus the robustness is extremely low. This would be the primary cause for the poor predictive power using the Gordon method.

24. See No. 25 and No. 34 in Table 3, for example. Estimation of No. 34 could be interpreted as an estimation applying the coefficient constraints $\theta_0 = 1$, $\beta_n = -\theta_n$ (n = 1, 2, 3) on No. 25. Performing the parameter restriction F-test, the null hypothesis that these linear restrictions are satisfied cannot be rejected at the 1 percent level.
25. This specification is the most preferable for the BM method in terms of the significance of the estimates of coefficients and adjusted R^2. Estimates for β_3 are considerably small for all specifications, so the results of the following analyses are basically the same for specifications which have more than two lagged inflation terms.
26. The actual values of the output gap and supply shock proxy are used for all these predictions. The aim here is not to generate predictions that could have been made in real time, but to see how good the dynamic predictions from each specification are conditional on the actual values of the output gap and the supply shock proxy.

Table 4 Recursive RMSE Results (50 Samples)

	Gordon-A, equation (2), n = 0	Gordon-AB, equation (3), n = 0	BM-A, equation (4), n = 3	BM-B, equation (5)
One quarter ahead	0.735 *87.5*	0.654 *66.7*	0.402 *2.4*	0.392
Two quarters ahead	0.995 *102.6*	0.949 *93.2*	0.506 *2.9*	0.491
Three quarters ahead	1.269 *102.5*	1.227 *95.9*	0.626 *−0.1*	0.626
Four quarters ahead	1.490 *106.5*	1.469 *103.7*	0.700 *−2.9*	0.722

Note: The figures in italics indicate the percentage deviation from the benchmark performance of equation (5). Negative figures indicate that the performance is superior to that of equation (5).

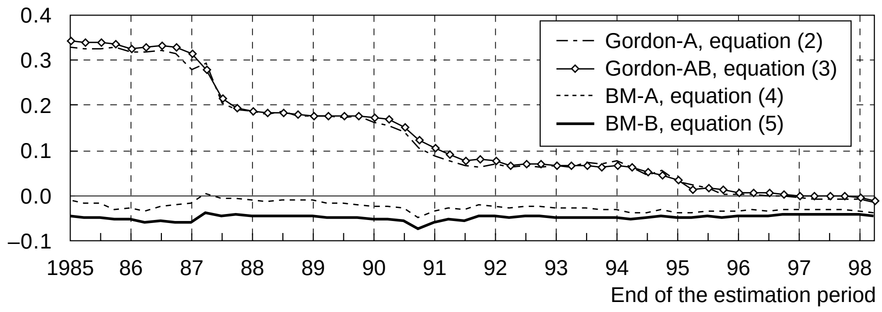
Table 5 CVs for the Estimated Coefficients (54 Samples)

		Gordon-A, equation (2), n = 0	Gordon-AB, equation (3), n = 0	BM-A, equation (4), n = 3	BM-B, equation (5)
Constant	α	2.274 *2,037.0*	1.423 *1,236.9*	0.199 *87.1*	0.106
Lagged inflation	β_1	0.036 *40.9*	0.049 *92.2*	0.025 *−0.7*	0.026
	β_2	0.309 *365.4*	0.211 *218.0*	0.087 *30.4*	0.066
	β_3	0.348 *288.9*	0.249 *178.3*	0.128 *42.9*	0.089
Output gap	γ_1	0.901 *644.1*	0.885 *631.0*	0.383 *216.1*	0.121
Supply shock	θ_0	0.176	0.222	0.015	
	θ_1			0.038	
	θ_2			0.074	
	θ_3			0.144	

Note: The figures in italics indicate the percentage deviation from the benchmark performance of equation (5). Negative figures indicate that the performance is superior to that of equation (5).

Figure 5 displays the point estimates of the coefficients for the output gap for four specifications. It turns out that for the Gordon-type specifications, coefficients for the output gap are positive, which is opposite to the prediction of the conventional Phillips curve model, until the estimation period is extended to 1997 or beyond. In contrast, for BM-type specifications, they are always negative, except for the specification ending in 1987/II for equation (4), and remain fairly stable even when the estimation period is extended.

Figure 5 Estimated Coefficients for the Output Gap



In addition, to check the parameter stability in a rough statistical manner, a stepwise Chow test is performed. Figure 6 shows the results. For Gordon-type equations (2) and (3), test statistics are considerably larger than those of BM-type equations (4) and (5), and test statistics are beyond the criterion at several points in time. This indicates that the null of no structural break is more likely to be rejected for Gordon-type specifications. Only equation (5) does not seem to have any break point during the estimation period.[27]

IV. Discussion

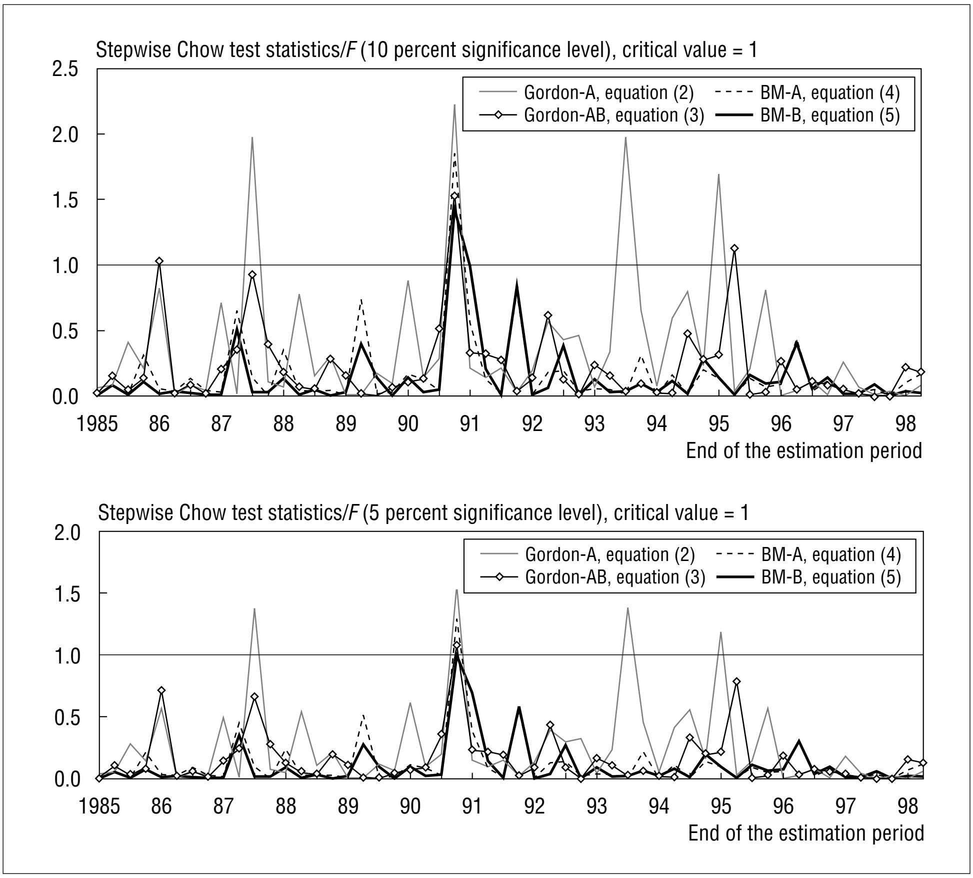
Empirical results shown in the previous section clearly indicate that the BM method which adopts the asymmetry of the price change distribution as a proxy for supply shock effect outperforms the traditional Gordon method in terms of robustness to the various lag specifications, predictive power, and parameter stability for changes in the estimation period. In this section, I discuss the background for these results.

A. Items Causing the Asymmetry of the Price Change Distribution

As presented in Figure 3, the relative import price used for the Gordon method and the asymmetry of the price change distribution used for the BM method basically do not seem to have a strong positive correlation except for the period around 1980. It is interesting that adding the relative import price to the right-hand side of the equation contributes to a reduction in the residual only for the period around 1980, when the two variables had a strong positive correlation (Figure 4). This suggests that in spite of not really being a systematic factor, the relative import price seems a good proxy since its introduction contributes to correcting the large underestimation

27. In applied study, it is not possible to use the ordinary *F*-criterion presented in this paper for testing unknown break points. Detecting an unknown break point, Andrews' Sup. *F*- or Mean *F*-criteria are more preferable (see Andrews [1993], table 1, for the Sup. *F* criterion). Since I don't have any prior information that the break occurred only one time in the estimation period, I choose instead to show a rough ordinary *F*-criterion.

Figure 6 Recursive *F*-Statistics and the Stepwise Chow Criterion



around 1980 and is highly significant. But eventually, this amendment probably reduces the robustness of the other parameter estimates in other periods.[28]

Combining this finding with the empirical results shown in the previous section implies that the large supply shocks which potentially hit broad sectors, but hit the limited sectors at some points in time, are the major sources for shifting the Phillips curve in the short run. This must be the reason why fixing the basket *a priori* is not an effective way for controlling the supply shock in the estimation of the Phillips curve.

B. Asymmetry of the Price Change Distribution and the Nominal Wage

In addition, controlling the supply shock not only for current inflation but also for lagged inflation by the BM method contributes to favorable empirical results. To explore this issue, I focus on the relationships among the asymmetry of the price change distribution, the nominal wage, and the inflation expectation.

28. See Ueda (1983) for another example suggesting the parameter instability using the Gordon method in Japan. He adopts the change in real import prices as a proxy for the supply shock during an estimation period of 1972 through 1981, and reports the rather strange result that the sign of the point estimates for the supply shock coefficient is reversed from positive to negative after 1976.

Needless to say, the inflation expectation, which is part of the inflation inertia, is assumed to play an important role in the nominal wage determination. The basic intuition of the expectation-augmented Phillips curve estimated in this paper is as follows: increases in nominal wages are determined by inflation expectations and the output gap, and nominal wages also feed back into inflation through markup pricing.

If the underlying inflation rate from which the supply shock effect has been eliminated functions as a good proxy for inflation expectations, interdependence between changes in the nominal wage and the underlying inflation rate should be found. In contrast, little interdependence between the changes in the nominal wage and the asymmetry of the price change distribution that represent the temporary inflation caused by the supply shocks should be found. To examine this explanation, I estimate a three-variable VAR model and perform variance decomposition. Variables used in the estimation are the changes in nominal wages, the trimmed CPI, and the asymmetry of the price change distribution, respectively. To calculate relative variance contribution, recursive order *SKEW*, *TRIM*, and *WAGE* is assumed for simultaneous relationship of the endogenous variables.

The results are presented in Figure 7. The innovation to the asymmetry of the price change distribution does not explain the variance in the trimmed CPI or the variance in the changes in nominal wages, or vice versa. This implies that the influence of the supply shocks to the limited sectors on the inflation inertia is minor. In contrast, innovations to the trimmed CPI explain, to some extent, the variations in the changes in nominal wages, and vice versa.

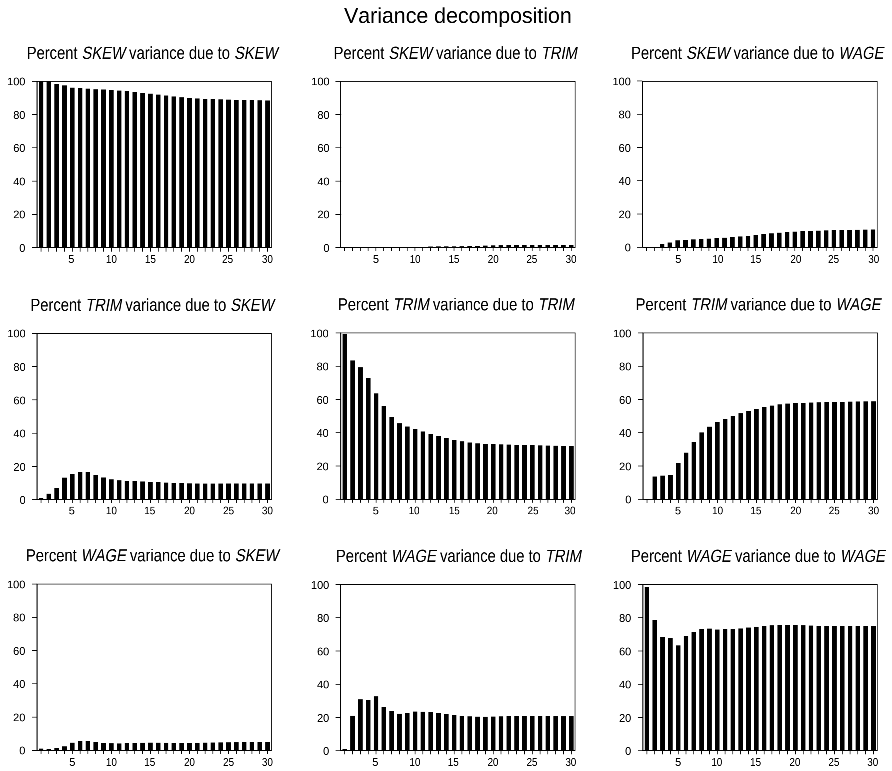
When workers are concerned about the real wage rate deflated by the cost of living, Gordon (1975) suggested the following condition for the inflation expectation to be the underlying inflation: the expected price changes in commodities that face supply shocks are unaffected by actual and temporary price changes of those due to supply shocks.[29]

I test this condition by examining the cointegration relationship between the changes in the headline CPI and the trimmed CPI. The intuition for this test is as follows: if both variables have unit roots and there is no cointegration relationship between the two with cointegration vector (1, –1), the asymmetry of the price change distribution also has a unit root. This means that the conditional expected value for the one-step-ahead proxy for the supply shock is its current value, which clearly seems to violate Gordon's condition.

To perform this test, first, I calculated the *implied log level index* for the trimmed CPI, since it is originally computed on a year-to-year change basis, i.e., the *first difference of the implied log level index* basis. Second, I conducted the ADF test for each log level index to verify the order of integration. The results indicate that both are $I(1)$. This implies that the direct test for Gordon's condition (the argument made in this subsection) is not possible since the first difference of the $I(1)$ series is, by definition, $I(0)$. Thus, I test the cointegration relationship between the log level index of the headline CPI and the trimmed CPI, assuming that the log level index should also satisfy Gordon's condition.

29. His original statement (Gordon [1975], p. 193) is as follows: "the expected (change in log) farm price is unaffected by a temporary increase in the actual (change in log) price level."

Figure 7 Variance Decomposition Based on the Estimated VAR Model



Notes: 1. *WAGE* is the change in nominal wage rate, *TRIM* is the 30 percent trimmed CPI, and *SKEW* is the asymmetry of the price change distribution.
2. The estimation period for VAR is 1973/I to 1998/II. A model with five lags for each variable is chosen by Akaike's Information Criterion (AIC). AIC is calculated by the following formula. $AIC = \log\hat{\sigma}^2 + 2(p + q)/T$, where $\hat{\sigma}^2$ = estimated variance of errors, p = order of lags, and T = sample size. Changes in the estimation period, lag order, and recursive order generally do not affect the result.

The following equation is estimated for the test.

$$\Delta diff_t = \psi diff_{t-1} + \sum_{i=1}^{n} \delta_i \Delta diff_{t-i} + v_t, \tag{6}$$

diff: headline CPI (log level) – 30 percent trimmed CPI (log level).

The results are presented in Table 6. The null for a unit root and thus no cointegration is rejected at the 1 percent level. This means that the divergence between the log level of the headline CPI and the log level of the trimmed CPI follows a stationary process. In other words, the log level of the headline CPI and the log level of the trimmed CPI diverges only temporarily, which satisfies Gordon's condition.[30]

30. Note that satisfying Gordon's condition is necessary but not sufficient, since the relative price changes of some fixed commodity basket will also satisfy this condition.

Table 6 Cointegration Test Results

	n = 0	n = 1	n = 2	n = 3	n = 4
ψ	−0.051 (−3.148)***	−0.048 (−2.980)***	−0.042 (−2.723)***	−0.042 (−2.745)***	−0.043 (−2.808)***
δ_1		−0.115 (−1.961)	−0.151 (−2.645)	−0.186 (−3.149)	−0.201 (−3.451)
δ_2			−0.266 (−4.669)	−0.288 (−5.016)	−0.325 (−5.455)
δ_3				−0.125 (−2.177)	−0.153 (−2.606)
δ_4					−0.124 (−2.153)
Adjusted R^2	0.033	0.046	0.115	0.130	0.144
DW statistics	2.21	2.05	2.05	2.02	1.99

Note: The estimation period is January 1975 to June 1998, using monthly data. Figures inside parentheses are *t* values. *** indicates that the null for the unit root is rejected at the 1 percent level. Assuming that the cointegration vector is known, the criterion for hypothesis testing is simply computed by Dickey-Fuller's τ distribution using MacKinnon's equation.

V. Conclusion

In this paper, I examined methods of controlling the supply shock in the estimation of the Phillips curve and discussed the relationship between the supply shock and inflation inertia.

The empirical results clearly show that controlling the supply shock not only for current inflation but also for lagged inflation, using the asymmetry of the price change distribution suggested by Ball and Mankiw (1995), outperforms the traditional method in terms of the robustness to the various lag specifications, predictive power, and the parameter stability for changes in the estimation period, which are the essential properties for the practical use of the Phillips curve. These results suggest that (1) because supply shocks hit broad sectors, it is not appropriate to restrict the proxy for the supply shock to the relative price changes of a fixed commodity basket; and (2) the inflation inertia corresponds to the underlying inflation rate from which the supply shock effect has been eliminated.

The approach in this paper is very practical. To explore the theoretical background that consistently explains the facts presented in this paper is indeed an important task.[31] Expanding the empirical research of the underlying inflation will also be fruitful. Most of the recent studies evaluate the performance of the alternative candidates for the underlying inflation in a limited sense: the smoothness of the extracted series, and the correlation and the causality to the monetary aggregates. Since the concept of underlying inflation is vital, especially in practice, broader empirical analyses—including this paper, which explores the interrelationship with the conditions in the real economy—are essential to the evaluation.

31. See Footnote 11.

It is worth noting that the Phillips curve augmented by lagged inflation remains a "clean little secret" of macroeconomics,[32] although it has faced strong criticism from the neoclassical viewpoint since the 1970s. Considering the empirical robustness against the change in the estimation period shown in this paper, along with the classic suggestion by Sargent (1976),[33] it might even be possible to say that the Lucas Critique did not do severe damage to the practical use of the Phillips curve conditional on the policy changes made in the estimation period. Indeed, there are some examples that attempt to derive the structural Phillips curve relationship.[34] Investigating the Phillips curve is still a fascinating concern, for which macroeconomists and policymakers should account.

32. Blinder (1997). Also see Stock and Watson (1999), who argue the advantage of the Phillips curve in terms of the prediction of the inflation rate.
33. His original statement (Sargent [1976], p. 637) is as follows: "Presumably, by estimating reduced forms for various subperiods or countries across which policy rules differed systematically, light can be shed on what way of writing the reduced form remains invariant."
34. See Footnote 4.

APPENDIX: ASYMMETRY OF THE PRICE CHANGE DISTRIBUTION

This appendix explains that the asymmetry of the price change distribution can be interpreted as the sum of the relative price change of items excluded from the trimmed CPI. The asymmetry of the price change distribution is calculated as equation (A.1):

$$SKEW_t = \dot{CPIttl}_t - \dot{Trim30}_t = \sum_{i \in N} w_{i,t}\pi_{i,t} - \sum_{i \in M(t)} w_{i,t}\pi_{i,t} \Big/ \sum_{i \in M(t)} w_{i,t}, \tag{A.1}$$

where

$SKEW_t$: asymmetry of the price change distribution at time t
$CPIttl_t$: headline CPI at time t
$Trim30_t$: 30 percent trimmed CPI at time t
N: set comprised of all items in the headline CPI
$M(t)$: set comprised of items included in the trimmed CPI at time t
$M^C(t)$: set comprised of items excluded from the trimmed CPI at time t
$w_{i,t}$: weight for the i_{th} item at time t
$\pi_{i,t}$: changes in the price of the i_{th} item at time t
Dots (•) above variables indicate year-to-year change.

By definition, changes in the headline CPI can be divided into two terms:

$$\dot{CPIttl}_t = \sum_{i \in N} w_{i,t}\pi_{i,t} = \sum_{i \in M(t)} w_{i,t}\pi_{i,t} + \sum_{i \in M^C(t)} w_{i,t}\pi_{i,t}. \tag{A.2}$$

Substituting equation (A.2) into equation (A.1) yields equation (A.3):

$$\begin{aligned} SKEW_t &= \sum_{i \in N} w_{i,t}\pi_{i,t} - \left(\sum_{i \in N} w_{i,t}\pi_{i,t} - \sum_{i \in M^C(t)} w_{i,t}\pi_{i,t} \right) \Big/ \sum_{i \in M(t)} w_{i,t}, \\ &= \sum_{i \in M^C(t)} w_{i,t}\pi_{i,t} \Big/ \sum_{i \in M(t)} w_{i,t} - \left(\sum_{i \in M^C(t)} w_{i,t} \Big/ \sum_{i \in M(t)} w_{i,t} \right) \times \sum_{i \in N} w_{i,t}\pi_{i,t}, \\ &= \sum_{i \in M^C(t)} \frac{w_{i,t}}{\sum_{i \in M(t)} w_{i,t}} \times \left(\pi_{i,t} - \dot{CPIttl}_t \right). \end{aligned} \tag{A.3}$$

Equation (A.3) indicates that the asymmetry of the price change distribution is equal to the sum of the relative price changes of items excluded from the trimmed CPI. Thus, the contribution of each item to the asymmetry of the price change distribution (Figure 1) is calculated by equation (A.4):

$$CONT_{i,t} = \frac{w_{i,t}}{\sum_{i \in M(t)} w_{i,t}} \times \left(\pi_{i,t} - \dot{CPIttl}_t \right) \quad \text{for } i \in M^C, \tag{A.4}$$

where

$CONT_{i,t}$: contribution of i_{th} item to the asymmetry of the distribution.

References

Álvarez, Luis J., and M.[a] de los Llanos Matea, "Underlying Inflation Measures in Spain," Banco de España Working Paper No. 9911, 1999.

Andrews, Donald W. K., "Tests for Parameter Instability and Structural Change with Unknown Change Point," *Econometrica*, 61 (4), 1993, pp. 821–856.

Bakhshi, Hasan, and Tony Yates, "To Trim or Not to Trim? An Application of a Trimmed Mean Inflation Estimator to the United Kingdom," Bank of England Working Paper Series No. 97, 1999.

Balke, Nathan S., and Mark A. Wynne, "An Equilibrium Analysis of Relative Price Changes and Aggregate Inflation," *Journal of Monetary Economics*, 45 (2), 2000, pp. 269–292.

Ball, Laurence, and N. Gregory Mankiw, "Relative-Price Changes as Aggregate Supply Shocks," *Quarterly Journal of Economics*, 110 (1), 1995, pp. 161–193.

———, and ———, "Interpreting the Correlation between Inflation and the Skewness of Relative Prices: A Comment on Bryan and Cecchetti," *Review of Economics and Statistics*, 81 (2), 1999, pp. 197–198.

Barro, Robert J., "Rational Expectations and the Role of Monetary Policy," *Journal of Monetary Economics*, 2 (1), 1976, pp. 1–32.

Blanchard, Oliver, *Macroeconomics*, Prentice-Hall, 1997.

Blinder, Alan S., "Is There a Core of Practical Macroeconomics That We Should All Believe?" *American Economic Review*, 87 (2), 1997, pp. 240–243.

Bomberger, William A., and Gail E. Makinen, "Inflation and Relative Price Variability," *Journal of Money, Credit, and Banking*, 25 (4), 1993, pp. 854–861.

Bruno, Michael, and Jeffrey D. Sachs, *Economics of Worldwide Stagflation*, Harvard University Press, 1985.

Bryan, Michael F., and Stephen G. Cecchetti, "Measuring Core Inflation," in N. Gregory Mankiw, ed. *Monetary Policy*, University of Chicago Press, 1994, pp. 195–215.

———, and ———, "Inflation and the Distribution of Price Changes," *Review of Economics and Statistics*, 81 (2), 1999a, pp. 188–196.

———, and ———, "The Monthly Measurement of Core Inflation in Japan," *Monetary and Economic Studies*, 17 (1), Institute for Monetary and Economic Studies, Bank of Japan, 1999b, pp. 77–101.

Cooley, Thomas F., and Vincenzo Quadrini, "A Neoclassical Model of the Phillips Curve Relation," *Journal of Monetary Economics*, 44 (2), 1999, pp. 165–193.

Debelle, Guy, and Owen Lamont, "Relative Price Variability and Inflation: Evidence from U.S. Cities," *Journal of Political Economy*, 105 (1), 1997, pp. 132–152.

Fair, Ray C., "Testing the NAIRU Model for the United States," *Review of Economics and Statistics*, 82 (1), 2000, pp. 64–71.

Fischer, Stanley, "Relative Shocks, Relative Price Variability, and Inflation," *Brookings Papers of Economic Activity*, 2, 1981, pp. 381–431.

Fuhrer, Jeffrey C., "The Phillips Curve Is Alive and Well," *New England Economic Review*, Federal Reserve Bank of Boston, March/April, 1995, pp. 41–56.

Galí, Jordi, and Mark Gertler, "Inflation Dynamics: A Structural Econometric Analysis," *Journal of Monetary Economics*, 44 (2), 1999, pp. 195–222.

Gartner, Christine, and Gert D. Wehinger, "Core Inflation in Selected European Union Countries," Oestrreichische Nationalbank Working Paper Series No. 33, 1998.

Gordon, Robert J., "Alternative Responses of Policy to External Supply Shocks," *Brookings Papers on Economic Activity*, 1, 1975, pp. 183–204.

———, "What Is New-Keynesian Economics?" *Journal of Economic Literature*, Volume XXVIII, 1990, pp. 1115–1171.

———, "The Time-Varying NAIRU and Its Implications for Economic Policy," *Journal of Economic Perspectives*, 11 (1), 1997, pp. 11–32.

Hercowitz, Zvi, "Money and the Dispersion of Relative Price," *Journal of Political Economy*, 89 (2), 1981, pp. 328–356.

Higo, Masahiro, and Sachiko Kuroda Nakada, "How Can We Extract a Fundamental Trend from an Economic Time-Series?" *Monetary and Economic Studies*, 16 (2), Institute for Monetary and Economic Studies, Bank of Japan, 1998, pp. 61–111.

———, and ———, "What Determines the Relationship between the Output Gap and Inflation? An International Comparison of Inflation Expectations and Staggered Wage Setting," *Monetary and Economic Studies*, 17 (3), Institute for Monetary and Economic Studies, Bank of Japan, 1999, pp. 129–155.

Jaramillo, Carlos Felipe, "Inflation and Relative Price Variability: Reinstating Parks' Result," *Journal of Money, Credit, and Banking*, 31 (3), 1999, pp. 375–385.

Mankiw, N. Gregory, *Macroeconomics*, Third Edition, Worth, 1997.

Mio, Hitoshi, and Masahiro Higo, "Underlying Inflation and the Distribution of Price Change: Evidence from the Japanese Trimmed-Mean CPI," *Monetary and Economic Studies*, 17 (1), Institute for Monetary and Economic Studies, Bank of Japan, 1999, pp. 103–132.

Monetary Authority of Singapore, Domestic Economy Division, "Measures of Core Inflation for Singapore," MAS Occasional Paper No. 10, 1998.

Nishizaki, Kenji, and Tsutomu Watanabe, "Output-Inflation at Near-Zero Inflation Rates," Discussion Paper Series A No. 375, Institute of Economic Research, Hitotsubashi University, 1999.

Okun, Arthur M., *Prices and Quantities: A Macroeconomic Analysis*, Oxford: Basil Blackwell, 1981.

Parks, Richard W., "Inflation and the Relative Price Variability," *Journal of Political Economy*, 86 (1), 1978, pp. 79–95.

Roger, Scott, "A Robust Measure of Core Inflation in New Zealand, 1949–96," Reserve Bank of New Zealand Discussion Paper G97/7, 1997.

Romer, Christina D., "Inflation and The Growth Rate of Output," NBER Working Paper No. 5575, National Bureau of Economic Research, 1996.

Romer, David H., *Advanced Macroeconomics*, McGraw-Hill, 1996.

Sargent, Thomas J., "The Observational Equivalence of Natural and Unnatural Rate Theories of Macroeconomics," *Journal of Political Economy*, 84 (3), 1976, pp. 631–640.

Shiratsuka, Shigenori, "Inflation Measures for Monetary Policy: Measuring the Underlying Inflation Trend and Its Implication for Monetary Policy Implementation," *Monetary and Economic Studies*, 15 (2), Institute for Monetary and Economic Studies, Bank of Japan, 1997, pp. 1–26.

Staiger, Douglas, James H. Stock, and Mark W. Watson, "How Precise Are Estimates of the Natural Rate of Unemployment?" in Christina D. Romer and David H. Romer, eds. *Reducing Inflation*, University of Chicago Press, 1997, pp. 195–242.

Stock, James H., and Mark W. Watson, "Forecasting Inflation," *Journal of Monetary Economics*, 44 (2), 1999, pp. 293–335.

Tanaka, Hidenori, and Takeshi Kimura, "Vector Error Correction Model Wo Mochi-ita Bukka Kettei Mechanism ni Kansuru Jisshou Bunseki (The Empirical Analysis for the Mechanism of the Price Determination Using Vector Error Correction Model)," Bank of Japan Research and Statistics Department Working Paper 98-10, 1998 (in Japanese).

Ueda, Kazuo, *Kokusai Makuro Keizaigaku to Nihon Keizai* (International Macroeconomics and the Japanese Economy), Toyo Keizai Shimposha, 1983 (in Japanese).

Vining, Daniel R., Jr., and Thomas C. Elwertowski, "The Relationship between Relative Prices and the General Price Level," *American Economic Review*, 66 (4), 1976, pp. 699–708.

Watanabe, Tsutomu, "Output Gap and Inflation: The Case of Japan," in *Monetary Policy and the Inflation Process*, Bank for International Settlements Conference Papers, Volume 4, 1997, pp. 93–112.